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Population Structure of Hawksbill Turtles on a Foraging Ground in the Dominican Republic

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ABSTRACT. – **A foraging hawksbill turtle (*Eretmochelys imbricata*) population in the southwestern Dominican Republic, at Jaragua National Park and Cabo Rojo, was predominantly composed of juveniles and sub-adults with a sex ratio heavily skewed towards females (2.71:1). The population showed specific site fidelity and highly variable growth rates. The lack of adult hawksbill turtles in the area (even during the reproductive season) is noteworthy. The high density of immature turtles (up to 96.8 turtles/km^2) encourage us to believe that these juvenile hawksbills, if protected, may successfully repopulate previously depleted areas.**

KEY WORDS. – **Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; population structure; growth; sex ratio; demography; site fidelity; developmental habitat; Jaragua National Park; Dominican Republic**

In the Dominican Republic, the hawksbill turtle (*Eretmochelys imbricata*) has traditionally been exploited for its eggs, meat, and decorative shell. The latter is sold in the form of curios in local markets (Stam and Stam, 1992; Domínguez and Villalba, 1994), and in the past has been exported to other countries. As much as 1820 kg of raw tortoise shell were legally exported in a single year (CEDOPEX, unpublished).

Despite the heavy exploitation this species has received in the Dominican Republic, no population studies have been conducted to assess its current status. In the early 1980s, the importance of the coastal area of Jaragua National Park and Cabo Rojo as a sea turtle habitat was suggested by aerial surveys and fishermen interviews (Ottenwalder, 1981). In the spring of 1996, we started conducting in-water surveys at these locations with the objective of obtaining biological information that could contribute to the elaboration of effective national and regional management plans for this endangered species. In this paper we present our findings on distribution, abundance, size, growth, sex ratio, and site fidelity of the hawksbill population found.

METHODS

Study Site. — Jaragua National Park (JNP) is located in the southwestern corner of the Dominican Republic (17°45'N, 71°30'W) (Fig. 1). It comprises a total of 1374 km^2, of which 905 are marine areas, including Beata and Alto Velo islands and Los Frailes (a group of small cays emerging from an offshore reef platform). Extensive sandy beaches border most of the coastline, being occasionally interrupted by rocky cliffs of variable height. Coral reefs and other hard-bottom communities are most abundant in the western portion of JNP whereas seagrass beds are the predominant benthic community to the south. The eastern marine area of JNP is characterized by high wave energy and swells on a narrow continental platform that makes it difficult for fieldwork.

Cabo Rojo is found just outside the northwestern limit of JNP, approximately 20 km from the Haitian border (Figs. 1 and 2). Two km north of Cabo Rojo is the Port of Cabo Rojo, constructed in the 1950s by a bauxite mining company that closed in 1983. This wharf has a breakwater nearly 900 m in length and a docking area 140 m wide. Presently, some limestone extraction occurs, but the dock only receives one cargo ship every two to three months (*pers. obs.*). Various hard-bottom and seagrass communities can be found in this area, only interrupted by Bahía Honda, a natural, deep (up to 200 m) channel extending west from the docking area. The Cabo Rojo area, along with western JNP, constitutes our main hawksbill study site.

Turtle Observation and Capture. — Daytime snorkeling censuses were conducted at most of the western coastal marine areas of JNP and Cabo Rojo with depths of approximately 15 m or less (see Fig. 1). The capture method was adapted from Diez and van Dam (1998). Generally, four observers were used, three in the water wearing snorkeling equipment and one operating a small motor-powered boat. The observers in the water started swimming in a parallel manner, remaining within eye contact with one another. When a turtle was spotted, the swimmer raised his hand and/or yelled to alert the others while keeping the animal in sight and pursuing it, if necessary. Next, one of two strategies was used: 1) one of the swimmers dove directly above the head of the turtle and grabbed it quickly by the base of the front flippers to bring it to the surface while at least one of the observers stayed above to follow the animal in case it escaped; 2) occasionally, when a turtle was followed, it descended to depths greater than 15 m, in which case one of the swimmers put on scuba gear to capture it in the manner described above. An additional capture method performed

