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In-Water Observations of Recently Released Juvenile Hawksbills (*Eretmochelys imbricata*)

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Direct observations of animals at different life history stages provide important information regarding habitat use and behavior. Furthermore, understanding daily movements and activity patterns of sea turtles can provide insights into important foraging and resting sites, and therefore critical habitats (Seminoff *et al.*, 2002) that may require specific conservation measures. Focal follows of marine turtles have been reported by several authors (Houghton *et al.* 2000; Diez *et al.* 2002; Houghton *et al.* 2003; Meadows 2004; Schofield *et al.* 2006). Meadows (2004) used focal-animal activity budget observations to study impacts of human-turtle interactions and categorized observed behaviors as inactive on the bottom, swimming in the water column, being at the surface, active on the bottom, and feeding. In addition to a variety of solitary behaviors such as resting, swimming (Booth & Peters 1972; Schofield *et al.* 2006), foraging (Booth & Peters 1972; Houghton *et al.* 2000; Schofield *et al.* 2006), food handling (Davenport & Clough 1985), and self-grooming (Schofield *et al.* 2006; Frick & McFall 2007), several authors have directly recorded social interactions of male and female turtles, including antagonism and mating in loggerhead turtles (*Caretta caretta*) (Schofield *et al.* 2006), and initial courtship interactions, mounting behavior and intermale aggression in green turtles (*Chelonia mydas*) (Booth & Peters 1972; Jessop *et al.* 1999). However, relatively few direct observations of juvenile sea turtle activities are available in the published literature (Davenport & Clough 1985; van Dam & Diez 1997; Houghton *et al.* 2003), and we are unaware of reports of direct, in-water observations of captive-held turtles that have been released.

In most cases, surveys for sea turtles are conducted in areas where individuals occur in high densities, and cover relatively small areas of distribution (van Dam & Diez 1997; León & Diez 1999; Diez *et al.* 2002). However, expanding observational investigations in areas with little previous work may provide critical habitat and behavior information important for management of turtle species. Although some work has been done on the behavior and habitat use of the critically endangered hawksbill turtle, *Eretmochelys imbricata*, in its juvenile stage (Limpus 1992; Boulon 1994; Musick & Limpus 1997; van Dam & Diez 1997; León & Diez 1999; Meylan 1999; Diez & van Dam 2002; Whiting & Koch 2006), direct, in-water observations of hawksbill behaviors have not previously been reported from the waters of Honduras, despite the fact that the Bay Islands have been recognized as one of seven major nesting areas on record in the Caribbean for this species (McClenachan *et al.* 2006). In addition, there are numerous anecdotes by local fishermen and unpublished reports of hawksbill sightings in the past, especially around the Bay Islands (Carr *et al.* 1982; Cruz & Espinal 1987).

Our purpose here is to provide the first report of findings for in-water observations of activities for captive-held, recently-released, juvenile hawksbills from Honduras.

Juvenile hawksbill turtles were incidentally hand captured by local fishermen around Port Royal between March 2006 and June 2007, and kept in a large sea pen at our research site for periods ranging from a few weeks to eight months. Turtles were fed approximately every other day, but were not fed on the day of release. Prior to release, turtles were flipper tagged with Inconel style 681 metal tags

Activity	Mean time of all activity ± S.E.	Range (min)	Proportion of observation time
Swimming	15.3 ± 2.9	0.3 – 45.0	78.9
Investigating	2.9 ± 1.8	0.1 – 30.3	15
Eating	0.2 ± 0.1	0.1 – 1.7	0.8
Resting	0.2 ± 0.2	0.1 – 3.1	1.1
Surfacing	0.8 ± 0.2	0.1 – 3.0	4.2

Table 1. Activity categories, mean time (min), time range of each activity, and proportion of total observation time of each activity for 19 juvenile *E. imbricata* released and observed near Port Royal, Roatán, Honduras.

(Archie Carr Center for Sea Turtle Research, supplier), and weighed with a digital scale (± 0.1 kg). Each turtle's straight carapace length (SCL) (± 0.1 cm) was measured from the nuchal notch to the tip of the supracaudal scale, and digitally photographed.

