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The Significance of Diurnal Terrestrial Emergence of Green Turtles (*Chelonia mydas*) in the Galápagos Archipelago

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ABSTRACT

The diurnal, nonreproductive emergence of green turtles *Chelonia mydas* in Galápagos apparently occurs throughout the year on several islands. Turtles on beaches have cloacal temperatures that exceed temperatures of adjacent coastal waters. Basking turtles are predominately females. We hypothesize that females bask to accelerate digestion and fat build-up, necessary antecedents to egg production in reproductive periods. Basking turtles show a trend to clump among available beaches. Such behavior may be a response to microclimatic differences between beaches, although such differences were not apparent to us. The occurrence of thermoregulatory behavior in marine turtles in Galápagos may be a response to the cool waters of the Humboldt Current.

DIURNAL, NON-NESTING EMERGENCES of *Chelonia mydas* on beaches have been reported from several areas of the Pacific Ocean: Hawaiian and Leeward Islands (Kenyon and Rice 1959; Amerson 1971; Balazs and Ross 1974; Balazs 1976, 1980), Australia (Bustard 1973a, b, and 1979), Revillagigedos and Socorro Islands off western Mexico (Slevin 1931, Slevin in Fritts 1981), and the Galápagos Islands (Rogers 1824; Dampier 1906; Slevin 1931, 1935; Parsons 1962; Carr 1967; Pritchard 1971a, b; Slevin in Fritts 1981). Parsons (1962) erroneously quoted Woodes Rogers (1824) as recording the behavior off the coast of western Mexico. Rogers' remarks actually referred to Galápagos (Fritts 1981). Balazs and Ross (1974) and Balazs (1976) referred to such emergences as land basking, and proposed that a thermal advantage would be incurred by the basking turtles, but provided no data on the temperatures of turtles exhibiting this behavior. Balazs also argued that emerged turtles would be safe from shark attack, and hence emergence could be a predator-avoidance strategy. Terrestrial emergence is a common thermoregulatory behavior in aquatic turtles (Hutchison 1979). Of the turtles Bustard (1973a, 1979) observed hauled out on beaches on islands off northern Australia, nearly all were females. He hypothesized that females used such forays to avoid frenzied and continued copulatory attempts of males. Joseph Slevin (in Fritts 1981, Fritts and Fritts 1982) found a high percentage of females (94%) on beaches in Galápagos in 1905 and 1906. Slevin as-

sumed (1931, 1935) that these turtles emerged simply to "dry off." His data indicate that only about half of the females collected on beaches had enlarged follicles or shelled eggs. The remainder presumably lacked enlarged ova indicating that they were either juveniles or adults in nonreproductive periods (Fritts 1981). Balazs and Ross (1974) and Balazs (1976, 1980) reported that males, females, and juveniles (sex undetermined) bask in Hawaii. However, in each case detailed by Balazs (1980) females were more commonly observed basking than were males. The diurnal, non-nesting emergence of green sea turtles is well documented by the above examples. Unfortunately, few data exist to test the interpretations of Balazs or Bustard.

This paper is based on observations and data collected from *Chelonia mydas* hauled out on beaches or resting in extremely shallow water in the Galápagos Islands. Our objectives were to: determine the size and sex of diurnal, non-nesting emergent turtles; investigate body temperatures of such turtles in relation to ambient air, water, and substrate temperatures; provide data on location, orientation, and general behavior of such turtles; and, examine the existing hypotheses that attempt to explain this phenomenon and to clarify the possible significance of such behavior.

MATERIALS AND METHODS

Observations of diurnally emergent turtles were made in two ways: incidental sightings were made during various times of the year while the authors were involved in other research in the Galápagos Archipelago; and two system-

