

# Ecology and Behavior of Green Turtles Basking at Kiholo Bay, Hawaii

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## INTRODUCTION

The long-term study of juvenile and subadult green turtles at Kiholo Bay, Hawaii over the past 13 years has shown an approximate ten-fold increase in this population. Along with the increased numbers, we have noted changes in foraging and resting behavior at this location (Balazs *et al.*, 2000; Balazs, 1996; Rice and Balazs, 2000; Harrington *et al.*, This volume). Of particular note is the increase in the number of turtles that are emerging to bask ashore. Whittow and Balazs (1982) conducted the most extensive study to date of basking green turtles at East Island, French Frigate Shoals in the Northwestern Hawaiian Islands. Their work with adult females and males showed that the animals basked in areas exposed to trade winds, apparently to reduce thermal stress. Basking turtles also exhibited certain behaviors such as flipping sand onto their carapace in order to keep their internal body temperature below harmful levels. The reasons presented for basking behavior at French Frigate Shoals include safety from predators, an increased rate of digestion and egg maturation for the adult females involved in nesting at this important breeding site. Balazs (1974), working with 121 captive post-hatchling

green turtles, noted frequent basking behavior on emergent tiles placed at either end of a holding tank. "On occasion the blocks were so crowded with basking turtles that the animals were lying one on top of the other." The behavior observed at Kiholo Bay may be a natural one precluded by outside factors (hunting by man) until recently.

At Kiholo, green turtles normally rest nocturnally underwater in the enclosed four hectare lagoon with a narrow entrance channel known as Wainanali'i lagoon. Work done at Kiholo between 1987 and 1994 saw no evidence of basking (Balazs *et al.*, 2000; Laber and Waller, 1994). Since that time, the number of basking turtles observed has climbed dramatically to where it is now considered a normal behavior. This study examined the ecology and behavior of the basking turtles at Kiholo in a effort to understand their characteristics and significance to overall sea turtle life history strategies.

## METHODS

Basking behavior was monitored by observers on 17 days between October 1999 and February 2000. There were

a total of 116 hours of observations. Basking episodes were counted when the duration was at least 10 minutes and at least one-half of the turtle's body was out of the water when basking commenced. Times of emergence, prevailing weather conditions, tide level, environmental temperature ( $T_e$ ), substrate temperatures ( $T_s$ ) near basking turtles and carapace temperatures ( $T_c$ ) of basking turtles were recorded approximately every 30 minutes, when it was possible to do so without disturbing the turtles. When turtles returned to the water, the time and the reason for the return were recorded. The deep-body temperature ( $T_b$ ) was taken after varying basking durations, and under varying environmental conditions with a Cole-Parmer Digi-Sense thermister thermometer (model 8522-10). The lubricated flexible probe was inserted at least 15 cm into the colon to reach the deep-body regions.  $T_s$  and  $T_c$  were taken from a distance with an Omegascope OS530 series hand held infrared thermometer and  $T_e$  was estimated using a black globe (Casella and Co., London) painted with Nextel Black Velvet Coating (Minnesota Mining Co.) suspended approximately 5 cm above the substrate. This distance was an approximation of the midpoint of the turtles' bodies. The rationale for the use of the black globe was presented by Whittow and Balazs (1982). Breath-hold intervals were measured by viewing continuous video tapes of the basking animals. This was necessary because the small respiratory movements made by basking turtles were nearly unobservable. Individual turtles were identified by numbers lightly etched into the left and right second lateral scutes.

## RESULTS AND DISCUSSION

The lagoon is salt water with a substantial amount of fresh ground water running into it. The surface water (down to ~0.5 m) has a temperature between 20-22°C and a salinity of 8 - 15 parts per thousand (ppt). The subsurface water (>0.5 m) has a temperature of 24-26°C and a salinity of 28-30 ppt. Sea water outside of the lagoon is 28 to 36 ppt. Basking behavior was observed only within the confines of the Wainanali'i lagoon, and two interconnected mixohaline tidal fish ponds at Kiholo (Harrington *et al.*, This volume). The north side of the pond is solid basalt and the south side is composed of basalt rocks and boulders with a small sand beach at the southeast end. The highest concentration of basking was found to occur in the southwest half of the lagoon where the largest turtles haul out. Smaller turtles do use the north side by hauling out on the solid basalt rock, a difficult task for the larger subadults. Basking was initiated during the daylight hours only, although basking did extend into the night on many occasions. However, when turtles were resting in shallow water and the tide went out, leaving them dry, they remained in place. There was a peak of basking activity in the mid-morning (0900 and 1000 hours) and then again in the early afternoon (1300 and 1400 hours).

### *Duration*

The length of basking episodes was found to vary greatly. The 35 complete basking episodes recorded had an average length of 2.6 hours ( $\pm 0.41$ , range: 13 minutes to 11 hours). The longest recorded basking period was 11 hours, but there were turtles that basked for more than 11 hours but were not observed reentering the water. Based on three nights of observation, the average number of turtles that continued basking after sunset was four.