Turtles were transported by boat approximately 3 – 8 km (up to 20 min) to release sites in the Port Royal area (N16°23.63', W 086°18.87') along the south-eastern coast of Roatán in the approximate location of capture (Figure 1). The exception to this was Site A which was also along the south coast, but west of the other release sites and approximately 1 km (10 min) from the temporary holding site (see Figure 1). These areas consist of shallow (< 20 m) coral reefs with large patches of sandy substrate. Hard corals of the family Pocilloporidae and Faviidae are highly abundant, while Acroporidae and Meandrinidae occur occasionally in this area. Soft corals in the Plexauridae and Gorgoniidae families are also abundant. Several of the tube and vase sponges in the family Demospongiae are commonly seen in the reef flat zone, while rope sponges in the genus *Aplysina* are abundant on the shallow reef slopes. In addition to coral reef habitat, there are large beds of turtle grass (*Thalassia testudinum*) along the shallow (<3 m) inshore areas toward the north. To the south, the main substrate is coral, with patches of coral rubble and sand. The reef flat slopes gently to the south until reaching the outer edge of the reef crest, where the reef wall drops to more than 300 m. All releases occurred between 0900 and 1430 hrs. A team of two divers used SCUBA to undertake 19 observations of juvenile hawksbills immediately after release. Each turtle was released alone and was followed for as long as possible, ranging in duration from 3 – 48 minutes. We measured the time of each activity with a Daigger waterproof, split-time, stop-watch (Daigger, Illinois, supplier) and kept records of times (1 ± 0.1 s) that individuals spent in each activity using an underwater notepad. We noted the running time when an activity started and ended, and recorded those times under the appropriate activity category. While following each turtle, we recorded general trends and durations of all activities. We classified all observed activities into five categories: swimming (continuous movement through the water column); investigating (the deliberate search for food material indicated by a pause in swimming and an intentional examination of material in the immediate vicinity of the individual); resting (coming to a stationary position on the sea floor); eating (the intentional ingestion of a substance); and surfacing (to breathe).

To investigate if body mass varied with straight carapace length we analyzed weight and SCL measurements by linear regression. Times spent in each activity were compared by general linear repeated-measures ANOVA. Since the data did not meet the assumptions of homoscedasticity, results are reported using the Greenhouse-Geisser statistic. We consolidated all carapace lengths into size classes (20.0 – 29.9, 30.0 – 39.9, and 40.0 – 49.9 cm) and compared the swimming times for each by a Kruskal-Wallis test. The significance level for all analyses was set at alpha = 0.05.

Turtle body mass ranged from 1.2 – 10.2 kg (mean = 5.0 ± 0.6 kg; N = 19; two turtles were measured twice in separate instances; 037-06, 135 d apart and 053-07, 56 d apart; see Figure 2). SCL for all turtles ranged from 21.8 - 46.0 cm, with a mean of 34.4 ± 1.6 cm; two turtles were measured twice in separate instances; 037-06, 135 d apart and 053-07, 56 d apart (Figure 3). Body mass was positively related to SCL ($r^2 = 0.923$, $P < 0.001$, N = 19; Figure 4).

Turtles were separated into three size classes based on SLC. We found 4 individuals within 20.0 – 29.9 cm, 12 individuals within 30.0 – 39.9 cm, and 3 individuals in the 40.0 – 49.9 cm class.

During 368.6 min of direct observations, swimming was the most common activity. Mean swimming time was 15.3 ± 2.9 min (Table 1), representing 78.9 % of all observed activity time. Although we did not specifically note the depths at which each activity took place, all turtles were released in approximately 8 - 10 m of water. All animals that dove toward the substrate spent the majority of time swimming less than 2 m from the substrate. As a result, on almost all occasions turtles swam into, and brushed up against soft corals (*Muricea* sp., *Muriceopsis* sp., *Plexaurella nutans*, *Pseudopterogorgia americana*, *Eunicea* sp.) and the hydroid, *Millepora alcicornis*. Turtles appeared to have no aversive reaction to the hydroid even when in contact with the soft tissue of the neck and flippers. At times, some turtles appeared to be temporarily caught in soft coral and extricated themselves by pushing against the coral, a nearby coral, the substrate, or by reversing their swimming