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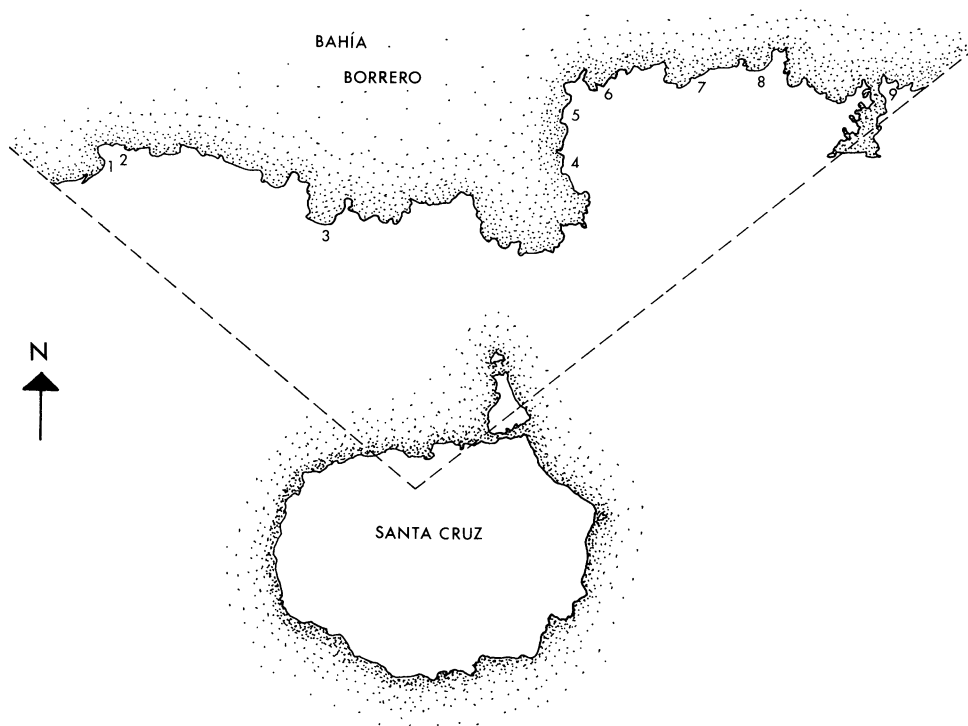


FIGURE 1. The central northern coast of Isla Santa Cruz with beaches numbered where emergent turtles were studied.

atic searches were made of a 12 km stretch of the north coast of Isla Santa Cruz (Fig. 1) where diurnal emergences were relatively common. Incidental sightings were usually made from small boats fishing, traveling or anchored close to shore. Such sightings were made on Isla Santa Cruz (12 December 1979), Baltra (13 January 1980), Santa Maria (=Floreana) (16 November 1979), and Fernandina (25 September 1978). Isla Santa Cruz is the second largest island in the Galápagos and occupies a central position in the volcanic island group. Fernandina is the westernmost and third largest of the islands, whereas Santa Maria is a smaller, southern island. Baltra is a small island just northeast of Santa Cruz (Fig. 2).

The systematic searches were made by cruising as close to shore as surf conditions would allow (usually <100 m offshore) in an inflatable boat propelled by an outboard motor with all participants (two or three people) watching for turtles on shore. The first systematic search was made on 29 November 1979, before the beginning of the 1980 nesting season. The second search was made on 31 January 1980, after nesting had begun. Since turtles were located from boats offshore, observers were most able to see turtles on light, contrasting backgrounds (*i.e.*, light-colored sand beaches); turtles hauled out on dark rocks could have been overlooked.

During the systematic searches and some of the in-

cidental sightings, the following procedure was used when a turtle was sighted on shore. The boat was landed if surf conditions allowed. If not, one person would swim ashore and collect the following data from as many turtles as possible: curved carapace length, curved carapace width, plastron length, sex, distance from the surfline (water), and cloacal temperature. Measurements were made with a flexible tape and temperatures were measured with a quick reading mercury thermometer. The area around each turtle was examined for tracks as evidence for active locomotion by the turtle. Usually the following data were recorded for each beach visited: visual estimates of beach length, temperature of the air, water, and surface of the beach sand, tidal stage, and evidence of nesting activity. At two beaches, both on northern Santa Cruz, neither landing nor swimming was possible. There, basking turtles were counted from the boat.

Cloacal temperatures were determined by inserting the thermometer about 10 cm into the cloaca. Air and sand temperatures were recorded at the level of the turtle farthest onshore. Air temperatures were read in the shade ten cm above the substrate; sand temperatures were read in the sun with the thermometer bulb covered by 1–3 mm of sand. Water temperatures were recorded in water one m deep near the beach. We termed the difference between a turtle's cloacal temperature and the water tem-