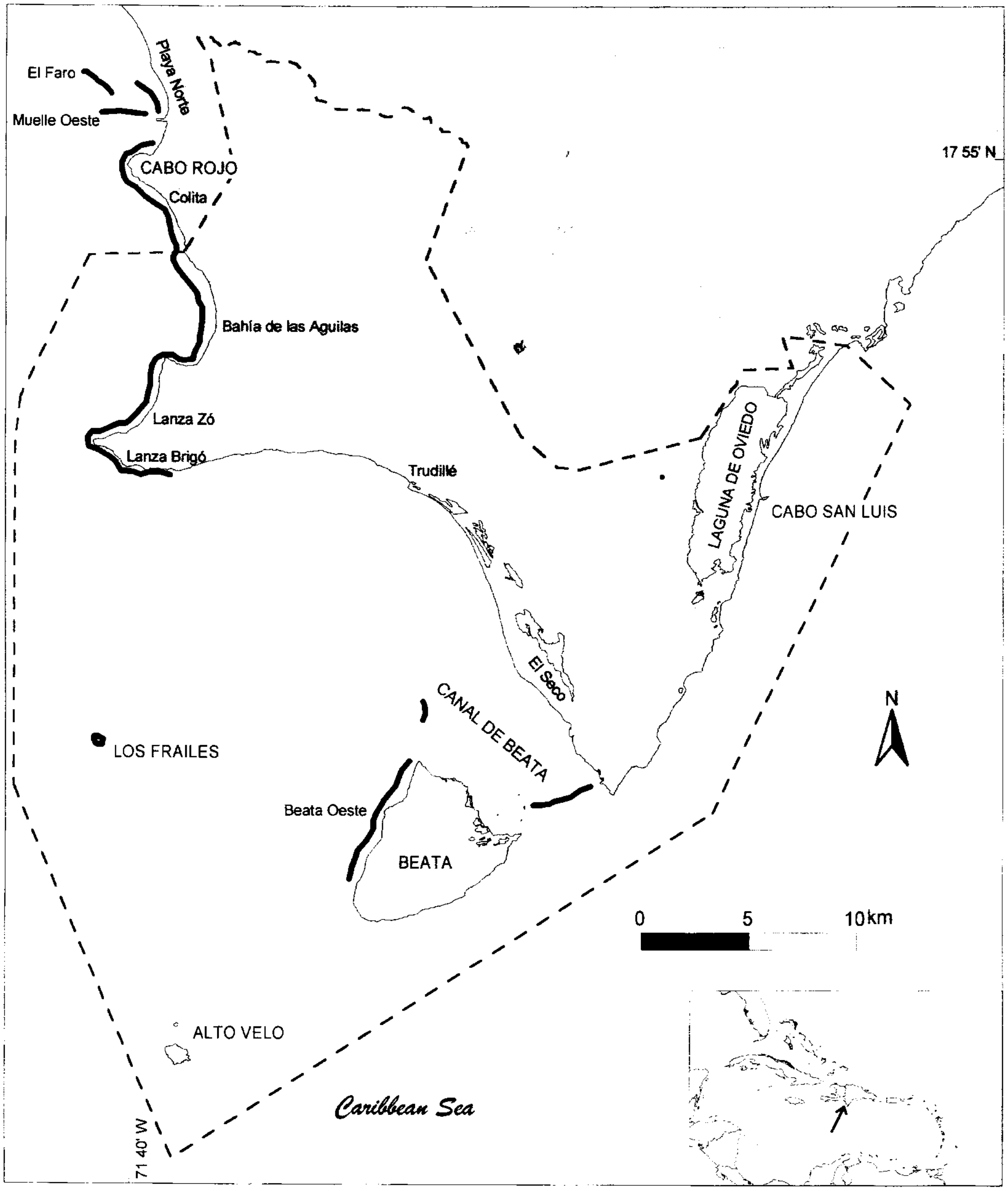

Figure 1. Map of study area. Broken line represents Jaragua National Park boundary and thick line along shore shows approximate location of near-shore surveys.

out of census time was employed when a turtle was sighted at the surface while the swimmers were still on the boat. In this situation, one person jumped quickly in the water (sometimes wearing only a mask) to visually follow the animal until other swimmers put on all snorkeling gear to capture it in the manner described above. All captured turtles were brought to the boat for tagging and data recording.

All turtles greater than 25 cm straight carapace length were tagged in both front flippers using monel stainless steel tags prior to their release. Additionally, most hawksbills were tagged with passive integrated transponder (PIT) tags inserted in the frontal right flipper muscle. We used an Avid Power Tracker IV reader (Norco, CA) capable of reading Avid PIT tags (applied in 1997 and 1998) and Trovan tags (mostly used in 1996).