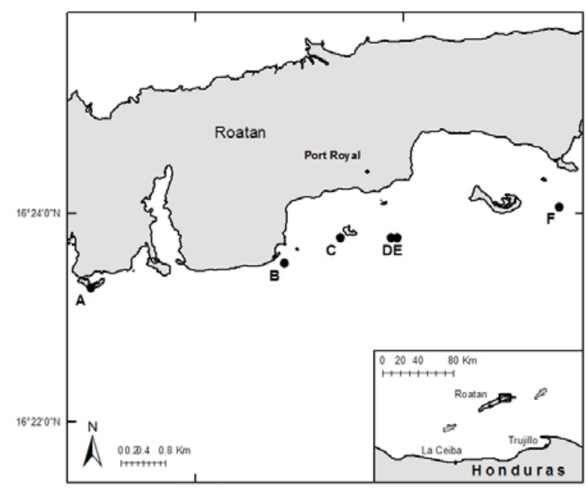

Figure 1. Port Royal area, Roatán. Honduras. Black points represent turtle release sites. Each letter specifies the identification number of turtles released at that site. A (N16°23'17.8", W086°21'0.90") – #057-07; B (N16°23'32.4", W086°19'07.2") - #014-06, #020-06, #048-07; C (N16°23'45.0", W086°18'36.0") - #037-06, #052-07; D (N16°23'46.2", W086°18'08.4") – #018-06, #033-06, #023-06, #053-07, #046-07, #055-07; E (N16°23'45.6", W086°18'01.8") - #045-06, #027-06, #044-06, #037-06; F (N16º24'03.0", W086º16'30.0") - #041-06, #040-06.

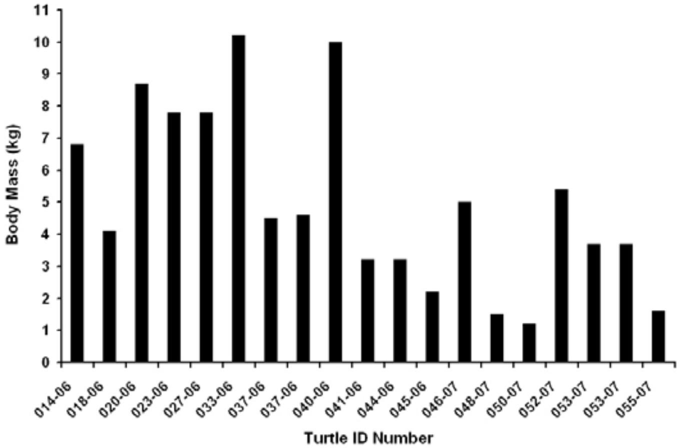

Figure 2. Body mass (kg) for each of the 17 turtles released during the study. Note that two turtles (037-06 and 053-07) were recaptured and released a second time, bringing the total number of releases to 19. See text for intervals between re-releases.

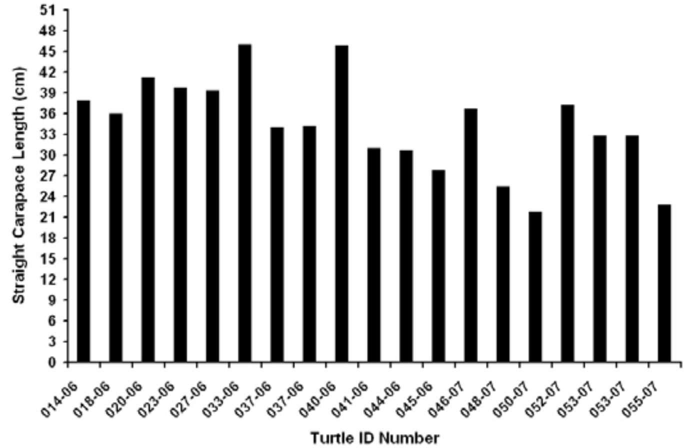

Figure 3. Straight carapace length (cm) for all 19 turtles released during the study. Note that two turtles (037-06 and 053-07) were recaptured and released a second time, bringing the total number of releases to 19. See text for intervals between re-releases.

strokes. On four occasions, we observed turtles swimming through yellowtail damselfish (*Microspathodon chrysurus*) territory and subsequently being attacked. However, in only two instances did we observe yellowtail damselfish actually biting the soft skin of hawksbills. In these cases, both turtles reacted by dipping laterally away from the attacker and generating 2 - 3 power strokes away from the immediate area. Subsequent to this response, these turtles then resumed normal swimming behavior. Even recent attacks did not deter a hawksbill from subsequently swimming through yellowtail damselfish territories.