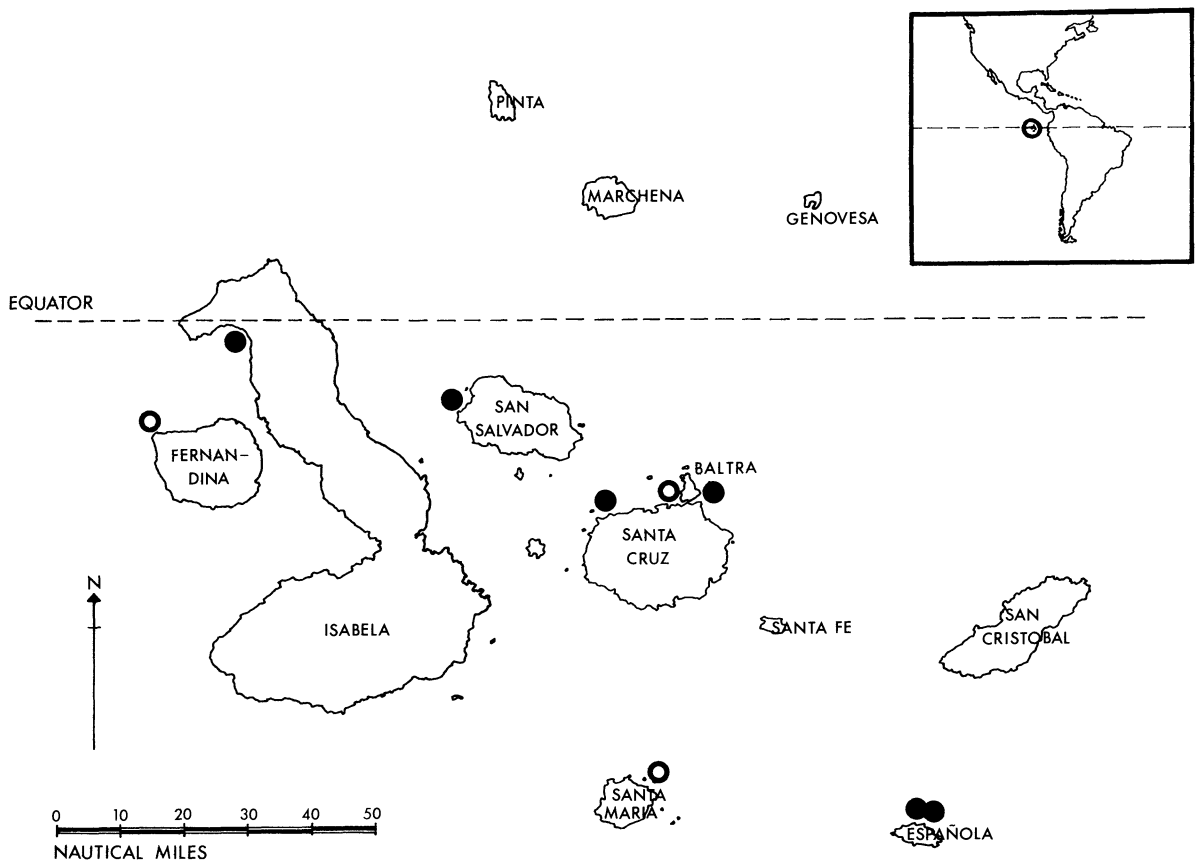


FIGURE 2. The principal islands of the Galápagos Archipelago. Open circles denote areas where emergent turtles were recorded during this study. Closed circles represent localities where emergent turtles were encountered by Slevin in 1905–1906 (Fritts 1981).

perature “cloacal temperature differential” and used this as a measure of the possible thermal advantage of diurnal emergence.

RESULTS

All turtles observed on beaches were *Chelonia mydas*. During the first systematic search (29 November 1979), 22 turtles were seen on eight of about 40 beaches examined between 1300 and 1630 hours. In the second systematic search (31 January 1980), six turtles were encountered on only one of the 40 beaches. The beach which contained turtles during the second search was the same beach that had contained the highest number of turtles in the first search (Beach #3). Incidental sightings included five turtles on Fernandina, two on Santa Maria, seven on Santa Cruz, and one on Baltra.

The locations of beaches on which turtles were observed during the systematic searches are shown in Figure 1. Turtles were seen at beaches one through eight on 29

November 1979. On 12 December 1979, turtles were noted on a beach in close proximity to Beach #9. On 31 January 1980, turtles were seen again at Beach #3. In the area surveyed on Santa Cruz about 40 small beaches were deemed suitable for emergence, but turtles were observed only on ten of these. Beaches were considered accessible to turtles (and therefore potential emergence sites) when signs of nesting activity were evident. Locations of our incidental sightings, as well as the locations of turtles captured on land by Slevin in 1905–1906 (Fritts 1981, Fritts and Fritts 1982), are shown in figure 2.