Distribution and Abundance. — To determine the location of each capture and to release the animals as near as possible to the place where they were first sighted, the geographic position of each individual was obtained with a Global Positioning System (GPS) receiver. A Garmin receiver, model 12XL, was used without differential correction. With this receiver, we also also calculated the distance between captures of an individual.

The relative sighting frequency of hawksbills among the different study sites was evaluated by dividing the number of turtles sighted by the time spent in the snorkeling censuses. The time unit was defined as one hour of in-water census employing the capture methods described above. Turtle density (turtles/km^2) and biomass (kg/km^2) were also estimated for selected localities (those where we had ad-

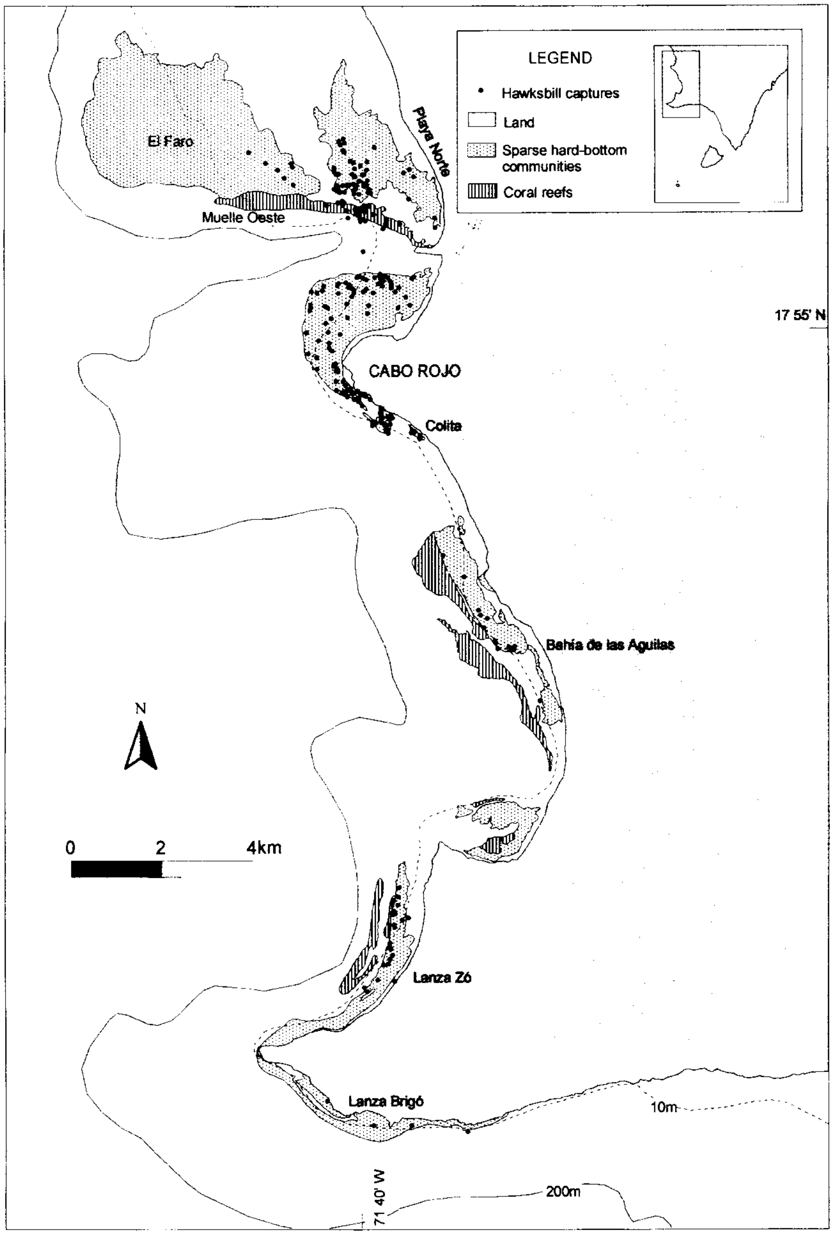

Figure 2. Map of marine area of northwestern Jaragua National Park and adjacent Cabo Rojo showing the distribution of hawksbill captures.

equately covered the whole area with our surveys). Turtles used for these density calculations included those captured both during and out of census time, or sighted without being captured during surveys carried out within a week's time. We obtained the surface area of the different study localities from 1:20000 scale natural-color aerial photographs, with final contours adjusted to the map base by hand. These contour polygons were then digitized into a PC ARC/INFO ver. 3.5.1 cover (ESRI, CA). For biomass estimates, we multiplied the number of turtles of each 5 cm size-class by the mean turtle mass of that size-class.

