Seasonal nesting of green turtles at Huyong Island, Thailand

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ABSTRACT
In this paper, we report the current results of the studies on the reproductive biology of green turtles nested at Huyong Island, Thailand. The Huyong Island is a year-round nesting rookery of green turtles. Although information on year-round nesting population of sea turtles is very important to understand the ecology of sea turtles, there were few comprehensive data sets on year-round nesting populations. Therefore, three methods were used to investigate reproductive features of year-round nesting population of green turtles. Firstly, tagging studies were conducted to examine nesting seasonality of female green turtles. Next, satellite tracking studies were conducted to examine horizontal distributions of the female green turtles during post-nesting periods. In addition, bio-logging studies using data loggers were used to examine diving behavior of the female green turtles during inter-nesting periods. Our results showed that: 1) nesting in the Huyong green turtles occurred more or less at the same time on an individual basis, 2) nesting throughout the season might be attributed to proximity to feeding grounds, 3) there is seasonal difference in reproductive output among individuals, and 4) diving behavior of females during inter-nesting periods may be a key determinant of the seasonal difference in reproductive output.

KEYWORDS: green turtles, Huyong Island, year-round nesting, seasonality, reproductive output, migration, diving behavior, seasonal difference

INTRODUCTION

Sea turtles are marine reptiles that spend most of their life in the sea, with the exception of gravid females, which land on beaches to nest. The green turtle (*Chelonia mydas*) is a circumglobal species; the majority of its nesting and feeding areas lie within the tropics (Prichard, 1997). Large nesting colonies are found on mainland shores (e.g., Costa Rica), barrier reef islands (e.g., Queensland, Australia), and remote oceanic islands (e.g., Ascension Island). Gravid green turtle females nest several times (typically three to five times) at approximately 2-week intervals during a nesting season. Generally, female green turtles do not reproduce every year, and the period between reproductive seasons is approximately 2.86 years (Miller, 1997). Mature turtles migrate between feeding and nesting locations with a high degree of accuracy. Molecular evidence suggests that female turtles return to their site of birth or an adjacent site to nest (Bowen et al., 1992; Miller, 1997), and the migration distance between feeding and nesting locations can be thousands of kilometers (e.g., Hays et al., 2002).

Huyong island (8° 29´ N, 97° 38´ E), Thailand is a nesting rookery of green turtles. At Huyong Island, green turtles nest throughout the year (Kittiwattanawong, 2003; Yasuda et al., 2006). Information on year-round nesting population of sea turtles is very important to understand the ecology of sea turtles. However, our knowledge of them is still rudimentary because few comprehensive data-sets of year-round nesting are available for sea turtles (Hamann et al., 2003). Thus, we can only speculate as to why and how turtles persist in using particular nesting seasons (Hamann et al., 2003).

Since 1995, the Royal Thai Navy and Phuket Marine Biological Center have conducted nesting surveys of green turtles nested at Huyong Island (Kittiwattanawong, 2003). Since 2000, a cooperative scientific project (SEASTAR2000) has been started, and brand-new ecological studies using new technologies, such as satellite tracking and bio-logging, have been conducted to examine the ecology of green turtles. In this paper, we report on the current status of the studies on green turtles nested at Huyong Island, Thailand.

REPRODUCTIVE SEASONALITY

In marine turtles, successful egg incubation depends on suitable beach and sand conditions (Ackerman, 1997). In particular, sand temperature strongly affects incubation (Mrosovsky, 1968; Ackerman, 1997). For example, eggs cannot hatch when the sand temperature exceeds the thermal tolerance range (TTR). The TTR is approximately between 25-27 and 33-35 ^{o}C when eggs are incubated at a constant temperature (Ackerman, 1997).

Green turtles in sub-tropical zones have a

distinct nesting season, usually the warmest month (Miller, 1997). At Ascension Island, the nesting season is from July to December, and peak activity is in March, with 90% of nesting occurring between 13 January and 7 May in 1999 (Godley et al., 2001). On this island, Godley et al. (2002) found that sand temperatures were close to the lower TTR during months when there was no nesting activity (July-October). This suggests that green turtles have evolved to nest during periods of the year when sand temperatures are highest, avoiding the months when nest temperatures may get too low (Godley et al., 2001; Godley et al., 2002). This suggested that the nesting season in green turtles is a genetic character and is stable during the entire life span. A year-round nesting rookery in the tropics is a suitable location to examine the seasonal patterns of nesting at the level of individual turtles, because the temporal distribution of nesting activity is little affected by environmental constraints such as cold sand temperatures (Zug et al., 2001; Brown & Shine, 2002).