Of the 43 turtles observed during diurnal, non-nesting emergence, the sex of four was undetermined (external sexual characteristics not visible from our sighting distance of 100 m), 35 (90% of the sexed sample) were females, and four (10% of the sexed sample) were males. Males were observed on 29 November 1979, and on 25 September 1978. All individuals were judged to be adults on the basis of carapace measurements (Table 1).

All turtles except two males and two females were

TABLE 1. Summary statistics for measurements of size, temperature, and position on beach for turtles examined on 29 November and 12 December 1979. The numerals in parentheses are the means \pm 1 standard deviation.

	Carapace length (cm)	Carapace width (cm)	Plastron length (cm)	Cloacal temp. (C)	Cloacal temp. diff. (C)	Distance from water (m)
29 November 1979						
Males	77.9–83.5 (80.1 \pm 3.0) N = 3	77.8–85.5 (80.8 \pm 4.1) N = 3	57.3–63.2 (60.7 \pm 3.1) N = 3	25.2–31.1 (28.7 \pm 3.1) N = 3	0.6 — N = 1	0–10 (6.6 \pm 6.8) N = 3
Females	76.5–87.7 (83.5 \pm 3.8) N = 12	77.0–93.0 (82.6 \pm 4.1) N = 12	56.0–68.0 (64.2 \pm 3.7) N = 11	25.2–28.1 (27.0 \pm 0.7) N = 12	0.0–1.8 (0.8 \pm 0.07) N = 9	0–5 (0.75 \pm 1.5) N = 12
12 December 1979						
Females	81.8–86.0 (83.2 \pm 1.9) N = 4	81.5–83.5 (82.6 \pm 0.9) N = 4	65.0–70.5 (66.6 \pm 2.6) N = 8	26.8–27.5 (27.8 \pm 1.1) N = 3	1.0–3.2 (1.9 \pm 1.1) N = 3	0–4.0 (1.0 \pm 2.0) N = 4

observed on the beach without tracks. This suggests that most turtles had swum into shallow water and allowed themselves to be stranded by the wave action. Eight turtles (19%) were observed above the wash, while 35 (81%) were in position where the waves contacted the turtles on the ventral surfaces and lowest margins of their carapace. Two of the three males seen on 29 November were ten m landward from the surfline, whereas the third was near the surfline. Of the 12 females observed on 29 November 1979, nine (75%) were beached in the wave wash; two were about two m landward from the surfline and one was five m landward. The four females studied on 12 December and the incidentally sighted turtles on Floreana (November 1979), and Baltra (January 1980) were all located in the wave wash. The sightings on Fernandina (September 1978) included turtles several meters up the beach and others in the wave wash (Fig. 3).

One female that crawled from the water had occupied a position five m from the water and then returned to the wave wash (as observed from her tracks), possibly to cool. She was motionless in the surfline when found, so it is unlikely that her foray ashore represented an aborted nesting attempt. Diurnal nesting for *Chelonia mydas* in the Galápagos is unreported.

Cloacal temperatures varied from 25.2–31.1°C (\bar{x} = 27.5°C, SD = 1.4, N = 18). The highest values recorded (31.1 and 29.7°C) were from males. The length of the tail influences the distance between the cloaca and the body, which in turn may affect the difference between cloacal and body temperatures (Mrosovsky 1980). Cloacal temperatures of males, with their longer tails and more distally positioned cloacas, may not be as accurate as those of females for estimating body temperature. For this reason we have limited our discussion and conclusions to comparisons of cloacal temperatures: males averaged 28.7°C (SD = 3.08, N = 3) females averaged 27.2°C

(SD = 0.81, N = 15). A comparison of these means via a Mann-Whitney U test indicated no significant difference ($U = 36.0$; $P = 0.4069$).

Water temperature varied from 24.6–27.3°C (\bar{x} = 25.6, SD = 0.92, N = 6), yielding cloacal temperature differential (CTD) values from 0.0–3.2 (\bar{x} = 1.04, SD = 0.89, N = 13). Thus, all values for the differential were at or above ambient water temperatures. Because the influence of sexual dimorphism in tail length on male cloacal temperatures was not determined, CTD values were calculated only for females.

