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Home Range and Foraging Ecology of Juvenile Hawksbill Sea Turtles (*Eretmochelys imbricata*) on Inshore Reefs of Honduras

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ABSTRACT. – **Despite the recognition of the historical importance of hawksbills in the Caribbean region of Honduras, prior sea turtle research in the area has been extremely limited, and little is known about hawksbill turtle (*Eretmochelys imbricata*) ecology from this region. We tracked 6 juvenile hawksbills (28.7–35.6 cm, straight carapace length [SCL]) with radiotelemetry off the coast of Roatán in the Bay Islands of Honduras, conducted habitat assessments at 14 sites, and examined the diet of 5 juvenile hawksbills (19.8–49.7 cm, SCL) using gastric ($n = 4$) and fecal ($n = 1$) samples. Home ranges of all 6 turtles were small, with 100% minimum convex polygons from 0.15 to 0.55 km^2, and a 50% fixed kernel density for all animals pooled of 5.46 km^2. The habitat assessment showed that common prey items in hawksbill diets were abundant in areas where juvenile hawksbills were resident and in nonresident areas, with sponges (*Chondrilla* sp., *Geodia* sp.) and octocorals (*Pseudopterogorgia* sp.) being most prevalent. We found sponge to be the primary component in the diet, comprising 59% of total ingesta. The most prevalent sponge species in the diet samples were *Melophlus ruber* and *Chondrilla caribensis*. Although *C. caribensis* is a common constituent of hawksbill diets, the current study provides the first report of *M. ruber* as a component of hawksbill diets. Home ranges of juvenile hawksbills in the Port Royal region of Roatán are small (< 1 km^2), and their primary dietary component is the sponge *M. ruber*. Conservation efforts on Roatán should be established in the Port Royal region, and should include protection of dietary items and turtles.**

KEY WORDS. – **fixed kernel density; hawksbill; minimum convex polygon; radio telemetry; sponges**

The hawksbill sea turtle (*Eretmochelys imbricata*) is critically endangered (Mortimer and Donnelly 2008), with a circumglobal distribution in tropical and subtropical waters (Carr et al. 1966; Baillie and Groombridge 1996; van Dam and Diez 1998; Meylan and Donnelly 1999; Tröeng et al. 2005). Worldwide populations of hawksbills have been greatly reduced, with Caribbean populations suffering a decline of as much as 95% since pre-exploitation, indicating a potentially precarious outlook for the species (Carr et al. 1966; Groombridge and Luxmoore 1989; Meylan and Donnelly 1999; Bjorndal and Jackson 2003; Tröeng et al. 2005). Hawksbills inhabit coral reefs throughout the main stages of their lifespan and, as large spongivores, play a critical role in maintaining reef biodiversity (Carr et al. 1966; Hill 1998; Leon and Bjorndal 2002; Blumenthal et al. 2009b). Hill (1998) and Leon and Bjorndal (2002) have shown that, without consumption of sponges by hawksbills, the diversity and health of reef ecosystems decreases due to competition for space between sponges and corals. With increasing coral reef degradation and declining hawksbill populations (Meylan and Donnelly 1999; Gardner et al. 2003; Blumenthal et al. 2009b), both the turtle and its habitat require protective measures. To implement appropriate conservation efforts, many factors, such as habitat use, migration corridors, foraging ecology, and the ecological role of hawksbills, require consideration (Bailey 1984; Seminoff et al. 2002; Godley et al. 2003; Seminoff and Jones 2006; Cuevas et al. 2007; Blumenthal et al. 2009a).

A home range is defined as the area in which an animal conducts its daily activities, and excludes atypical migrations or unpredictable movements (Bailey 1984). Adult sea turtles establish large overall home ranges (Horrocks et al. 2001), whereas most juveniles establish small home ranges. The small home ranges of juveniles are established by recruiting to developmental grounds, distributing themselves among suitable foraging areas, and increasing their access to resources (Renaud et al. 1995; Musick and Limpus 1997; Seminoff et al. 2002; Avens et al. 2003; Makowski et al. 2006). However, if foraging abundance or population densities change, juveniles may undertake migrations as well (Bjorndal et al. 2000; Godley et al. 2003). To determine the home range of any animal, repeated sightings must be obtained over time (White and Garrott 1990).

Home ranges are calculated by data acquired in tracking studies, which may also highlight migratory pathways and habitat use of sea turtles, and are usually conducted through satellite, radio, and sonic telemetry (Boarman et al. 1998). The telemetry method employed typically depends on the developmental stage of the turtle. Satellite transmitters have been used for determining juvenile home range (Polovina et al. 2000; Godley et al. 2003), but their low positional accuracy, large size, and high cost make them more appropriate for use in studies of adults (Blumenthal et al. 2009b). Radio and sonic telemetry have proven useful for juvenile home range (Renaud et al. 1992; van Dam and Diez 1998; Seminoff et al. 2002; Makowski et al. 2006; Seminoff and Jones 2006) because they provide better accuracy for small ranges (Renaud and Williams 1997; Cuevas et al. 2008). Results from previous studies of juvenile hawksbill home ranges are inconsistent, with some studies indicating little movement and a small home range (van Dam and Diez 1998; Cuevas et al. 2007; Blumenthal et al. 2009b), whereas others have documented long migrations and large home ranges (Boulon 1989; Marcovaldi and Filippini 1991). Studies using radio telemetry yield very few data points because the signal is only intermittently available when the turtle surfaces to breathe.

