

ing and play, responses that appear to change reliably with advances in chronological age (Mann and Mellgren, 1997 and unpublished observations). Burghardt (1988) predicted that if play behaviors were to occur among reptiles, well-fed sea turtles in warm oceans would be the likely species given the relative energy efficiency of their aquatic habitats and taking into account their changing energetics during early development.

Green sea turtles maintained in captivity for a year showed pronounced changes in growth and little mortality (*i.e.*, only 4 out of 36 green hatchlings failed to survive to one year). Hawksbill hatchlings that exhibited deficient weight gains at 67 and 90 days posthatch (*i.e.*, 9 out of 36) died within the next two months. Therefore, weight per se may be an important factor for survivorship of individuals of this species. We note, too, that intraspecific aggression was apt to occur in hawksbills beginning at 90 days posthatch, suggesting that this may be a behavioral variable critical to survival and perhaps of special importance when growth has been compromised. Future work will address the ontogeny of intraspecific aggression in this species with the aim of remediating rearing situations that cause injury to young turtles.

As noted by Chaloupka and Musick (1997), there have been few longitudinal studies of growth in captive reared turtles. However, such data are essential for understanding the constraints on growth when diet and environmental conditions are stable relative to those factors in the wild. Allometric analyses (*e.g.*, Reiss, 1989) may prove useful for understanding the behavior and ecology of these species. Such analyses already have been performed to understand some aspects diet selection and the foraging ecology of sea turtles and could be extended to the rehabilitation of turtles recovered from degraded foraging habitats (Bjorndal, 1997).

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DIVING, BASKING, AND FORAGING PATTERNS OF A SUB-ADULT GREEN TURTLE AT PUNALU'U, HAWAII

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INTRODUCTION

Punalu'u is a small sheltered bay on the southeast coast of the Ka'u district on the Island of Hawaii. The area is a county park and a popular tourist stop and has been a green turtle study site since 1976. Green turtles (*Chelonia mydas*)

in Hawaii feed primarily on benthic algae in the rocky foraging pastures around the eight major Hawaiian Islands. The primary food source for green turtles at Punalu'u is an intertidal red alga, *Pterocladia capillacea* (Balazs *et al.*, 1994).

Green turtles are known to spend most of their time feeding or resting underwater. Foraging behavior of green turtles is well documented and in Hawaii is typically characterized by numerous short dives in shallow water (<3 m) with short surface intervals (<5 sec) (Balazs, 1980). Resting periods are characterized by longer dives (>20 min) in deeper water. The amount of time that turtles spend foraging versus resting is still largely unknown. Previous studies have observed foraging and resting behavior over relatively short periods of time (Ogden *et al.*, 1983; Brill *et al.*, 1994; Balazs, 1995). In addition to feeding and resting behavior, turtles in Hawaii have been exhibiting a new behavior, terrestrial emergence (basking). Basking behavior, mainly involving adults, has been known for many years to occur in the Northwestern Hawaiian Islands (Whittow and Balazs, 1982), but was rarely observed in the main islands until recently (Balazs, 1995). The reasons for basking behavior in green turtles are unknown although several theories have been postulated (Garnett, 1984; Swimmer *et al.*, 1996). At Punalu'u, several sub-adult and juvenile turtles regularly crawl out onto the black sand beach and bask. This behavior is normally observed during the day, but lack of night-time observations makes it difficult to know the frequency of nocturnal basking. The purpose of our study was to determine the relative allocation of time given to each of the three major behaviors (diving, basking and foraging) over an extended period of time.

MATERIALS AND METHODS

Data were obtained from November 15, 1996 to July 22, 1997 from a sub-adult green turtle hand captured in shallow water using snorkeling equipment at Punalu'u, Hawaii. This turtle, hereafter known as Turtle 257, was first captured at Punalu'u in July, 1990. Turtle 257 had an apparent 7 year history of residency at Punalu'u. At the time the TDR and sonic tag were applied, the turtle measured 72.5 cm in straight carapace length and it weighed 52.5 kg.

A Wildlife Computers, Inc. MK5 time-depth recorder, and a Sonotronics, Inc. CHP-87-L sonic tag, were attached to the third lateral scute on the right side of the carapace. To set the MK5 and sonic tag in place, a two part silicon elastomer was first applied to the base of the tags which were then placed on the sanded and cleaned scute. The tags were safely and securely attached using pigmented polyester resin and fiberglass cloth. In addition, a small square of fiberglass cloth was placed high on the second lateral scute on the left side to facilitate identification during field observations. Two students from the University of Hawaii, Hilo conducted visual searches from shore and while snorkeling in the bay on 23 different days. The observations of the turtle's location, behavior and activity were noted along with the time and date. These data were later compared with the TDR data to associate certain behaviors with specific MK5 data profiles. The MK5 sampling protocol was set to record depth every minute. When the tag was out of the water, sampling was suspended and the time of emergence was recorded.

Turtle 257 was electronically monitored for a total of 249 days, and data from 226 days were used in this study (days lost represent time when TDR memory was full). The data for the day after each capture/release were not used in this study as our work elsewhere indicates that capture/release changes normal behavior for approximately 24 hours. Data was downloaded in the field using the Wildlife Computers, Inc. interface hardware and a Macintosh Powerbook.