A single female (carapace length 84.0 cm) was captured while swimming in a shallow cove on 13 January 1980. Her cloacal temperature was 26.6°C, while the surrounding water temperature was 26.4°C; CTD was 0.2°C.

The distribution of turtles among the beaches sampled during the first systematic survey suggests that some beaches may be more frequently used as sites for emergence than others. On 29 November we recorded 22 emergent turtles located on only eight beaches. Four beaches had one turtle and four beaches had two, three, four, and nine turtles, respectively. Probability values were calculated based on a null hypothesis which assumed a random distribution of the 22 turtles among the 40 suitable beaches. The probabilities of the beaches containing one to three turtles were not sufficiently low to reject the null hypothesis ($P = .55$, $P = .30$, $P = .17$, respectively). However, the low probabilities of beaches with four and nine turtles ($P = .09$ and $P = .005$, respectively) suggest that the null hypothesis should be rejected. In the survey of 12 December, the only six turtles observed were hauled out on a single beach, an extremely improbable occurrence ($P = .00001$), if turtles are actually selecting beaches randomly. Incidental sightings also included aggregations of emergent turtles. A single beach on Fernandina



FIGURE 3. *Chelonia mydas* basking near the surfline and further up on beach near Cabo Douglas, Isla Fernandina, Galápagos, September 1978.

had five turtles and a beach on Santa Cruz had seven turtles. Observations on Baltra and Santa Maria were of solitary turtles. It is unlikely that turtles are randomly choosing the beaches upon which to emerge. Balazs (1980) noted a similar pattern in Hawaii.

We observed no copulations directly offshore before landing at any of the 13 beaches sampled. However, turtles often fled into the water when approached by an observer, and in two instances, copulations were observed immediately after females had fled into the water. In one of those instances, the mounted female was definitely a female which had fled from the beach. Swimming turtles were often observed immediately offshore from beaches with emergent turtles, and some of those swimming were males. However, we could not accurately quantify sexes and numbers of swimming turtles. At about 50 percent of the beaches sampled, turtles both motionless and slowly swimming in water less than five m from shore seemed more abundant than emergent turtles. This was especially apparent at beaches where the surf was minimal. Water temperature this close to shore was measured to be 1–2°C higher than water farther offshore.

Air temperature ranged between 25.8 and 27.3°C, while sand surface temperature ranged between 25.8 and 30.0°C. Turtles were observed emergent on cloudy, partially cloudy, and clear days.

DISCUSSION

These data demonstrate that diurnal emergence by *C. mydas* results in elevated cloacal temperatures. Resting in the warm waters of shallow lagoons may confer a similar thermal advantage over cooler waters farther from shore. However, the relationship between cloacal temperature and body temperature remains somewhat speculative. Mrosovsky (1980) showed that cloacal temperatures could be as high as 1.1°C above body core temperature if the thermometer was inserted only six cm into the cloaca. When a thermometer was inserted 15 cm into the cloaca, he found no difference between cloacal temperature and deep body temperature. Our thermometer insertion was ten cm. If the cloacal/deep body temperature difference increased linearly from 6 to 15 cm, a ten cm insertion would yield cloacal temperature values approximately

0.6°C above deep body temperature. Subtracting that from the average cloacal temperature differential presented in this study still leaves a probable body temperature higher than that of the adjacent water.

Balazs (1976) described turtles throwing sand over the carapace as a method of moderating surface heating and prolonging the basking for maximal heat gain of the body core. Turtles in Galápagos demonstrated a similar behavior. The habit of remaining in shallow water or the periphery of the surfline with most of the body exposed to solar radiation and air may also moderate body surface temperatures. The temperature of shallow water close to shore was measurably warmer at the beaches we sampled than offshore water. Hence, turtles remaining in the water at shore may be thermoregulating for higher temperatures as well. Whittow and Balazs (1979) noted that *Chelonia mydas* in Hawaii tended to emerge on north-facing beaches where substrate temperatures were lower than other exposures. The solar radiation and air temperatures in Galápagos are moderated during the garua season, an overcast period from June through December. During this period, the orientation of the beach might be less important than in Hawaii. Such factors would be expected to prevent overheating and allow longer periods of emergence than exposure to direct sunlight and high substrate temperatures.