Ideally, home range studies of juvenile hawksbills should be conducted in tandem with foraging ecology studies that elucidate links between recruitment to particular foraging grounds and the sizes of home ranges established. Understanding the diet of sea turtles provides insight into trophic ecology, digestive physiology, health, dietary contaminants, energetics, and endoparasites (Forbes 1999). Despite the usefulness of understanding these parameters, food selection and diet preferences have been poorly studied for all sea turtle species (Lopez-Mendilaharsu et al. 2008).

Despite the prior suggestion that hawksbills are opportunistic omnivores (Carr and Stancyk 1975), work by several investigators has clearly demonstrated that they are primarily spongivores (Meylan 1984; Meylan 1988; Anderes Alvarez and Uchida 1994; van Dam and Diez 1997; Broderick et al. 2001), with sponges comprising approximately 95.3% of hawksbill diets in the Caribbean (Meylan 1988). *Chondrilla nucula* is reported to be the most commonly consumed sponge, and composes the majority of reported sponge content in hawksbill diets (Meylan 1988; Vicente and Carballeira 1991; Vicente 1994; Hill 1998; Leon and Bjorndal 2002). The Caribbean population of *Chondrilla nucula*, a Mediterranean species, has recently been recognized as genetically distinct and named *Chondrilla caribensis* (Rützler et al. 2007). Although hawksbills are primarily spongivores, their diet may also include a variety of other prey species, such as tunicates (Broderick et al. 2001), marine plants (Broderick et al. 2001), cnidarians (Leon and Bjorndal 2002), algae (Bjorndal et al. 1985), soft corals (Bjorndal 1997), zoanthids (Dunbar et al. 2008), polychaetes (Bjorndal et al. 1985), gastropods (Den Hartog 1980), holothurians (Vicente and Carballeira 1991), and anemones (Den Hartog 1980).

The purpose of this study was to examine links between diet, food availability, and home ranges of juvenile hawksbills. Understanding these links can augment knowledge of the migratory behavior of hawksbills, highlight important foraging areas, and stimulate focused conservation efforts in the Caribbean.

METHODS

Study Area. — Roatán is located approximately 60 km off the north coast of Honduras (lat 16°20′24″N, long 86°19′48″W), and is part of the Bay Islands. These islands form part of the Mesoamerican Barrier Reef complex, which consists of hard and soft corals interspersed with sponges, beds of *Thalassia testudinum*, and sandy substrate. The Port Royal area of Roatán is on the southeastern coast of the island, and experiences less commercial tourism and fishing pressure than other parts of the island. The reef flat in the area is shallow (< 20 m) and slopes gently for approximately 2.2 km, until it reaches the reef crest where the wall drops more than 300 m (Dunbar et al. 2008). The upper portion of the reef slope comprises mainly of turtle grass (*T. testudinum*) and sand beds. As the reef slopes toward the crest there is a mixture of hard corals of Faviidae, Milleporidae, and Pocilloporidae; soft corals of Gorgoniidae and Plexauridae; and sponges of Chondrillidae, Geodiidae, and Petrosiidae (Dunbar et al. 2008).

Turtle Capture and Transmitter Attachment. — Juvenile hawksbills were incidentally captured by hand by local fisherman on the southeastern coast of Roatán, and brought to a holding pen where they were measured, tagged (as per Dunbar et al. 2008), and kept for a maximum of 1 wk. Upon delivery of each turtle, fishermen were interviewed to identify the capture location. This was done so that each turtle could be released as close as possible to its capture site to minimize disorientation.

Each turtle was tagged on the right front and right rear flippers with Inconel style 681 metal tags (Archie Carr Center for Sea Turtle Research, Gainesville, FL), measured for straight carapace length (SCL) and curved carapace length (notch–notch) and width (± 0.1 cm), weighed (± 0.1 kg), checked for epibionts, and digitally photographed prior to transmitter attachment. For each turtle in the study ($n = 6$), 2 small holes were drilled into the lower right marginal scutes, and an AI-2 radio transmitter (Holohil Systems Ltd, Carp, ON, Canada) was secured to the carapace (supported by rubber rings to prevent chafing against the scutes) with zip ties, and covered with Powerfast 2-part marine epoxy. Care was taken to reinforce the base of the antenna and streamline the transmitter as much as possible. The placement and attachment of the transmitter did not appear to restrict movement or affect swimming ability, and we observed no apparent problems with submergence subsequent to transmitter attachment.

Turtle Release and Tracking. — We transported turtles by boat to the Port Royal area and released them in the approximate location (within 0.25 km) of their capture. Release sites were selected based on the closeness of their location to capture sites and the availability of anchored

