Chelonian Conservation and Biology, 1999, 3(2):257–263

Reproduction and Nesting of the Hawksbill Turtle, *Eretmochelys imbricata*, in the Cuban Archipelago

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Abstract. – Hawksbill turtle (*Eretmochelys imbricata*) reproduction in the Cuban archipelago has been studied primarily by examination of the reproductive status of samples of animals (*n* = 8711, 1983–95) taken during the historical turtle fishery. The smallest females with oviductal eggs were 51–55 cm straight carapace length; 50% of females appeared mature by 76–80 cm, and 100% after 80 cm. Males appear to reach maturity around 68 cm. The cycle of reproduction in *E. imbricata* caught in different parts of Cuba varies with regard to both timing and the proportion of females that are reproductively active. The main nesting areas in Cuba are in the southeast, particularly around the Doce Leguas Keys, and most survey work to date has been concentrated in this region. To date 47 nesting beaches have been located on various islands and keys, with more being identified each year. Nesting, nests, eggs, and hatchlings are similar to those described elsewhere, although nest predation levels are generally lower. The full extent of hawksbill nesting in Cuba is unknown, but is estimated to be in the range of 1700–3400 nests annually.

Key Words. – Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; reproduction; nesting; sexual maturity; population; conservation; Cuba

Hawksbill turtles (*Eretmochelys imbricata*) are distributed throughout the extensive mosaic of shallow water habitats surrounding the Cuban archipelago (Carrillo and Contreras, 1998). The coastlines of the main island and 2128 smaller islands and keys provide a range of beaches that appear suitable for *E. imbricata* nesting. Surveys have confirmed that the Doce Leguas Keys, within the Archipiélago de los Jardines de la Reina, off the southern coast (Moncada et al., 1998a) is probably the most significant nesting area in Cuba.

Nesting of *E. imbricata* in Cuba involves both solitary individuals nesting in isolation outside of the main nesting season, and multiple females nesting on a single beach during a clearly defined season, as described elsewhere (e.g., Limpus, 1980, 1992; Limpus et al., 1983; Bjorndal et al., 1985; Horrocks and Scott, 1991; Hoyle and Richardson, 1993; Loop et al., 1995).

Since the early 1980s a number of studies have examined different aspects of *E. imbricata* reproduction in Cuba (Moncada and Nodarse, 1994; Moncada et al., 1998a). During the historical harvest (particularly 1984–86; Carrillo et al., 1998a) the reproductive status of large numbers of captured animals was determined during processing. This allowed the relationship between maturity and size to be quantified (Moncada et al., 1987, 1998a) so that size limits could be evaluated, and it allowed closed seasons to be better synchronized with the main nesting periods in different parts of Cuba (Moncada, 1998; Carrillo et al., 1998a). Opportunistic surveys have been undertaken to identify beaches used by *E. imbricata* for nesting (Moncada et al., 1998a), but detailed systematic surveys have only recently been started (1997–98). This paper summarizes information gathered to date on *E. imbricata* reproduction and nesting in Cuba.

MATERIALS AND METHODS

Reproductive Data. — Data on the reproductive status of individual *E. imbricata* were obtained through a sampling program initiated during the historical harvest (Carrillo et al., 1998a). Data were collected according to four Cuban Fishery Zones (Zones A–D; Fig. 1), in all months of the year. Other than body weight, length [straight (SCL) and/or curved carapace length] and sex, the information gathered was very basic: the presence or absence of enlarged ovarian follicles and/or shelled oviductal eggs. During this program 6789 female *E. imbricata* were examined. More recently, the histology of the gonads of a small sample of males was examined after fixation in Bouin's solution and haematoxylin and eosin staining of 5–7 μm sections.

Nesting. — A preliminary survey of turtle fishermen and coastal people within each Fishery Zone was carried out in the 1980s to identify known nesting areas. From 1987–93 some of these areas were visited by land or boat, and some were surveyed from the air using a helicopter. Following identification of significant nesting in the Doce Leguas Keys in Zone A (Fig. 1), additional surveys were undertaken there each year.