The Royal Thai Navy personnel and cooperating researchers staying on Huyong Island have investigated the nesting beach on foot. The turtles were tagged internally using passive integrated transponder tags, and externally using metal tags on both fore flippers. The results of the nesting survey from 1996 to 2004 show that nineteen females of the 94 identified turtles returned to Huyong Island. We found that nesting in the Huyong green turtles occurred more or less at the same time on an individual basis (Fig. 1). This indicates that in green turtles, the nesting season is fixed for each individual, and variation in the nesting season among individuals is the key determinant of year-round nesting. The relationship also suggests that the nesting season of an individual does not fluctuate widely during its life span.

A satellite tracking study has been conducted since 2000. The movement of seven turtles during the post-nesting period was tracked using ARGOS system. The results demonstrated that female turtles that nested at Huyong Island moved to the Andaman Islands or Phura Tong Island after nesting (Fig. 2). These may be the feeding areas for this population of green turtles, because turtles remained near the coasts of these islands. Therefore, the migratory period and the distance between nesting and feeding locations of the Huyong Island population were less than 10 days and 854 km, respectively (Yasuda et al., 2006). Both the migratory duration and distance may be affected by oceanographic factors, such as ocean currents, which may undergo seasonal fluctuation. Our data cannot be used to evaluate the differences in migration routes between seasons. However, the satellite tracking study showed that the short durations and distances of the observed migrations suggest that seasonal differences in the cost of the post-nesting migration have little effect on nesting dates in the turtles.

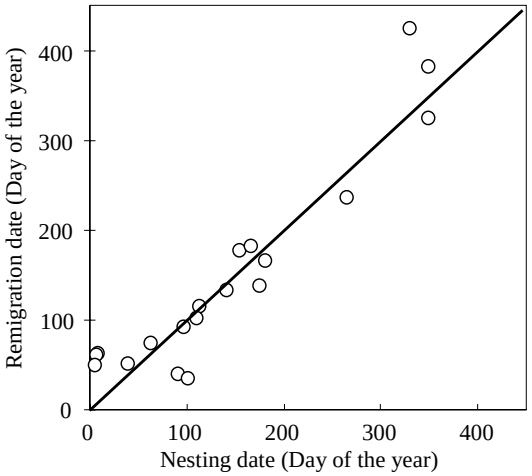

Fig.1. Relationship between nesting day and remigration day for green turtles that re-migrated (Spearman rank correlation r_s = 0.90, n = 19, P < 0.0001). The line indicates 1:1 (redrawn Yasuda et al., 2006). Nesting date indicates the day when an individual laid first clutch within a season. Remigration day indicates the day when an individual laid first clutch within a next nesting season.

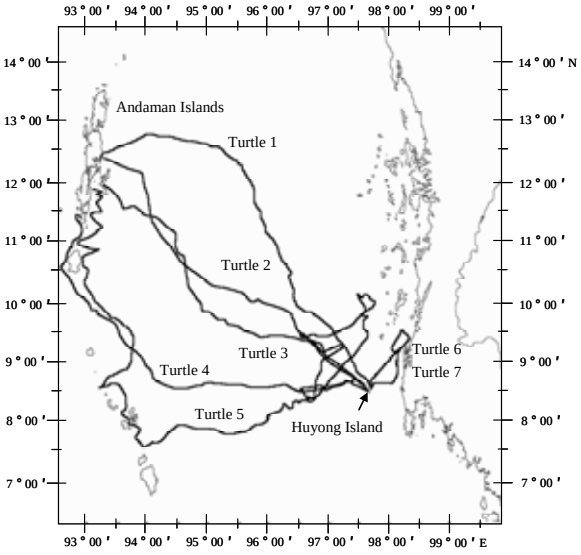

Fig.2. Post-nesting migration routes for seven female green turtles that nested at Huyong Island, Thailand. (Yasuda et al., 2006).

REPRODUCTIVE OUTPUT

The vast majority of reptiles are seasonal in reproduction (Zug et al., 2001) because the reproduction of reptiles is constrained by various environmental factors – for example, temperature (e.g. Godley et al., 2002), moisture (e.g. James & Shine, 1985), and so on. Cold winter temperature is a major constraint on reproductive seasonality of reptiles in

temperate zones. Therefore, in many temperate reptiles, ovulation of eggs occurs in spring, egg deposition occurs in early to midsummer, and hatching occurs in late summer (Zug et al., 2001). In contrast, continuous reproduction occurs in tropical populations which may be free from the temperature constraint.