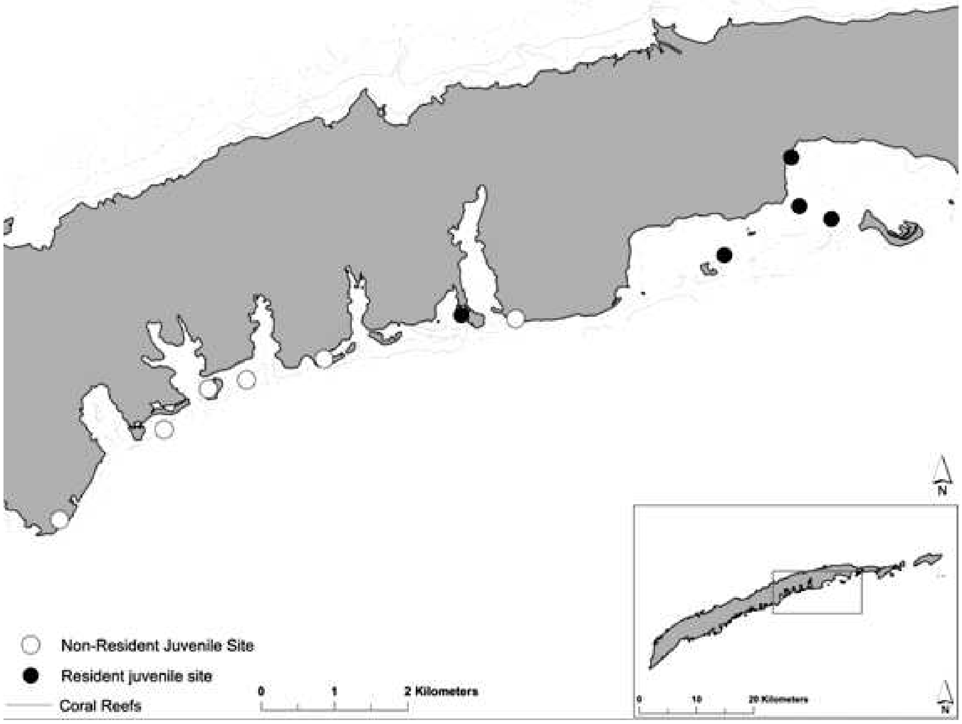

Figure 1. Resident (harboring juvenile hawksbill turtles) and nonresident survey sites (juveniles not encountered by us or local divers) around Roatán, Honduras. Inset: Island of Roatán with the study area marked.

buoys for boat attachment. Upon release, in-water observations of each turtle were obtained with the same method as reported by Dunbar et al. (2008), although different turtles were used, and each turtle was given a 24-hr acclimation period prior to the onset of tracking. Tracking occurred between 0600 and 1600 hrs, using a 3-element Yagi antenna (Wildlife Materials, Murphysboro, IL) and Yaesu VY-500 portable receiver (Amateur Electronic Supply, Las Vegas, NV). We attempted resightings of each turtle daily, and with each resighting we recorded the latitude and longitude of the turtle's position with a Garmin 72 global positioning system. Resighting locations were taken at least 24 hrs apart to reduce autocorrelation in the home range analysis (Schmid et al. 2002). We tracked turtles from June to September 2007 and from June to September 2008.

Home Range Analysis. — Minimum convex polygon (MCP) and fixed kernel density (FKD) were calculated from the resighting coordinates using the HRE: The Home Range Extension for ArcView (Rodgers and Carr 1998) in ArcMap 9.3 (Esri, Redlands, CA). We used 100% MCP because of the low number of resightings for each turtle (Boyle et al. 2009) and because it allowed us to compare our results with other studies (Hooge et al. 1999). All resighting coordinates were combined for all turtles and FKDs were calculated using the reference bandwidth as a smoothing factor. We reported only the 50% FKD, which shows core areas of use (Worton 1989; Griffin 2002) and is less sensitive to outliers than other FKD isopleths (Yasuda and Arai 2005). Areas where MCP or FKD crossed over land were subtracted from the home range calculation.

Survey Transects. — We selected survey sites based on extensive prior knowledge (from our own observations and those of other fishermen and divers) of presence of juveniles in the area, and accessibility for frequent dive visits. A total of 14 sites were surveyed from June to September 2008, both in areas known to be inhabited by juvenile hawksbills (resident juvenile sites; $n = 8$), and without recorded sightings of juveniles (nonresident juvenile sites; $n = 6$) (Fig. 1). Following methods by Dunbar (2006), we placed transects at random in each survey site, and obtained Universal Transverse Mercator readings for both the start and end points of each transect. A 2-m-wide swath on each side of the transect was surveyed for abundance of prey species (Dunbar et al. 2009). We conducted a total of 48 transects, with 27 transects in resident sites and 21 in nonresident sites.

We surveyed for specific sponges in the families Chrondrosiidae, Geodiidae, Stellettidae, Spirastrellidae, and Suberitidae; soft coral in the genus *Pseudopterogorgia*; the zoanthid *Palythoa caribaeorum*; and the anemone species *Anemonia sulcata* because of their inclusion in the literature from hawksbill diet studies (Meylan 1984; Meylan 1988; Leon and Bjorndal 2002; Cuevas et al. 2007; Dunbar et al. 2008). The number of each species per site was counted, and the mean abundance for each species in both nonresident and resident areas was calculated for comparison. All data are represented as mean ± SD.

Table 1. Summary of data on physical characteristics collected for each turtle on which gastric lavages were performed, and the dietary contents (ranked by percentage) obtained during lavage.

Turtle ID	SCL[a] (cm)	Weight (kg)	Dietary contents
075-08	19.8	0.9	Algae, *Melophlus ruber*, *Cinachyrella* spp.
086-09	25.1	2.6	*Chondrilla caribensis,* plant, hard coral, crustacean
087-09	26.4	2.0	*Melophlus ruber, Chondrilla caribensis*, *Geodia gibberosa* or *Sidonops neptuni*, Plakinidae, algae, hard coral, crustacean, bivalve
092-09	24.3	1.6	*Melophlus ruber*, crustacean, carbonate, plant, algae
094-09	49.7	14.5	*Melophlus ruber*, plant

[a] SCL represents the minimum straight carapace length.