Nesting beaches at Doce Leguas were described (length, width, and slope of the beach), and the dominant vegetation and fauna recorded. Nests were located mainly during the day, by following tracks made by females crawling up the beach and by probing the sand in areas where there was some indication that a nest might be present. When older nests

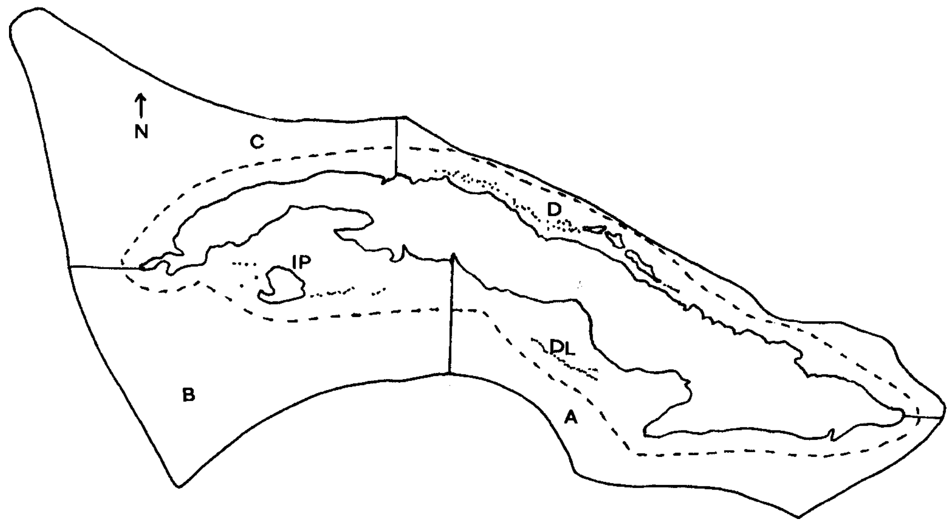

Figure 1. Cuba's territorial waters (broken line) and economic zone (solid line) subdivided into four Fishery Zones (A, B, C, D). IP = Isle of Pines; DL = Doce Leguas Keys.

were located, an egg was opened to determine the extent of embryological development, and estimate date of hatching. Information on the distance of nests from the high water level, moon phase, and size of tracks was also recorded. Some nests were revisited near the time of hatching to quantify clutch size, and the percentage of eggs which were infertile, hatched, or died during incubation.

From 1988–89 to 1996–97, the objectives of these field trips were to identify new nesting areas within and near the Doce Leguas Keys, collect eggs and/or hatchlings for an experimental ranching program (Nodarse et al., 1998), and to tag *E. imbricata* caught in the area. No systematic nest surveys were carried out in Doce Leguas until the 1997–98 nesting season, when 10 beaches were patrolled for at least 10 days per month by researchers walking the beaches each night. During these nest surveys, other beaches and islands were visited opportunistically during the day. A more rigorous relationship between embryo size and age was used this season to estimate the date of nesting with more precision.

Survey effort in Doce Leguas has been more intensive over the last four seasons, but remains incomplete for any beach in any year. The variation in nests located in different sites surveyed from year to year in part reflects search effort, which for most years has not been quantified precisely. Bad weather conditions (e.g., hurricanes) over the last three nesting seasons have forced surveys at different times of the year to be abandoned, and have contributed to inconsistent search effort between seasons. In addition, and perhaps more importantly, bad weather greatly affects the ability of researchers to locate nests, as tracks and diggings are washed away.

RESULTS

Sexual Maturity. — The relationship between SCL and reproductive status for females caught during the annual historical harvest between 1983 and 1993 indicates that the smallest female *E. imbricata* which attain maturity are 51–55 cm SCL (Table 1). Around 50% of females are mature at 76–80 cm SCL and 100% mature by 80+ cm SCL.

The size at which male *E. imbricata* reach maturity is poorly known. Histological examination indicates males of 54–57 cm SCL (n = 2) are immature, males 65–67 cm SCL are sometimes mature (n = 5; 2 with spermatogenesis) and males 68–81 cm SCL are all mature (n = 6; all with spermatogenesis).

Table 1. Relationship between straight carapace length (SCL, in cm) and reproductive status in a sample of 6789 female *E. imbricata* examined between 1983 and 1993. "Follicles" = enlarged ovarian follicles, but no oviductal eggs; "Eggs" = shelled oviductal eggs (in almost all cases these individuals also had enlarged follicles). "Estimated % Mature" is based on a correction of 2.42 (nesting interval: Hoyle and Richardson, 1993; Garduño and Márquez, 1996) for females < 81 cm SCL, and assumes that all females above 81 cm SCL are mature (after Moncada et al., 1998a).