Mass and Body Measurements. — We measured the straight carapace length (SCL, in cm, measured from the nuchal notch to the posteriormost tip of the carapace) using a Haglof 60 cm tree caliper. Mass was obtained to the nearest 0.1 kg using a Pesola spring scale of 20 kg x 200 g. To minimize measurement errors, the same observer (YML) took all measurements.

Sex Determination. — The sex of individuals was obtained by measuring blood serum testosterone levels and comparing the values with those obtained for the Mona Island (Puerto Rico) hawksbill population (Diez and van Dam, 1994), which were determined by laparoscopic observation of the gonads. According to that study, the maximum testosterone level indicative of a female was 16.1 pg/ml, while 20 pg/ml was the minimum for a male. Intermediate results between these two values were catalogued as intersex. Blood samples were taken from the cervical sinus (Owens and Ruiz, 1980) employing Vacutainer sterile vacuum tubes and placed in an ice cooler. After the serum separated, it was collected with a pipette and placed in sterile 1 ml vials to be frozen until analyzed. All of our samples were processed using radioimmunoassay techniques (Owens et al., 1978) by the staff of David Owens' laboratory (Dept. of Biology , Texas A&M University).

RESULTS

Turtle Distribution and Abundance. — We conducted a total of 193.9 census hours in the study area from April 1996 through April 1998, yielding 275 captures (Table 1). Also, we performed 23 additional captures out of census time, bringing the total number of individuals studied to 298. An additional 49 turtles were sighted but could not be captured.

Hawksbills were observed year-round in the JNP-Cabo Rojo area. The distribution of captures at western JNP-Cabo Rojo, the main study site, is presented in Fig. 2. Considerable variation was found in sighting frequency among localities (Table 1). El Faro and Playa Norte, two sparse hard-bottom sites north of Cabo Rojo, had the highest sighting frequency, with 3.43 and 3.28 turtles/hr, respectively, while Beata Oeste had the lowest, with 0.08 turtles/hr. We estimated turtle density and biomass for five localities (Tables 2 and 3). Los Frailes and Colita, the two coral reef sites, showed considerably higher density and biomass than all other sites.

Size-Class Composition. — All turtles were within the size range of 19.5 to 69.7 cm SCL (Fig. 3). The majority of turtles captured and sighted were juveniles, with the 25–35 cm size-class being the best represented. Very small turtles, considered to be recent recruits from pelagic habitats, were also an important part of our sample, with 46 (15.4%) of all captures made having SCL < 25 cm. In addition to small size, many of these small turtles (56.5%) had dark brown patches on their plastronal scutes, which were interpreted as remnants of the darker coloration present in post-hatchlings.

Table 1. Relative frequency of hawksbill turtles (*n*) sighted and captured (per census hour) among localities during snorkeling censuses. Turtles sighted includes turtles captured.

Location	Census hours	Sighted *n*	Sighted *n*/hr	Captured *n*	Captured *n*/hr
B. de las Aguilas	19.9	20	1.01	17	0.86
Beata Oeste	12.5	1	0.08	0	0.00
Cabo Rojo	89.3	154	1.72	126	1.41
Canal Beata	6.8	11	1.62	6	0.88
Colita	3.0	6	2.00	6	2.00
El Faro	2.3	8	3.43	8	3.43
Lanza Brigó	7.5	5	0.67	3	0.40
Lanza Zó	18.8	28	1.49	27	1.43
Los Frailes	5.8	13	2.23	10	1.71
Muelle Oeste	10.6	21	1.98	18	1.69
Playa Norte	17.4	57	3.28	54	3.11
TOTAL	193.9	324	1.67	275	1.42

Only one turtle captured was of adult size (69.7 cm SCL), and was presumably an adult female (since its tail did not protrude noticeably from the carapace) caught at Muelle Oeste in September 1997. The presence of at least one nesting hawksbill in the area had been confirmed by a nest and two nesting attempts observed at Bahía de las Aguilas beach the previous day (the only nesting activity observed during the entire study period). Another possible adult turtle (or large sub-adult) was sighted at Bahía de las Aguilas, but could not be captured for measurement. Even though no special efforts were made to search water deeper than 15 m, occasional deep scuba dives did not produce sightings of adult sized animals. In fact, our deepest hawksbill capture (30 m) was of a 30.8 cm individual at a coral reef site in Canal de Beata.