At Huyong Island, green turtles exhibit continuous nesting (Kittiwattanawong 2003; Yasuda et al. 2006) together with other reptilian species. However, the seasonal fluctuations observed in the tropics, although relatively low compared with higher latitudes, are usually related to the rather variable pattern of rainfall, or increased storm frequency during the monsoon period. The west coast of Thailand experiences 2 main seasons: the relatively calm dry season (November to April) and the stormy rainy season (May to October). The dry season is characterized by northeasterly dry wind off the Asian continent. Heavy rain and strong winds characterize the dry season. However, very little was known about ecological variation in reproduction in sea turtles because there were few comprehensive data sets on nesting ecology of the year-round nesting population. Therefore, we examined whether there is seasonal difference in a reproductive outputs of female green turtles nested at Huyong Island, Thailand.

The nesting frequency within a season is shown in Figure 3. The clutch frequency within a season may be a key determinant of reproductive output because an individual rarely laid less than 50 % or more than 150 % of the size of the first clutch throughout her nesting season, although clutch size did vary with clutch order (Yasuda, unpublished data).Therefore, this result suggests seasonal differences in reproductive output between the dry season and the rainy season. Female green turtles spend time around the Huyong Island during inter-nesting period (Kittiwattanawong, 2003). Previous studies reported that female green turtles during this period rest on the seabed to save energy for the next nesting (Hays et al. 2000). Therefore, behavior during inter-nesting periods may be a key factor of the seasonal difference in reproductive output because a relationship between diving behavior and energy consumption during inter-nesting periods would be expected. Figure 4 shows the time-series of depth of two female green turtles during an inter-nesting period. Both female turtles continuously dived during the inter-nesting period. However, there was a difference in diving behavior between the rainy season and the dry season. Mean maximum dive depth for the rainy season was deeper than that for the dry season, and mean dive efficiency (proportion of bottom time to dive time) for the rainy season was smaller than that for the dry season (Yasuda et al. unpublished). These results suggest that energy consumption of female turtles during inter-nesting periods for the rainy season was greater than that for the dry season. This difference may be explained by a difference in oceanographic condition between the rainy season and the dry season. However, future study needs more extensive analysis on diving behavior of female turtles during inter-nesting periods. In addition, our inference must be also verified by future studies using data loggers which can estimate activity of marine animals in the sea (Yasuda et al. 2004).

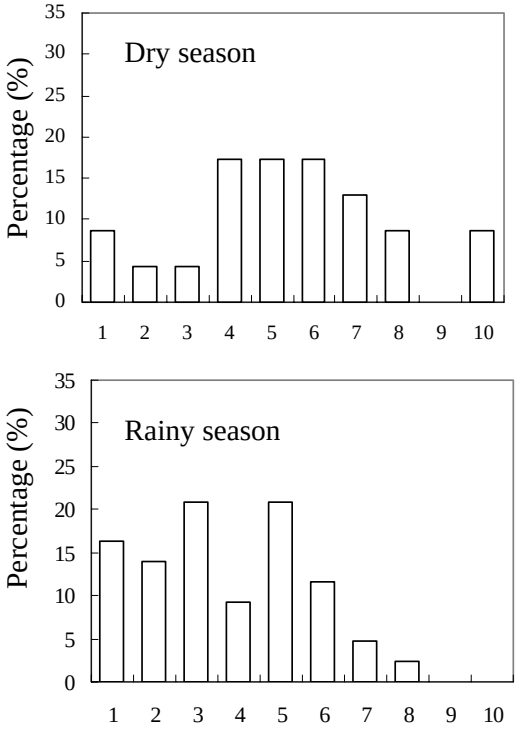

Fig.3. Histograms of the number of clutches of green turtles lay within a season for dry season (above) and for rainy season (below).

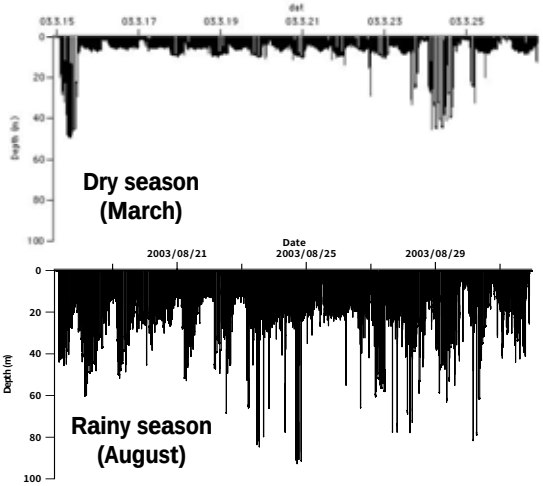

Fig.4. Time-series of depth for female green turtles during inter-nesting periods. Above; from March 15, 2003 to March 27, 2003. Below; from August 17, 2003 to August 31, 2003.

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