SCL (cm)	31-40	41-50	51-55	56-60	61-65	66-70	71-75	76-80	81-85	86-90	>90
Sample Sizes (n)	32	395	643	849	973	1091	1022	896	481	271	136
Follicles (%)	0	0	1.2	1.3	1.9	3.0	5.9	13.8	30.6	40.2	36.8
Follicles and Eggs (%)	0	0	0.3	0.4	0.9	1.5	2.0	5.0	5.6	8.9	6.6
Eggs (no Follicles) (%)	0	0	0.0	0.0	0.1	0.0	0.0	0.3	0.4	0.0	0.0
Reproductively Active (%)	0	0	1.5	1.7	2.9	4.5	7.9	19.1	36.6	49.1	43.4
Estimated % Mature	0	0	4	4	7	11	19	46	100	100	100

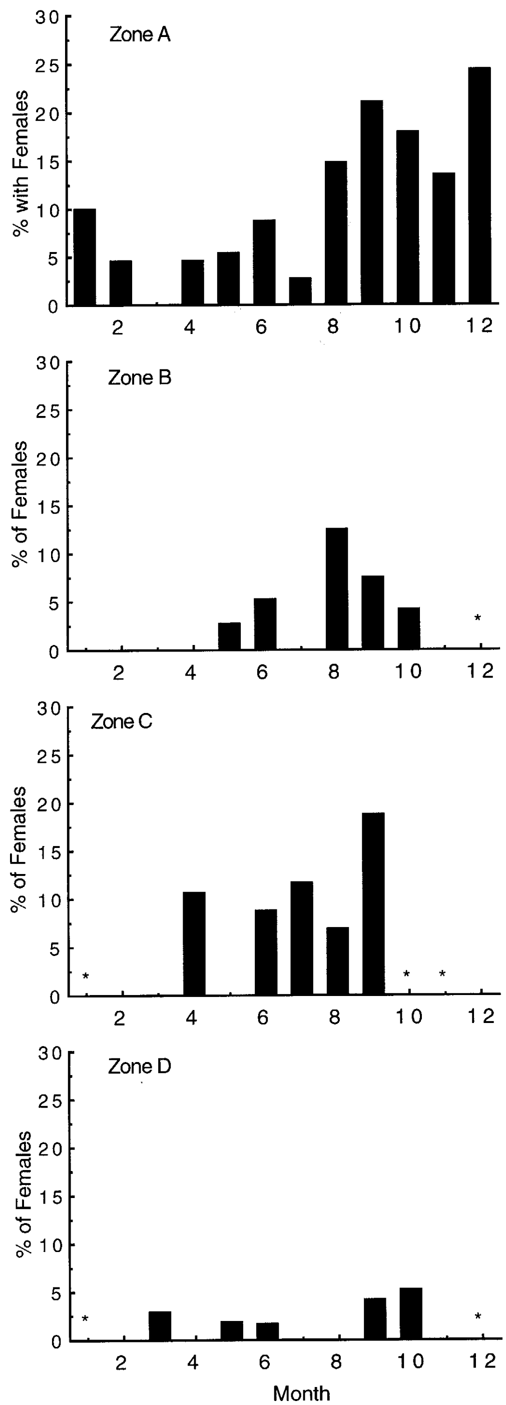

Figure 2. Percentage of female *E. imbricata* > 75 cm SCL containing oviductal eggs in different months, within the four Cuban Fishery Zones (see Fig. 1). * = less than 10 animals in the sample, data not used. Months are: 1 = January, 2 = February, etc.

Nesting Females. — As nest surveys were until recently undertaken during the day, only 21 female *E. imbricata* have actually been observed nesting. The smallest female observed nesting at Doce Leguas was 58.5 cm SCL, and the largest 83 cm SCL. Measurement of tracks at Doce Leguas are consistent with nesting females from 60 to 85 cm SCL.

Reproductive Cycle. — The historical harvest data indicate that female *E. imbricata* with enlarged follicles and/or oviductal eggs occur in all Fishery Zones, and at least some individuals with oviductal eggs occur in Cuban waters in all months of the year. These individuals may have been destined to nest in areas outside Cuba, although this would seem more likely in animals with enlarged follicles rather than oviductal eggs. There is significant asynchrony between Zones in the proportion of females with oviductal eggs in particular months (Fig. 2).