The data obtained showed a depth reading for the turtle every minute giving 1440 data points each day. If Turtle 257 left the water to bask, the total time basking was recorded. Each day's data were graphed and analyzed as to whether the depth and breath-hold profiles represented resting or foraging behavior. Diving profile characteristics were evaluated based on observations at Punalu'u and experience from other sites in Hawaii. Diving profiles were characterized as resting dives (dives to a relatively constant depth for more than 20 minutes), and foraging dives (generally short, shallow dives from 0 to 3 M). Terrestrial emergence (basking) behavior was noted as dry periods by the TDR and is represented as a negative depth (-4 meters) by the analysis software. Figure 1 shows a sample 24 hours of data with resting, foraging and basking periods indicated.

RESULTS

Resting Dives: Resting dives showed a depth range from 4 to 38.5 meters. The average depth of resting dives was 12.9 M. Dives deeper than 14 meters were uncommon and appeared to be exploratory dives. Resting dives had a mean duration of 59 minutes with a range of 20 to 117 minutes. On the average, there were 12 resting dives per day with a range of 2 to 25. Surface intervals during resting dives averaged 2.8 minutes (N=84). None of the data indicates that Turtle 257 made resting dives inside the bay, although we have occasionally observed a few animals resting on the bottom in the bay during night observations.

Terrestrial Basking:

Turtle 257 exhibited basking behavior on 64 days (82 incidences) for a total of 176 hours or 3.2% of the observed time. The average length of terrestrial basking was 130 min with a range of 7 to 945 min. Basking has normally been observed to occur during the day, but data from Turtle 257 showed that terrestrial basking does occur at night. While basking normally began during the middle of the day (median 1100 hours), there were 10 occasions when basking continued into the night for a total of 44.4 hours or 25% of the total basking time. Basking was never initiated after dark. The reason(s) turtles bask is still not understood. It is clear, however, that the behavior accounts for a significant portion of Turtle 257's behavior.

Foraging Behavior:

Dives made in shallow water for short periods of time were interpreted as foraging behavior. TDR dive profiles do not allow ready determination of dive time or surface intervals, but direct observations and data from other observers give dive times of 4 to 8 min. with a mean of 4.5 min. Forag-

ing turtles normally take one breath between feeding bouts and are only on the surface for a matter of seconds. Numerous green turtles can commonly be found feeding in shallow water at Punalu'u during daylight hours when the tide is medium to high. *Pterocladia capillacea* is an intertidal algae and the tide must be medium to high for the turtles to access it. Often turtles were observed with their entire carapace exposed briefly as they fed in shallow water. Turtle 257 was observed feeding in very shallow water on several occasions. The foraging depth data does not allow us to determine actual feeding time and certainly includes other activities.

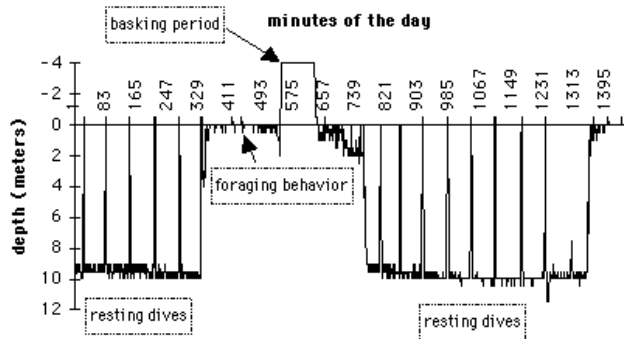


Figure 1. Sample 24 hour diving profile for Turtle 257 showing resting dives, foraging and basking behavior.

Data that fits the foraging profile show that most foraging occurs at between 0 and 2 M depth for an average of 8.9 hours/day. The range of foraging time was between 0 and 20 hours/day. The cause of this variation is unknown but could be related to weather, food availability, tides, or any of a number of factors. Before green turtles in Hawaii were fully protected in 1978, they fed nocturnally at Punalu'u. Since that time, they have begun to feed primarily during daylight hours. Seventy-two percent of foraging behavior in Turtle 257 occurred between the hours of 0600 and 1800. This is in line with observations of Punalu'u turtles in general and Turtle 257 in particular.

Although this study involved only one sub-adult green turtle, all indications are that this particular animal has exhibited a consistent behavior pattern over time. Turtle 257 has been well known by residents and scientists who regularly visit the area and has at least a 7 year residency history at Punalu'u. On the average, Turtle 257's daily behavior pattern was divided into approximately 12 hours of resting dives, 9 hours of foraging behavior, 1 hour of basking behavior and 2 hours of surface/travel time. The range of time devoted to various activities was very large. There were days when no foraging behavior was exhibited and the total time was allocated to resting dives. On other days, the foraging behavior was nearly continuous for up to 20 hours. Terrestrial basking occurred approximately every 3.5 days throughout the monitored period and averaged 130 minutes per emergence. The factors involved in promoting this variability remain to be determined. Tidal level, food availability, weather and other factors undoubtedly influence green turtle behavior.

The use of TDR's in the study of green turtle behavior has revealed significant information about their daily diving and basking patterns. Continuing work using TDR's at several locations in Hawaii will undoubtedly clarify many of the questions raised in this study.

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