For comparisons of resident and nonresident sites, we closely examined the transect data for each of the 11 prey types. Data were sparse (encountered on $< 25\%$ of surveys) for 5 prey types (*Ancorina* sp., *Anemonia sulcata, Chondrosia reniformis, Spirastrella coccinea,* and *Suberites* sp.) and largely failed to meet parametric assumptions of normality and homoscedasticity. Data were deemed adequate for the remaining 7 prey types (*Chondrilla caribensis, Geodia gibberosa, Palythoa caribaeorum, Pseudopterogorgia elisabethae, Pseudopterogorgia* sp., *Sidonops neptuni,* and *Suberites* sp.), of which 6 (all but *S. neptuni*) were rank-transformed to meet parametric assumptions. We compared abundance between resident and nonresident sites using a nonparametric Mann-Whitney test for the 5 rare species, and independent *t*-tests for the 7 abundant species. The 7 abundant species were also included in a discriminant function analysis (including leave-one-out cross-validation) to evaluate distinctiveness of resident vs. nonresident sites. We computed Cohen's *d* using pooled standard deviation (Hojat and Xu 2004) for each of the 11 prey types to determine effect size. Cohen's *d* values of approximately 0.5 are generally considered moderate and ≥ 0.8 large (Cohen 1988). All analyses (other than Cohen's *d*) were conducted using SPSS 13.0 for Windows, with alpha set at 0.05.

Dietary Analysis. — This study was initially designed to address home range and habitat structure. However, after conducting the habitat assessment we decided that an examination of juvenile hawksbill diets was justified to investigate links between home range establishment and habitat structure. The turtles used in the lavage section of this study (19.8–49.7 cm, SCL; Table 1), were different than those turtles in the home range section (Table 2). We carried out successful lavages on 4 turtles, and collected fecal matter from another turtle between April and November 2009. Prior to lavages, turtles were measured, weighed, and tagged using the same methods described previously. The input and retrieval tubes used in the lavage were carefully cleaned, disinfected, sanded to remove sharp edges, and marked at 10-cm intervals. For lavages, we generally followed methods by Forbes (1999), but made modifications for smaller turtles. Animals were placed on their carapaces in the lap of an assistant, with the turtle held at a downward angle in a manner that inhibited free movement of the front flippers. Total lavage time required approximately 5 min. In one case when a gastric lavage was not successful in retrieving stomach contents, a sample of fecal matter was obtained (for turtle 086-09). Both gastric and fecal samples were stored in 40% ethanol and refrigerated until analyzed.

Each lavage sample was viewed under a dissecting scope, subsampled, and separated into major taxa. Percent composition of a prey item was determined by comparing the dry weight of a species to the total dry weight of the sample. Sponges were isolated from the rest of the ingesta and identified to the lowest taxa possible by spicule type and spongin content.

We used compositional analysis (Aebischer et al. 1993) to assess the differences between select prey species consumed by the juvenile hawksbills and the availability of corresponding prey items in the turtle-occupied habitat. Prey species were categorized into 3 sponge groups (*C. caribensis, G. gibberosa*, and ''other'') for both prey species consumed (''used'') and those available (''available''). The prey species *Melophlus ruber* was not included in the compositional analysis because this species was discovered in the gut contents after the habitat assessment was completed. The 3 categories were chosen based on which prey species were most abundant in the habitat assessment. Compositional analysis was conducted using Adehabitat for R software 2.11.0, with an alpha set at 0.05 (Calenge 2006).

RESULTS

Tracking. — The overall results of our tracking study are presented in Table 2. We tracked 6 turtles (5 in the first tracking season, 1 in the second) ranging in size from 28.7 to 35.6 cm (32.6 ± 2.6 cm SD) $\mathrm{SCL}_{\mathrm{minimum}}$ and in weight from 2.9 to 5.4 kg (4.2 ± 1.0 kg SD). Tracking duration ranged from 15 to 60 d (49.2 ± 18.3 d SD). Although we attempted one resighting for each turtle per day, the number of resightings per turtle ranged from 4 to 6 (5 ± 0.9 SD). The number of times per turtle a transmitter signal was detected without resighting ranged from 3 to 11 (8.2 ± 3.1 SD), and the number of days between signal reception ranged from 1 to 23 d (4.2 ± 4.2 d SD). Although we attempted to relocate each of the 5 turtles from the first tracking season during the second tracking season, none were found.

Table 2. Summary of data collected for each of the 6 turtles tracked, including estimated home range sizes, tracking information, and physical characteristics. Straight carapace $\text{length}_{\text{minimum}}$ (SCL) and weight were collected prior to release. Home range estimate of minimum convex polygon (MCP) was calculated using HRE: The Home Range Extension for ArcView.

Turtle ID	SCL (cm)	Weight (kg)	Tracking duration (d)	No. of sightings	Mean duration between sightings (d)	MCP area (km^2)	No. of days receptions were obtained without re-sighting	Range of days between reception without resighting
037-06	32.2	4.6	27 Jul–5 Sep 5 (41)	4	8.5	0.17	11	1–6
044-06	28.7	2.9	8 Jul–5 Sep (60)	8	6.5	0.55	10	1–23
046-07	35.2	5.0	9 Jul–5 Sep (59)	5	11.8	0.45	10	1–11
052-07	35.6	5.4	8 Jul–5 Sep (60)	4	11.8	0.15	6	1–13
053-07	30.7	3.7	8 Jul–5 Sep (60)	6	8.3	0.33	9	1–9
073-08	33.0	3.7	23 Jul–6 Aug (15)	5	2.0	0.48	3	2–3

Home Range. — The 100% MCP of individual turtles ranged from 0.15 to 0.55 km^2 (0.36 ± 0.2 km^2 SD; Table 2), and all 6 turtles had overlapping home ranges established over inshore reefs (Fig. 2). The 50% FKD for all turtles combined was 5.46 km^2 (Fig. 3).