In Zone A, which contains Doce Leguas, females containing oviductal eggs were recorded in 11 months of the year (not in March) (Fig. 2). There were two peaks (September and December; Fig. 2) in the proportion of females containing oviductal eggs. These correspond generally with the peak of nesting activity at Doce Leguas (Moncada et al., 1998a).

In Zone B, females with oviductal eggs were recorded between May and October; none were recorded between January and April (Fig. 2). A peak in the proportion of females with oviductal eggs occurs in August. A study currently underway in Cayo San Felipe, west of the Isle of Pines (Fig. 1), indicates peak nesting activity is June–August. Some *E. imbricata* nests have been located on the southern coast of the Isle of Pines (see Moncada et al., 1998a) during June–July. Like Zone A (see above), the reproductive data from the historical harvest (times at which females carry oviductal eggs) are correlated with the Zone-specific times of nesting.

Data for Zone C are not as complete. The seasonal pattern of females carrying oviductal eggs is similar to Zone B (Fig. 2), with peaks between April and September (April, July, and September).

In Zone D, a low proportion of females contained oviductal eggs in any month (Fig. 2), and the correlation with time of nesting is unknown.

Nesting Sites. — Nesting of *E. imbricata* has been confirmed in Zone A (e.g., Doce Leguas) and Zone B (e.g., Isle of Pines, Cayo San Felipe, Cayo Canarreos) (see Moncada et al., 1998a). Previous records of nesting in Zone C (Moncada et al., 1998a) remain to be confirmed. Other than in Zone A, the extent and timing of nesting remains poorly known. A survey program was initiated in mid-1998 in Zones B and C, but to date no confirmed nesting sites are known from Zone D (which also has the lowest percentages of females with oviductal eggs; Fig. 2).

The main nesting areas identified are the Doce Leguas Keys (in Zone A; Fig. 1), which lie some 60 km off the southern coast of Camaguey Province. Doce Leguas is comprised of a chain of 45 islands and keys, spanning some 120 km in length. The islands and keys are up to 25 km long, with 60% of them containing sandy beaches considered potentially suitable for *E. imbricata* nesting. These beaches typically have an oceanic front with long coral barriers which are more pronounced in the western than the eastern part of the archipelago. The remainder of the keys are comprised of mangroves and rocky shores which appear unsuitable for nesting. A number of inner keys, lying between Doce Leguas and the mainland, contain short sandy beaches known to support *E. imbricata* nesting (Table 2).

Table 2. Numbers of *E. imbricata* nests located during surveys at Doce Leguas Keys and small “inner” keys between the latter and the mainland. ’88 = 1988–89, ’89 = 1989–90 nesting season, etc.; (a) = beach surveyed for first time in 1995–96; (b) = beach surveyed for first time in 1996–97; (c) = beach surveyed for the first time in 1997–98; (d) = nests not allocated to a specific beach, but to a key (in square brackets); * = the 10 monitoring sites used in 1997–98.