Growth. — During our study, 51 growth increments were recorded for 37 turtles recaptured over intervals ranging from 45 to 571 days and initial size from 21 to 45.2 cm. Growth rates were very variable, averaging 5.76 cm/yr (SD = 2.68; range = 0.5–12.4). Growth rates for 22 growth

Table 2. Density and biomass estimates for selected localities. Biomass data derived from Table 3.

Locality	Date of Survey	Total Area (km^2)	Habitat Type	Turtles Sighted	Density (turtles/km^2)	Biomass (kg/km^2)
Playa Norte	20-26 Apr 98	3.59	Sparse hard bottom	20	5.6	35.8
B. de las Aguilas	2 Dec 1997	1.52	Sparse hard bottom	10	6.6	40.0
Cabo Rojo	7-13 Apr 97	4.02	Sparse hard bottom	33	8.2	58.8
Los Frailes	26 Sep 97	0.10	Coral reef	6	58.3	161.6
Colita	21 Apr 98	0.03	Coral reef	3	96.8	568.1

Table 3. Biomass calculation for each locality by 5 cm size-class. Size-class categories are in cm of SCL. For each size-class category, the mean turtle mass (in kg) for that particular class is given. * Not Acquired: for 11 sighted turtles that had no recorded size-class value (2 at B. de las Aguilas and 9 at Cabo Rojo), we assigned a mean mass of 4.4 kg, the mean weight of all turtles (SD = 2.9).

Locality	Size-class: Mean mass: *n*	20-25 (1.67)	25-30 (2.64)	30-35 (4.41)	35-40 (6.60)	40-45 (9.48)	45-50 (11.62)	N.A.* (4.40)	Total Biomass
Playa Norte	20		7.92	26.46	33.00	37.92	23.24		128.50
B. de las Aguilas	10		7.92	4.41	6.60	18.96	11.62	8.80	58.30
Cabo Rojo	36	6.68	15.84	30.87	46.20	18.96	11.62	39.60	163.20
Los Frailes	6	1.67	10.56	4.41					16.60
Colita	3			4.41	13.20				17.70
TOTAL	75	8.35	42.24	70.56	99.00	75.84	46.48	48.40	384.30

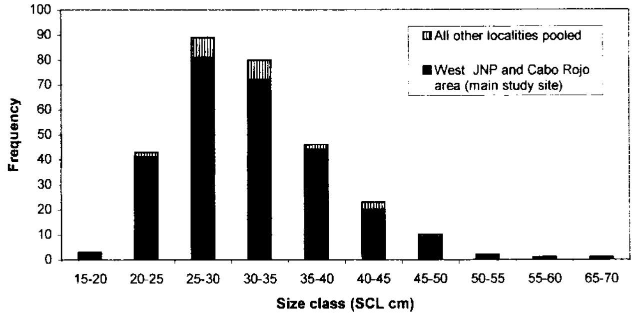

Figure 3. Size-class frequency distribution of all captured hawksbills.

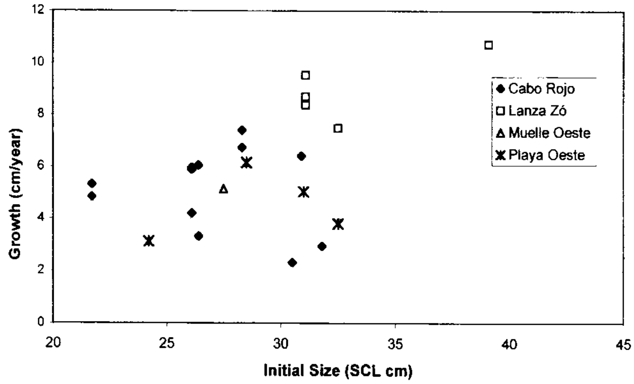

Figure 4. Annualized growth rates for recaptured animals with more than 6 months growth at different localities. Multiple recaptures of four individuals are included.

increments recorded for periods greater than 6 months (180 days) are presented in Fig. 4. We found no significant differences in growth rates among size-classes. However, animals captured at Lanza Zó appeared to grow faster than those captured elsewhere.