Survey Transects. — An area of approximately 11.5 km^2 was surveyed during the habitat assessment. The potential dietary species with the highest total abundance in all survey sites were *G. gibberosa*, *P. elisabethae*, and *C. caribensis*. The species with the lowest total abundance in all sites were *Suberites* sp., *A. sulcata*, and *C. reniformis*. In nonresident areas, species with the highest mean abundances were *Pseudopterogorgia* sp., *G. gibberosa*, and *C. caribensis*, whereas species with the lowest mean abundances were *A. sulcata*, *Suberites* sp., and *S. coccinea.* In resident areas, the species with the highest mean abundances were *G. gibberosa*, *P. elisabethae*, and *C. caribensis*, and the species with the lowest mean abundances were *Suberites* sp., *A. sulcata*, and *Ancorina* sp. The 3 species to show a significant difference in mean abundance between resident and nonresident sites were *G. gibberosa*, *Pseudopterogorgia* sp. and *S. coccinea* (Table 3).

The discriminate function analysis for the habitat assessment included 7 of the 11 prey species. The overall Wilks' lambda was significant (Wilks' lambda = 0.48, $\chi^2{}_7 = 31.3$, $p < 0.001$), confirming the difference between resident and nonresident sites. Resident and nonresident sites were correctly classified 92.6% and 76.2% of the time, respectively, with an overall predictive success of 85.4%. Leave-one-out classification also revealed a high level of classification success (resident 81.5%, nonresident 71.4%, overall 77.1%). Differences in abundance of *Pseudopterogorgia* sp. and *G. gibberosa* provided the best discrimination between sites.

Diet Analysis. — The 5 turtles in the lavage study ranged in size from 19.8 to 49.7 cm (29.1 ± 11.8 cm SD) $\text{SCL}_{\text{minimum}}$, and in weight from 0.9 to 14.5 kg (4.32 ± 5.5 kg SE) (Table 1). Lavage samples revealed that juvenile hawksbills at our study site consumed a variety of specimens, with sponges comprising the main dietary component. Approximately 59.0% of ingesta consisted of various sponges (Fig. 4), with percentage of composition among various genera and species ranging from 0.3% to 75.3% (Table 4). The exception was turtle TIN075-08, whose primary dietary component was an unidentified algae. *Melophlus ruber* and *C. caribensis* were the most prevalent sponge species found in the gut contents of examined turtles (Table 4), having high percentages of composition in several of the lavage samples (Fig. 4).

Compositional analysis revealed lack of preference for the 3 prey categories (*C. caribensis, G. gibberosa*, and other) using randomization (Wilks' lambda = 0.212, df = 2, $p = 0.086$), but suggested prey preference using parametric testing ($p = 0.021$). The ranking of prey item preference indicated *C. caribensis* > *G. gibberosa* > other.

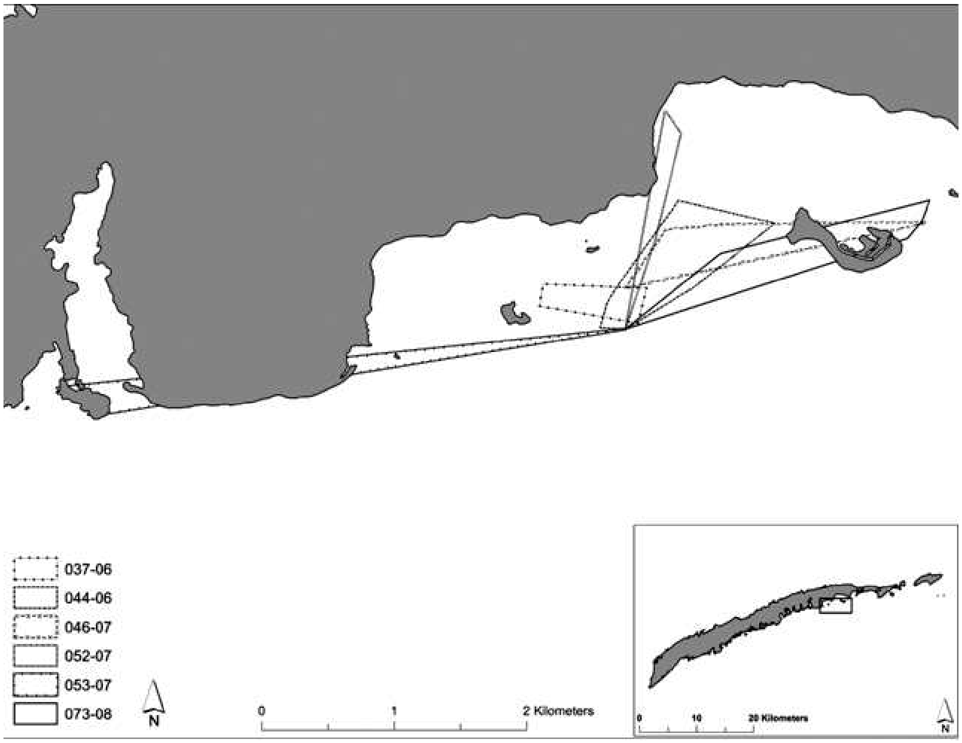

Figure 2. Minimum convex polygons (MCP) of 6 juvenile hawksbill turtles in this study. All MCPs overlap in the Port Royal, Roatán (Honduras) area. Inset: Island of Roatán with the study area marked.