Beach/Key	’88	’89	’90	’91	’92	’93	’94	’95	’96	’97	
Doce Leguas Keys											
Alcatracito	1	-	-	-	1	-	-	3	0	1	
Alcatraz	-	-	1	-	2	-	17	5	0	8	
[Cayo Anclitas] (d)	4	-	7	3	-	-	-				
Caballones Este	7	5	-	-	2	1	-	-	7	0	*
El Datiri	-	-	-	-	-	-	4	5	1	12	*
El Manchao	-	-	-	-	-	-	1	-	0	1	
Los Pinos	-	-	-	-	-	-	5	1	3	10	
La Cana	-	-	-	-	-	-	-	3	3	0	
La Canita (b)	-	-	-	-	-	-	-	-	0	2	
Ballenas	-	-	-	-	9	-	-	2	18	7	*
Bartula	-	-	-	-	-	-	1	6	3	8	
Boca Piedra Chiquita	-	-	-	3	-	-	4	-	12	13	
Boca de Piedra	-	-	2	-	-	-	-	1	-	0	
Boca Seca	-	-	3	2	-	-	30	15	5	6	*
Campo Santo (a)	-	-	-	-	-	-	-	3	-	0	
[Cayo Caballones] (d)	-	-	-	2	-	-	-				
Caballones Oeste	-	-	-	-	3	3	11	8	10	3	*
Playa Bonita	-	-	-	-	-	-	9	1	0	0	*
El Guinchos	-	-	-	-	-	9	13	-	4	8	*
La Llana	-	-	-	-	-	-	-	1	0	2	
Carabineros	2	4	1	-	1	-	11	-	0	4	
Barrabas	-	-	-	-	2	-	8	-	1	0	
Chaciboca	-	-	-	1	-	-	-	2	6	0	*
El Faro	-	-	-	-	-	-	7	-	3	0	*
Indios Chiquitos	-	-	-	-	-	-	4	-	0	3	
[Cayo Grande] (d)	2	1	-	-	-	-	-				
Bayameses	-	-	-	-	3	-	5	2	0	4	
Almendron	-	-	-	-	-	-	13	-	0	4	
Los Cocos	-	-	-	-	-	-	12	-	0	0	
Boca de Guano	-	-	2	-	1	3	44	-	5	5	
Caleta Blanca	-	-	-	-	-	-	6	1	-	0	
Boca Grande	-	-	3	-	6	-	-	-	3	7	
Piedra Grande	1	-	-	-	-	-	-	2	-	0	
La Piedra (b)	-	-	-	-	-	-	-	-	1	3	
Mano Negra (b)	-	-	-	-	-	-	-	-	4	4	
Cinco Balas	-	-	3	-	-	-	1	3	6	12	
Indios Grande	-	-	-	-	-	-	3	-	0	0	
Juan Grin	-	-	-	8	-	-	11	13	8	0	*
Crucesitas	-	1	-	1	3	-	3	2	3	0	
Las Cruces	-	-	-	-	-	-	13	2	8	35	
Los Hierros	-	-	-	-	-	-	15	13	4	7	
Inner Keys											
Algodones (a)	-	-	-	-	-	-	-	8	-	6	
Algodoncito (a)	-	-	-	-	-	-	-	2	-	1	
Balandra (c)	-	-	-	-	-	-	-	-	-	1	
Dos Hermanos (c)	-	-	-	-	-	-	-	-	-	0	
La Loma (c)	-	-	-	-	-	-	-	-	-	7	
La Palomo (a)	-	-	-	-	-	-	-	1	-	0	
Mata Coco (c)	-	-	-	-	-	-	-	-	-	1	
Punta Arenas (c)	-	-	-	-	-	-	-	-	-	1	
Rabihorcada (c)	-	-	-	-	-	-	-	-	-	3	
Santa Maria (b)	-	-	-	-	-	-	-	-	4	9	

Beaches in the Doce Leguas Keys range in length from 0.05–5.5 km, and are 1–25 m (mean = 9 m; n = 34) wide. They are generally sloped (around 8º) along their length, and the mean height is 1.1 m above high tide level. Vegetation along the beaches is mainly native bushes such as yana (*Conacarpus erecta*), yuruguano (*Cocothrinax miraguana*), patabán (*Laguncularia racemosa*), salvia marina (*Tournefortia anphalodes*), and platanillo (*Piper aduncun*). The inner, shallow water areas of the keys contain banks of *Thalassia testudinum* and areas of *Siringodium* sp.

Nests. — In Zone A, 47 beaches on 26 separate islands and keys have so far been confirmed as *E. imbricata* nesting sites. Inner keys were visited in the 1995–96, 1996–97, and 1997–98 seasons (Table 2), and of the 10 visited to date, 9 support *E. imbricata* nesting.

The maximum number of nests found in any one season in Zone A was 251 nests (on 25 beaches in 1994–95; Table 2). In addition, 105 nests were found in 1995–96, 122 in 1996–97, and 198 in 1997–98, for a total of 676 nests over four seasons. The survey results for these four seasons were combined (due to the varying search effort

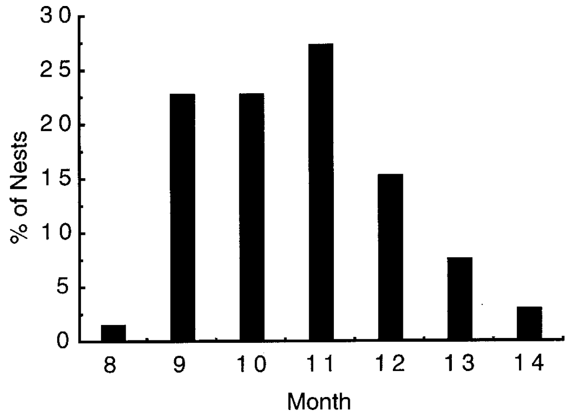

Figure 3. Month of laying for 66 *E. imbricata* nests at Doce Leguas Keys, 1997–98 nesting season. Months are: 8 = August 1997, ..., 13 = January 1998, etc.

per beach from year to year) by adding the maximum recorded number of nests located per season per beach in any season. This method yielded an adjusted total of 409 nests on 47 beaches as a combined maximum seasonal value for the period 1994–98.