If there is thermal advantage conferred by terrestrial emergence, it might accelerate digestion of foods and the fat build up necessary for egg production. A large percentage of the emergent females dissected by Slevin (Fritts 1981) appeared to have quiescent ovaries. This suggests that the focal point of the reproductive thermal advantage would be accelerated digestion and metabolism necessary for increasing fat reserves in anticipation of future reproduction rather than the metabolism of fats for ovulation and egg formation in the immediate future.

Pritchard (1971a) suggested that the primary nesting period for green turtles in Galápagos extended from December through March. Most data on emergent turtles presented here were obtained within one month of the primary nesting period. However, the observations of emergent turtles on Fernadina in September confirm that the behavior occurs outside of the nesting season. In addition, Slevin recorded emergent turtles in Galápagos during all months of the year except May, June, August, and October (Fritts 1981).

The presence of swimming turtles near beaches where emergence occurred is similar to observations of Bustard (1973a, b) in Australia, and Slevin (in Fritts 1981) on Isla Socorro off western Mexico. In each case, reproductively active males were occasionally present. Bustard (1973a) interpreted the emergence behavior by females to be a means of avoiding copulatory advances of males. He stated (1979) that emergent turtles were nearly always females. This hypothesis does not account for the male

emergences which occur in Galápagos (present report as well as Slevin in Fritts 1981), and in Hawaii (Balazs 1980), although our observations of copulations involving females which returned to the water support the possibility that male avoidance may be a factor in emergent behavior. Fritts (1981) hypothesized that the high proportion of females among emergent turtles might be a result of a selective advantage. Females have a greater caloric investment in reproduction due to both the large clutch size and the tendency to produce multiple clutches in a single reproductive season. Males would also be reducing their chances of obtaining copulations if they spent much time emerged since they can apparently copulate only when swimming.

Pritchard (in Balazs 1976) and Balazs (1980) hypothesized that diurnal terrestrial emergence by green turtles in Galápagos had occurred in previous centuries, but probably did not occur in modern times. The present data confirm that the behavior is relatively common throughout the archipelago.

Two explanations are available to account for the high proportion of females observed on beaches. 1. Females tend to emerge on land more than males due to a behavioral difference. Such a behavior may result from avoidance of males or increased metabolic requirements for reproduction. Conversely, males may tend to remain in the water to increase their probability of mating. 2. Females potentially show an equal tendency to emerge on land as males, but their abundance on beaches reflects a greatly skewed sex ratio in populations in which females outnumber males.

If there are naturally more females present than males then no behavioral difference is required to account for their greater abundance on land. In view of the recent work on environmental sex determination in turtles (see Bull 1980 for review), such skewed sex ratios are possible. Clearly additional data are needed on sex ratios in natural populations.

Like *Chelonia* in Hawaii, green turtles in Galápagos are often recorded on land in close aggregations. Our data demonstrate that emergent turtles are not randomly distributed among available beaches. However, the beaches occupied by emergent turtles did not appear to differ from other beaches in size, exposure, or slope. Whether this clumped distribution of emergent turtles has social significance or represents independent selection of sites with specific characteristics remains to be investigated.

Basking on land and in shallow waters may be an important thermoregulatory response to the cool waters of the Humbolt Current which sweeps past the Galápagos Archipelago. The coolest water and air temperatures in Galápagos occur from June through November during the garua (fog) season and the preponderance of sightings farther up the beach during this period may be the result of increased basking due to colder waters and mild-

er air temperatures than in the December through May period. The potentially warm equatorial temperatures on land in the Galápagos are moderated by the turtles remaining in shallow waters, in the wave wash, and by sand thrown onto the body and carapace. Terrestrial temperatures in Galápagos are also moderated by cool air masses related to the garua season. The habit of passively stranding instead of crawling higher on the beach results in turtles contacting moist sand with more moderate temperatures than dry areas found higher. All of these factors potentially contribute to allowing turtles to bask longer, elevating body temperatures significantly without excessive heating of body surfaces. The data available suggest that the elevation of body temperature is a primary role of terrestrial emergence. However, more data on the time turtles spend on the beach and the temperatures of turtles before and after such emergence is important to evaluating the significance of such behavior in the thermal biology of green turtles.

The fact that among sea turtles only *Chelonia mydas* is known to bask on land may stem from the herbivorous

food habits of this species. Plant material is difficult to digest and elevated temperatures may facilitate digestive processes.

Green turtles basking on beaches are known only from oceanic and offshore island situations. The absence of this behavior on continental beaches may be a result of predatory pressures by large mammals, including man.

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