Sex Ratio. — Serum samples from 143 individuals were analyzed for testosterone level to determine sex (Fig. 5). The percentage of females was 71.5%, the percentage of males was 26.4%, and indeterminate individuals (possible intersexes) constituted 3.0%. Excluding indeterminate individuals, the sex ratio was skewed towards females (2.71:1).

Home Range. — Using data from 34 recaptured individuals, the mean distance between first and last capture position of individual turtles was 0.36 km (SD = 0.32, range = 0.06–1.55). The mean time interval between first and last capture was 204.4 days (SD = 141.0, range = 45–571).

DISCUSSION

The high density of juveniles and sub-adults in the JNP-Cabo Rojo area clearly indicates that it is an important recruitment and foraging ground for hawksbills in the region. Only two previous studies have attempted to quantify the presence of hawksbills on foraging grounds: one in Mona Island, Puerto Rico (Diez and van Dam, 1998) and one in the southern Great Barrier Reef, Australia (SGBR) (Limpus, 1992). In terms of capture frequency (catch per unit effort) some of our study sites were either comparable or had higher values than Mona Island (range: 0.86–3.43 and 0.48–2.38 turtles/hr, respectively). With respect to the SGBR population, our maximum sighting frequency was more than twice that of Heron and Wistari Reefs (3.43 vs. 1.29 turtles/hr) and our density estimates for all localities were considerably higher than the reported 3.34 turtles/km^2 for Heron Reef. However, in terms of biomass, only our coral reef sites had higher values than the 0.82 kg/ha (= 82 kg/km^2) reported for Heron Reef, confirming the observation that hawksbills are more likely to be found in those areas having vertical faces to the coral formations (Limpus, 1992). Nevertheless, it should be noted that these biomass comparisons are affected by the smaller minimum recruitment and mean turtle size for Caribbean versus Australian hawksbills.

A distinctive feature of the studied population is the near-total absence of adult-sized animals. The concept of

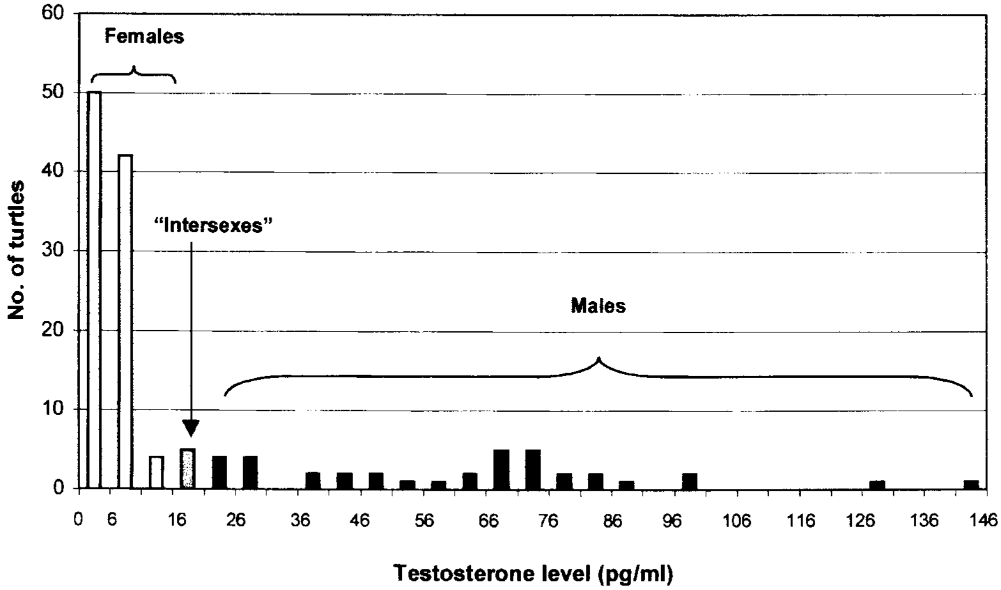

Figure 5. Testosterone level distribution of captured hawksbills: sex determination based on comparison to values obtained by Diez and van Dam (1994) on Mona Island, Puerto Rico.

developmental migration (Carr and Caldwell, 1956; Carr, 1980) or developmental habitat (Ehrhart and Redfoot, 1995; Musick and Limpus, 1997) has been used to account for the differences in size-class distribution of turtles found on different foraging grounds. The idea that turtles move from developmental to adult foraging habitats as they grow has been accepted as an explanation for the immature hawksbill population living on the SGBR (Limpus, 1992) and on Sumatra Island (Kamezaki and Hirate, 1992). It is possible that the JNP-Cabo Rojo area is one such developmental habitat. However, in other areas of the Caribbean, such as Mona Island (Diez and van Dam, 1998) and Las Coloradas, Mexico (Garduño, 1997), hawksbills of all size classes, including adults, can be observed.