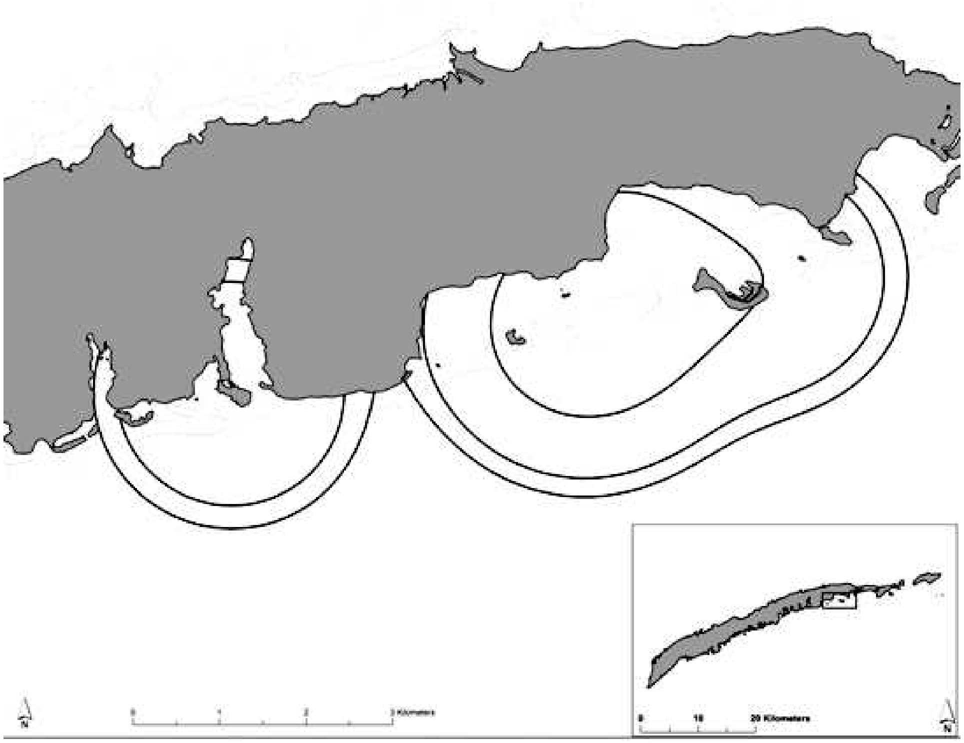

Figure 3. Fixed kernel density (FKD) isopleths of all juvenile hawksbill resightings. The innermost isopleth represents 50% FKD, the middle isopleth represents 90% FKD, and the outermost isopleth represents 95% FKD. Inset: Island of Roatán with the study area marked.

Table 3. Comparison of mean abundance (± SD) for 11 prey species between transects in resident ($n = 27$) and nonresident juvenile turtle sites ($n = 21$), including probability (p) of statistical difference between sites and effect size (Cohen's d).

Prey species	Resident site	Nonresident site	p	Cohen's d
Ancorina sp.	0.48 ± 1.03	0.67 ± 1.28	0.60[b]	0.16
Chondrilla caribensis	30.48 ± 23.49	27.71 ± 28.92	0.38[a]	−0.11
Chondrosia reniformis	0.67 ± 2.07	0.38 ± 1.51	0.58[b]	−0.15
Geodia gibberosa	58.93 ± 43.91	28.05 ± 37.5	0.002[a]	−0.75
Sidonops neptuni	0.81 ± 2.13	1.52 ± 2.15	0.26[a]	0.33
Pseudopterogorgia elisabethae	42.30 ± 55.55	12.57 ± 16.86	0.75[a]	−0.69
Pseudopterogorgia sp.	16.81 ± 24.89	38.67 ± 28.50	< 0.001[a]	0.82
Spirastrella coccinea	2.19 ± 5.46	0.19 ± 0.87	0.034[b]	−0.48
Suberites sp.	1.22 ± 2.70	1.48 ± 2.02	0.20[a]	0.11
Anemonia sulcata	—	0.26 ± 0.77	0.12[b]	−0.40
Palythoa caribaeorum	3.07 ± 2.86	6.19 ± 6.60	0.13[a]	0.64

[a] Independent t-test.
[b] Mann-Whitney test.

DISCUSSION

Home Range and Foraging Ecology. — Although this study yielded relevant data on juvenile hawksbill home ranges and foraging ecology, we recognize the need to address some caveats. Turtles were captured by local fishermen, and although care was taken to release turtles as close as possible to the capture site, there may have been slight discrepancies between the capture and release site coordinates. Turtles were given a 24-hr period prior to the onset of tracking to orient themselves and to return to their home range if displacement did occur. Previous work suggests that despite displacement of turtles, they may reorient themselves close to their recapture site (Avens et al. 2003).