The 10 nesting beaches at Doce Leguas monitored for 10 days or more each month in the 1997–98 season indicated reduced nesting relative to spot checks on these same beaches in the previous seasons (Table 2). It was felt that the presence of people on the nesting beaches and general boat activity ferrying staff to and from nesting beaches disturbed females such that they nested elsewhere. In addition, 3 of the 10 beaches selected for monitoring (El Datiri, Playa Bonita, El Guincho; Table 2) were greatly eroded by exceptional wave action the previous year, and may no longer be suitable for nesting.

Taking all nests for which relatively precise embryo aging data were available for the 1997–98 season, nesting in Doce Leguas peaks in November (Fig. 3). Results of a study underway at Cayo San Felipe, in Zone B, indicate a peak of nesting there between June and August with 20–25 *E. imbricata* nests per year on one beach. Sporadic nesting is also known from Playa Larga, a 4 km long beach on the south coast of the Isle of Pines (Moncada et al., 1998a), and from a number of beaches in Cayo Canarreos (east of the Isle of Pines; Fig. 1), but the full extent and time of nesting have yet to be quantified.

At Doce Leguas, nesting occurred almost exclusively at night between 2030 and 0500 hrs, particularly on dark nights without bright moonlight. Mean distance from high tide mark to a nest was 7.6 m (SE = 4.9, n = 595; range = 1–25 m). The mean renesting interval determined from 4 tagged females was 19.5 ± 1.6 (SE) days. Mean clutch size at Doce Leguas has varied little from year to year (linear regression; $r^2 = 0.00$, $p = > 0.99$), with the mean of 10 annual means being 135.2 ± 0.71 (SE) eggs per nest (Table 3). An average of 69.2% of eggs in monitored nests produced hatchlings which emerged; the remaining embryos either died during development, died in the nest when development was complete, or the eggs were considered infertile (includes very early developmental failures). Loss of eggs or hatchlings to natural predators has not been observed at Doce Leguas, but it is likely that hatchlings are taken by birds, crabs, and other predators at the time of hatching. Some nests are flooded each year as a result of being laid too close to the waterline, or as a result of wave action caused by bad weather. About 85% of nests are located under vegetation and are shaded for most of the day. In exposed nests, overheating may cause some embryo mortality. Some nests appear excessively damp due to the low angle of slope of the beaches and seepage from inland lagoons, which could contribute to increased mortality. Mean SCL of hatchlings from 10 nests was 40.1 ± 0.5 mm (SD; n = 500).

Table 3. Mean clutch sizes and hatching success for *E. imbricata* nests at Doce Leguas Keys, 1988–89 to 1997–98 nesting seasons.

Season	*n*	Mean Clutch Size	Infertile (%)	Dead in Nest (%)	Hatched (%)
1988–89	17	137.3	11.4	13.5	75.1
1989–90	11	132.2	15.3	18.9	65.8
1990–91	22	137.4	11.7	17.5	70.8
1991–92	20	133.4	18.9	15.2	65.9
1992–93	33	136.8	14.6	19.0	66.4
1993–94	17	131.8	-	-	-
1994–95	106	136.4	13.7	16.1	70.2
1995–96	105	137.0	-	-	-
1996–97	85	133.2	13.9	15.0	71.2
1997–98	96	136.3	13.2	18.0	67.7
Mean of means		135.2	14.1	16.7	69.2

DISCUSSION

Size and Age at Maturity. — The size at sexual maturity for marine turtles varies within and between different regions of the world (Hirth, 1971), and *E. imbricata* in Cuba appear to be on the smaller end of the scale for this species. Mature female *E. imbricata* of 53.3 cm SCL have been reported in the Sudan (Hirth and Abdel Latif, 1980), which parallels the smallest females reaching maturity in Cuba (around 51–55 cm SCL). However, most females do not appear to be mature until they are >75 cm SCL. The smallest female *E. imbricata* observed nesting at Doce Leguas (58.5 cm SCL) is comparable to the smallest females nesting in Puerto Rico (Thurston and Wiewandt, 1976) and the Solomon Islands (McKeown, 1977). The limited data available for males indicates that 100% of them are mature by about 68 cm SCL in Cuba.