### *Site Utilization*

As is the case with the known green turtle's diel foraging and resting behavior at Kiholo Bay, basking site selection by individual turtles was quite predictable. We are not yet able to predict when a turtle will bask, but in cases where we have identified individuals (lightly etched carapace numbers or natural physical characteristics), we could usually predict where they would bask. Most turtles we have identified basked repeatedly within a few meters of a given site unless there was a disturbance or other turtles occupying the area. In some instances, the turtles will return to the exact same spot (within an area of 0.5 m<sup>2</sup>).

### *Basking Frequency*

Turtles that were captured and marked could be identified during subsequent basking episodes. There were 12 carapace-numbered turtles that were found basking in the lagoon subsequent to their in-water capture and marking by us. Based on the number of times that they were observed basking, and the total number of observations, a rough estimate of the basking frequency was made. On average, a specifically numbered turtle was found basking on every third observation. Observations indicate, however, that basking tends to occur in episodes with a turtle basking on several consecutive days and then not basking at all for several days. More data are needed. The average basking episode lasted 2.6 hours and occurred on the average of once every three days. Thus, an average of 3.6% of the turtles' time is given to basking behavior. Work done at Punaluu (Rice *et al.*, 2000) showed that a turtle there utilized 3.2% of its time in basking behavior. Adult turtles studied at French Frigate Shoals were estimated to spend 4.6% of their time basking (Whittow and Balazs, 1982).

### *Behavior During Basking*

Turtles that were hauled out and basking were generally very still with their eyes partially open. As the basking episode progressed, their degree of alertness decreased and many closed their eyes and remained oblivious of most stimuli. In some cases, the animals appeared comatose even after they were captured for deep-body temperature measurements, indicating that they were indeed in a state of deep "sleep." These animals would lie absolutely still throughout the duration of the basking episode, moving only slightly to take a shallow breath. Breathing during these basking episodes did not involve the usual raising of

the head to take in air. The turtles would, in many cases, not raise their heads and could only be observed to breath by watching the carapace rise. Breath-hold duration varied a great deal between animals and during individual basking episodes. The average breath-hold duration for a large turtle was 3.0 minutes ( $\pm 0.43$ ,  $n = 7$ ) and 4.1 minutes ( $\pm 1.24$ ,  $n = 11$ ). The average for a medium size turtle was 3.1 minutes ( $\pm 0.05$ ,  $n = 6$ ) and 1.2 minutes ( $\pm 0.07$ ,  $n = 44$ ). For a small turtle (carapace #2, 7 kg), the average was 4.8 minutes ( $\pm 1.6$ ,  $n = 11$ ) with a range of 26 seconds to 15.4 minutes on one occasion. In a subsequent 50 minute count (on a different day) for the same turtle, the average period of apnea was 1.5 minutes ( $\pm 0.06$ ,  $n = 35$ ).

#### *Temperature Regime*

Substrate and environmental temperatures were recorded approximately every 30 minutes during observations of basking behavior. These temperatures were compared with deep-body temperatures recorded from basking turtles. The average deep-body temperature ( $T_b$ ) of turtles that were basking for at least 3 hours (between 0800 and 1700 hours) was 30.3°C ( $\pm 0.74$ , range = 26.9°C to 34°C). Average carapace and environmental temperatures were 33°C ( $\pm 0.67$ ) and 35.7°C ( $\pm 0.45$ ), respectively, for the same time period. The surface temperature of the water in the lagoon was 20 - 22°C and the subsurface temp was 24-6°C. Within two hours, basking turtles could warm up internally to as much as 10°C above ambient temperature, depending on environmental conditions. They appear to reach thermal equilibrium between 32-34°C. Since this study was conducted during the fall and winter months in Hawaii, environmental temperatures were lower than would be expected during the summer months. None of the animals measured had  $T_b$ s that were critically high (Lutz and Musick, 1996) and, as a consequence, we believe that few of the turtles returning to the water were stimulated by overheating. This may not be so during the warmer months at Kiholo Bay. At night,  $T_b$  was lower depending on the amount of time after sunset and the size of the turtle. We speculate that the turtles remain out of the water after dark because they have a positive deep-body heat bank which takes hours to dissipate and reach equilibrium with  $T_e$ . The external temperature of the carapace of these turtles drops very rapidly in step with the decreasing environmental temperature. While more data are needed, there is a steady decline in  $T_b$  over time in the evening, and the length of night basking is dependent on the time it takes  $T_b$  to decrease to near ambient water temperature. Once that is reached, the animal is stimulated to return to the water. The recent deployment of remote, interactive video cameras (SeaTurtleCam) at Kiholo Bay will significantly enhance our ability to learn more about the basking phenomenon at this special place (Balazs *et al.*, This volume).

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