Another cause for the predominantly juvenile and subadult population in JNP-Cabo Rojo may be over-exploitation by local people. Ottenwalder (1981) documented carcasses of at least 8 adult hawksbills near Cabo Rojo. During the 1980s, S.J. Incháustegui (*pers. comm.*) collected and observed carcasses of adult-sized hawksbills from Beata and Alto Velo islands, Lanza Zó, and El Seco. Additional anecdotal accounts from local people seem to indicate that the sandy beaches nearby the studied feeding grounds were previously important nesting grounds for hawksbills.

A predominance of females was found in our population (2.71:1). A similar female-biased sex ratio has been predicted for other immature sea turtle populations (Wibbels et al., 1987; Limpus, 1992; Bolten et al., 1992). However, a slightly male-skewed sex ratio was found for hawksbills at Mona Island (Diez and van Dam, unpublished data). The sex of a hatchling depends on the temperature at which its egg was incubated (Yntema and Mrosovsky, 1980; Mrosovsky, 1980). Studies on the sex ratio of sea turtle hatchlings have shown that the sex ratio can vary considerably depending on the time of hatching within a given season (Mrosovsky et al., 1984) and even on the beach selection of the same island (Limpus et al., 1983). These observations may explain our skewed sex ratio, for they imply that each population may have a different and perhaps dynamic ratio, different from the primary sex ratio of 1:1 indicated by evolutionary theory (Fisher, 1930). It is possible that over very long periods of time, sex ratios tend to self-correct for major deviations from 1:1, but at any given point they probably reflect the temperatures that happened to prevail when the population in question was incubating. We believe that, as Wibbels et al. (1987) have stated, the mere existence of this sexual bias argues for further studies of sex ratio in sea turtle populations and its implications.

Comparisons of our growth rates with other studies are difficult because of our limited data set and large standard deviation. The considerable differences in growth rates measured may be attributed to a combination of factors, such as age, sex, genotype, and environment. Limpus (1992) and Chaloupka and Limpus (1997), on two comprehensive growth studies of wild hawksbills, concluded that immature hawksbill growth on the SGBR peaked at 50 to 60 cm of curved carapace length. Additionally, Chaloupka and Limpus (1997) found a significant difference between sex-specific growth rates. On the other hand, for the western Atlantic and Caribbean, Bjorndal and Bolten (1988) and Boulon (1994) have proposed a monotonic decreasing size-specific growth rate function for immature hawksbills, while Diez and van Dam (unpublished data) detected increased growth rates for 30–40 cm hawksbills from Mona Island and significantly different growth rates among study sites. Our limited data set does not allow us at present to detect any of these growth patterns.

Several studies have suggested the fidelity of hawksbills, especially juveniles, to specific sites (Limpus, 1992; van Dam and Diez, 1998). The relatively reduced net displacement of the recaptured individuals in our study is similar to the results of van Dam and Diez (1998) at Mona Island, where hawksbills moved an average of 0.45 km (SD = 0.66) between captures. This indicates that immature hawksbills probably remain within a fairly specific area for at least several years. Therefore, it is important that the nearshore areas of western JNP and Cabo Rojo have habitat protection ensured on a long-term basis in order to sustain these turtles during their residence there. In view of the high density of immature turtles recorded at specific localities here, we believe that these hawksbills, if protected, may help repopulate previously depleted areas in the Caribbean.

RESUMEN

Una población de carey (*Eretmochelys imbricata*) estudiada en el suroeste de la República Dominicana, a Parque Nacional de Jaragua y Cabo Rojo, estuvo compuesta mayormente por individuos juveniles y subadultos, los cuales mostraron tasas de crecimiento muy variables, proporción sexual sesgada hacia las hembras (2.71:1) y fidelidad a áreas específicas. La ausencia de careyes adultos en la zona, aún durante la época reproductiva, fue notoria. Sin embargo, las altas densidades de juveniles registradas (hasta 96.8 tortugas/km^2) nos hacen pensar que estas tortugas, si son protegidas estas áreas, podrían repoblar exitosamente áreas devastadas en el pasado.

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