Mean time for investigating substrate for food material was 2.9 ± 1.8 min, representing 15.0 % of overall activity (Table 1). We observed 5 turtles about to pass small crevices, mounds of sponges and patches of zooanthids, change direction and investigate these objects. In some cases, animals pushed under small ledges or entered crevices to search the rock or coral substrate. Investigations sometimes resulted in hawksbills sampling food items which they either ingested or rejected. On three separate occasions, one turtle took sample bites of materials, but discontinued eating. This individual sampled the zooanthid, *Palythoa caribaeorum* on two occasions resulting in ingestion. During a third instance, the same individual sampled an unidentified hard, branching coral, but subsequently rejected the sample. During the current observations, turtles spent an average of 0.2 ± 0.1 min eating, representing only 0.8 % of all activity time observed (Table 1).

The results of this study suggest hawksbills spend little time resting during the period of the day when observations were made. Overall, a mean of 0.2 ± 0.2 min (1.1 % of all activity time) was used for resting (Table 1).

The mean surfacing time for all turtles observed was only 0.8 ± 0.2 min (Table 1), representing 4.2. % of all activity time observed. We noted a change in behavior between the first one or two surfacing times and successive surfacing. Most individuals approached the surface the first and second time with what appeared to be hesitation. While still submerged approximately 1 m below the surface, turtles would exhale, then immediately surface for only a very brief period (usually less than 0.1 min). This would quickly be followed by strong, rapid power strokes to descend to just above the substrate. However, on subsequent surfacing, turtles appeared less hesitant to approach the surface and spent 0.4 – 0.6 min there. In some cases, turtles surfaced multiple times after very brief (< 2-3 min) dives.

When all activity data were compared, we found a significant difference in the mean time spent on the activities observed (Friedman, $\chi^2_4 = 52.8$, $P < 0.001$; Table 1). Post-hoc Wilcoxon pair wise comparisons showed significantly more time spent swimming than investigating, resting, eating or surfacing. However, when size classes were compared, we found no significant difference in time spent swimming among the three classes ($\chi^2 = 0.46$; $P = 0.80$).

We found a significantly positive relationship between body mass and carapace length for juvenile hawksbill turtles. According to Georges & Fossette (2006), body mass is linked with the capacity of the organism to buffer changes in food availability, as well as in estimating food consumption of a population. At present, however, our limited data set does not allow us to either determine growth rates, or assess food consumption patterns for these individuals. These turtles are likely juveniles, with some individuals potentially being recent recruits. Although no data are available on sizes of breeding adults from Roatán, work by others (Boulon 1994; van Dam & Diez 1996, 1997; León & Diez 1999) indicates that turtles with SCL >69.7 cm may be considered adults. Since all turtles in our study had SCL <69.7 cm, they were likely juveniles. Turtles captured with SCL < 25.0 cm were possibly recent recruits from pelagic habitats. The presence of juveniles and absence of adults suggests that the inshore area on the south-east of Roatán may be an important area for foraging and recruitment of hawksbills in the region, and may represent a developmental habitat from which juveniles eventually migrate to adult foraging grounds.

The majority of turtles spent the greatest amount of time swimming, compared with the time investigating, eating, resting or surfacing. The amount of time spent swimming and investigating may represent the amount of effort turtles spend to find either preferred or sufficient amounts of food materials. Van Dam & Diez (1997) found dives by immature hawksbill on shallow reef areas were characterized by continuous variation in depth, indicating that turtles were likely foraging, traveling or undertaking predator avoidance. In contrast, Houghton *et al.* (2003) found juvenile

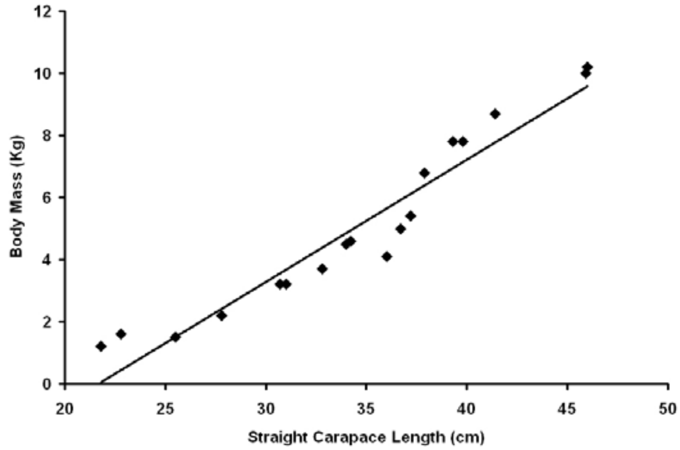

Figure 4. Pearson Correlation of body mass (kg) by straight carapace length (SCL) in cm, for *E. imbricata* released and observed near Port Royal, Roatán, Honduras. Body mass was estimated with the equation: Body mass (kg) = 0.3944 • SCL (cm) – 8.5569 .

hawksbills in the Seychelles to undergo alternating bouts of foraging-resting-foraging, with foraging efforts at depths of 2 – 4 m, while resting occurred at depths of 6 – 9 m.