Home ranges (MCP) of each of the 6 juveniles were less than 1 km^2 and the core area of activity (50% FKD) for all juvenile resightings pooled was 5.46 km^2. Although resightings were few, tracking results were informative because signals were obtained numerous times without directly observing the turtle, resightings were obtained over an 8.5-wk interval for most (4 of the 6) subjects, and the turtles were resighted by divers and fishermen in the same home range area subsequent to completion of our study. The home range areas of juvenile hawksbills in our study are similar to those of other studies. Home ranges for juvenile hawksbills in Puerto Rico were even smaller, ranging from 0.07 to 0.14 km^2 (van Dam and Diez 1998), and in Japan, Okuyama et al. (2005) reported the home range for a single juvenile hawksbill to be less than 1 km^2. Some studies have obtained similar results for juvenile green sea turtles. For example, the home ranges of juvenile greens in Oahu, Hawaii, were 2.62 km^2 (Brill et al. 1995). In Palm Beach, Florida, they ranged from 0.69 to 5.05 km^2 (Makowski et al. 2006), and in South Padre, Texas, they ranged from 0.22 to 3.11 km^2 (Renaud et al. 1995). In

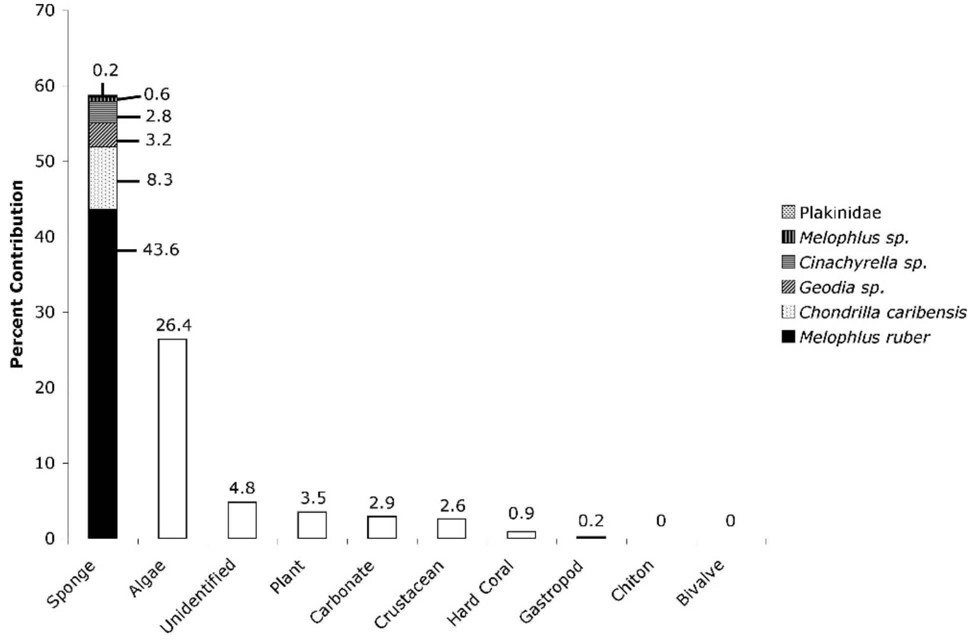

Figure 4. Diet composition of juvenile hawksbill sea turtles ($n = 5$) determined by gut content analyses, with sponges identified to genus and species (where possible).

Table 4. Sponge species identified in the diet of juvenile hawksbill sea turtles, the percentage of composition of each species in the sponge component of the diet, and the rank of each species.

Order	Family	Species	% Composition	Rank
Astrophorida	Ancorinidae	*Melophlus ruber*	75.3	1
	Chrondrosiidae	*Chondrilla caribensis*	14.1	2
	Geodiidae	*Geodia gibberosa* or *Sidonops neptuni*	5.4	3
Spirophorida	Tetillidae	*Cinachyrella* spp.	4.9	4
Homosclerophorida	Plakinidae	N/A	0.3	5

subadult greens in the Gulf of California, Mexico, the home ranges varied from 5.80 to 39.08 km^2 (Seminoff et al. 2002). Because the size of a home range may depend on where it is established, small home ranges in the Caribbean could result from high-quality prey items at foraging sights. When Cuevas et al. (2008) observed that the hawksbill with the smallest home range foraged at a Caribbean site, whereas the hawksbill with the largest home range foraged at a Gulf of Mexico site, they proposed that Caribbean habitats might contain higher-quality food items, allowing the turtle to occupy a smaller home range. We propose that the high abundance of food resources on the inshore, shallow reefs, and the plethora of resting places may explain the small home ranges.

We found that the home ranges for all 6 juveniles in the current study overlapped, which generally agrees with results obtained in other studies. In Bahía de los Angeles, Gulf of California, Mexico, Seminoff et al. (2002) found overlapping home ranges for 11 of the 12 subadult green turtles in their study on neritic foraging grounds. In west-central Florida, Schmid et al. (2003) reported that subadult Kemp's ridley turtles had home ranges that overlapped in a foraging ground. Similar findings were obtained for 6 juvenile green turtles in Palm Beach, Florida, possibly indicating adequate resources in this developmental area that made site fidelity an efficient strategy for exploiting available resources by reducing energetic costs involved with large-scale movements (Makowski et al. 2006). In our study, the reef structure and overlapping home ranges may be an indication of the high-quality habitat in this area, where other juvenile hawksbills are often sighted (Dunbar and Berube, 2008; Dunbar et al. 2009). On the other hand, if the main prey item identified by stomach lavages, *M. ruber*, is in short supply, juveniles may be congregating in the area to compete for this limited resource. Future surveys for this prey species would be useful to clarify this issue.

Overall abundances of sponge species in both resident and nonresident areas demonstrated that *G. gibberosa, C. caribensis*, and *P. elisabethae* had the highest abundances whereas the 3 species showing a significant difference in mean abundance between resident and nonresident sites were *P. elisabethae*, *Pseudopterogorgia* sp., and *S. coccinea.* The discriminate function analysis suggested that *G. gibberosa* and *Pseudopterogorgia* sp. provided the best discrimination between resident and nonresident sites, with an overall predictive success of 85.4% (77.1% leave-one-out classification). This correlates well with results from other work showing that hawksbills have a preference for *Chondrilla* spp., *Pseudopterogorgia* spp., and *S. coccinea* (Leon and Diez 1999; Leon and Bjorndal 2002; Diez et al. 2003; Cuevas et al. 2007). It is possible that these prey species are some of the most abundant sponge and soft coral species located within the reefs around Roatán. Although we recognize that localities considered to be nonresident sites may have supported juveniles that we and other divers failed to detect, we suggest—based on the available data—that hawksbills may be establishing their home ranges based on the nutrient content or defense systems of prey items.

We found that juvenile hawksbills in the Port Royal region of Roatán are primarily, but not strictly, spongivores, and that hawksbills feed preferentially on certain sponge species. For example, *C. caribensis* was the second-highest-consumed sponge species, which agrees with previous hawksbill diet research. *Chondrilla* has few spicules, little silica, densely packed collagen fibrils, and both a high nitrogen and energy content (Meylan 1984). In a study of hawksbills from 7 different Caribbean countries, Meylan (1988) demonstrated that 95.3% of their diet consisted of sponge, with *C. caribensis* (her *C. nucula*) having the highest rank (12.6% average dry weight). In the Dominican Republic, Leon and Bjorndal (2002) noted sponge as the most frequent diet item, but the hawksbill's diet also contained large amounts of the corallimorpharian *Ricordea florida.* The most prevalent sponge species in the diet of Dominican Republic hawksbills was *Chondrilla nucula/caribensis* (59% of volume at Bahía; 14% at Cabo Rojo). In Puerto Rico, van Dam and Diez (1997) showed that sponges from Demospongiae were present in 95.5% of their diet samples, with *Geodia neptuni* (48.2%) and *Polymastia tenax* (30.4%) having the highest ranking.

However, although *Chondrilla* is widely reported as a common dietary item for hawksbills, our study revealed some unique results about hawksbill diet composition that raise interesting questions for future research. First, this study constitutes the first record of *M. ruber* as component of hawksbill diets. *Melophlus ruber* (Ancorinidae, Astrophorida) was first described by Lehnert and van Soest (1998) from shallow to deep (0.2–88 m) reefs and framework-cave habitats in Jamaica. It is a dark red, vase-shaped sponge with a tough consistency and a robust siliceous skeleton. The genus has one other species, *Melophlus sarasinorum* Thiele, which has an Indo-Malayan distribution (Lehnert and van Soest 1998). Moreover, one turtle (TIN 075-08) had a diet composed solely of algae. This turtle was also the smallest turtle lavaged (19.8 cm SCL, 0.9 kg), which suggests that this turtle was transitioning from the pelagic to neritic stage, and was consuming floating material that was composed of a variety of specimens (Meylan and Carr 1982). Similarly, van Dam and Diez (1997) reported juvenile hawksbills in Puerto Rico that were under 30 cm SCL consumed nonsponge organisms, such as *Lepas* sp. and other items associated with flotsam. Further dietary composition analyses and habitat assessments are needed to resolve the extent to which these apparently unique diet items (e.g., *M. ruber*, algae) are significant components of juvenile hawksbill diets.

The varied diet of hawksbills in the current study suggests that juveniles are not indiscriminately feeding, but that their diet may be the result of available prey abundance and selectivity for certain species. In releases of other juvenile hawksbills in Roatán, we observed them feeding on the zoanthid *P. caribaeorum*, but this species was not identified in any of the gastric lavage samples. Similarly, hawksbills are known to distribute themselves on hard bottom sites where soft corals, such as *Pseudopterogorgia* sp., are prevalent (Cuevas et al. 2007). However, this species was also absent from all gut samples in our study. Therefore, hawksbills in Roatán may be showing selectivity for particular prey species, although other more-abundant prey items are available. However, variations in how different prey types are digested and thus available for observation during gut content analyses must also be considered while interpreting diet composition results. In future diet studies in this location, stable isotope analysis would also be beneficial because it provides dietary information over long periods of time as opposed to the short-term picture provided by gastric lavage samples (Seminoff et al. 2006).

Conservation. — When evaluating conservation efforts for critically endangered sea turtles such as the hawksbill, both the turtle and its habitat are important factors for decision-makers and resource managers to consider. Although the entire habitat range of a sea turtle species should be considered (Meylan and Donnelly 1999; Channell and Lomolino 2000; Bjorndal and Bolten 2010), James et al. (2005) recommend that high-use areas be the primary focus for conservation efforts, especially if there is high mortality of turtles in those areas. Although adults are still the primary focus of many conservation efforts, it is becoming increasingly clear that protecting juveniles and subadults is also likely to result in long-term sustainability of sea turtles (Crouse et al. 1987; Griffin 2002; Schmid et al. 2003). Home range and diet studies of juveniles are vitally important for focusing conservation efforts, because site fidelity and core areas can highlight hotspots where habitat characterization and use can be examined (Broderick et al. 2007; Cuevas et al. 2007; Blumenthal et al. 2009b). This can focus conservation efforts on specific areas of resources that are important for juvenile development (Makowski et al. 2006), particularly recruitment and development grounds.

In this study, we have made the first determinations of important prey items for the population of juvenile hawksbills in the Caribbean waters of Honduras. Resulting small home ranges may be a reflection of high-quality habitat in the Port Royal region. The nearshore, shallow reefs in this area have a high abundance of food resources, and the structure of the reef itself may allow for sufficient resting areas under ledges, resulting in less travel between foraging and resting grounds, and less energy expenditure. Conversely, competition for limited resources may also be a factor in limiting home range area. The current study may be useful in implementing more rigorous conservation efforts in the Bay Islands of Honduras.

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