We found no difference in the amount of time spent swimming among size classes, although we recognize that our sample sizes within each class were small. In contrast, van Dam & Diez (1996, 1997) found a strong, positive relationship between carapace length and duration of foraging dives. However, van Dam & Diez (1996, 1997) found the number of hours spent foraging per day was not related to size.

The juvenile hawksbills in our study did not spend a high proportion of their daylight time resting, at least between 0900 and 1530 hrs. Work by van Dam & Diez (1996, 1997), as well as personal observations (SGD) suggest juvenile hawksbill turtles tend to be less active at night than during the day. Renaud & Carpenter (1994) found adult loggerhead turtles made fewer and longer submergences at night, presumably resting, and therefore needing to surface less often than during active periods of the day. Van Dam & Diez (1997) suggested that juvenile hawksbills may be unable to forage efficiently at night, since they normally seek cryptic and irregularly distributed food items. However, hawksbills, like green turtles, likely have excellent underwater eyesight (Ehrenfeld & Koch 1967). It is possible we may have missed the intermittent, resting behavior reported for juvenile hawksbills by van Dam & Diez (1996) in Puerto Rico, and Houghton *et al*. (2003) in the Seychelles. In any case, the current study would be well served to make detailed observations of juvenile hawksbills at night.

The proportion of time spent surfacing during this study (4.2 %) was similar to that observed by van Dam & Diez (1996, 1997) for juvenile hawksbills in Puerto Rico (3.6 % in 1996, and 4.0 % in 1997), and by Meadows (2003) for green turtles less than 76 cm in length in Hawaii (5 %). We noted that some turtles surfaced multiple times after very brief dives. In these cases, turtles may be exhibiting orientation behavior. Since we cannot be certain that turtles were released in the exact location where they were incidentally captured by local fishermen, we presume some turtles may be spending time at the surface to orient toward a specific location. Other studies have suggested the potential use of visual landmarks, among other cues, in adult green turtles (Luschi *et al.* 1996; Luschi *et al.* 2001; Lohmann & Lohmann 2006) and in loggerheads (Avens *et al.* 2003). Despite evidence for the use of visual cues, the significance of landmarking above water remains unclear, since sea turtle eyes (at least loggerheads, greens, and hawksbills) are reported to be myopic out of water (Walls 1963; Ehrenfeld & Koch 1967). Still, juvenile turtles in close proximity to land may be able to use visual cues both above and below water to orient.

We recognize there may have been some affect of observer proximity to released turtles in our study during observations. Meadows (2004) found a significant affect of the presence of snorkelers (usually groups of up to 10) and their proximity on turtle behavior in the shallow waters of Maui, Hawaii. Turtles appeared to react adversely when snorkelers were within 3 m. In the current study, however, we observed turtles from a lateral position by SCUBA rather than from above, and with a maximum of three observers who at no time attempted to chase the turtles. Almost all subjects we observed did not appear to be intimidated by our presence. Since the area of Port Royal is frequented by local fishermen who fish by free diving, these turtles may have been habituated to recurrent interactions with humans.

Although we recorded behaviors in water depths of no more than approximately 10 m, the study would be improved by recording the exact depths at which the various behaviors occurred, as has been done in other studies with time depth recorders. Furthermore, we recognize that very limited observations of some turtles for only a few minutes immediately after release may actually represent uncharacteristic, frantic behavior.

In any case, in-water observations of sea turtles and their daily activities, such as those reported here, are of value and increase our understanding of how individuals affect, and are affected by, their local habitats. Such observations may, for example, include the use of crevices for feeding or resting, and foraging movements influenced by food availability and depth. Understanding these and other activities is critical to ensuring that important foraging and recruiting grounds are adequately protected. In addition, information on individual activity may have important implications for population scale effects of turtles on local habitats, especially if these habitats act as important grounds for development or recruitment linked to specific life history stages. Therefore, field studies of behavior through direct observation are critical, both for contextualizing information gathered remotely from instrumentation, and for decision-making in the management of sea turtle habitats and populations.

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