Growth rates of wild *E. imbricata* show extreme individual and geographic variation (see Carrillo et al., 1998b), and so the time taken to reach maturity will vary considerably between populations. Caution must be exercised when extrapolating growth rates for a species in one area to the same species in a different area (Bjorndal et al., 1998; Carrillo et al., 1998b; Chaloupka, 1998). In Cuba, other than possible genetic factors, growth rates are likely to depend on food availability, water temperature (Nodarse et al., 1998), reproductive status, and possibly density (e.g., Bjorndal et al., 1998; Chaloupka, 1998). The extensive, shallow, warmer waters of southern Cuba, like those of Mexico, may contribute to the higher growth rates recorded there (Garduño and Márquez, 1994; Carrillo et al., 1998b; Garduño, 1998).

The smallest females in Cuban waters could reach maturity at around 10 years of age, but the average age when 100% of females are mature is probably closer to 20 years (Carrillo et al., 1998b). If male and female growth rates are similar, 100% of males may be mature by about 12–15 years of age. Data from the southern Great Barrier Reef (Australia) suggested ages to maturity of around 30+ years, reflecting the much lower growth rates reported there (Limpus, 1992; Limpus and Miller, 1996).

Reproductive Cycle and Nesting. — The relationship between the reproductive data from harvested animals (Fig. 2) and nesting in Cuban waters remains unclear for Zones C and D. In Zone A, the peak time of nesting correlates with the highest proportion of harvested females with oviductal eggs, and thus they were probably destined to nest in the Zone in which they were caught. Although not as extensive, data from Zone B suggest a similar correlation between the time animals with oviductal eggs were harvested and the time females nest in the Zone. However, the peak of nesting in Zones A and B varies. The peak of nesting occurs in September–December in Zone A and June–August in Zone B (Fig. 2).

There are clearly significant numbers of females caught in Cuban waters with eggs at non-peak-nesting times of the year. Whether these nest within or outside Cuban waters is unknown. Data being gathered on the mitochondrial DNA profile of harvested animals (Díaz-Fernández et al., 1998; Moncada et al., 1998b) and movement patterns (Manolis et al., 1998; Moncada et al., 1998b) may shed more light on this.

Nests. — Nesting of *E. imbricata* within the Cuban archipelago appear to be similar to what has been reported elsewhere (Meylan, 1984). The distance of nests from water parallels the situation described in Barbados (Horrocks and Scott, 1991) and Antigua (Hoyle and Richardson, 1993), and the more extended distances from water reported from Quintana Roo in Mexico (Gil Hernandez et al., 1991) are probably a reflection of different beach profiles. Clutch sizes are within the range of those described elsewhere (Witzell, 1983; Márquez, 1990) and have shown no significant increase or decrease over the last 10 years (Table 3).

Extent of Nesting. — There is no reliable way at present to estimate the full extent of nesting within Cuban waters. It is clear that there are many more nests than those actually found to date, but the level of correction is unknown. Considerable logistic difficulties have been encountered carrying out nest surveys, due in part to the remote nature of the known nesting areas, and the occasional bad weather conditions, particularly during the last three nesting seasons.

Above and beyond these biases, the number of nests found at any one beach is largely a reflection of the effort spent looking for them. The combined maximum seasonal value of number of nests located in spot checks on 47 beaches in Zone A during the last four seasons (409) is clearly an underestimate of the full annual extent of nesting that could be expected if all beaches were surveyed intensively throughout all seasons (Hoyle and Richardson, 1993; Loop et al., 1995). Nonetheless it does provide an index of nesting in Zone A.

If the maximum seasonal value of number of nests on any beach reflected 25–50% of the total nesting on those particular beaches in any one year, it would suggest about 800–1600 nests per year on those 47 beaches in Zone A. If these in turn reflect around 75% of nesting in Zone A, it would indicate about 1100–2200 nests there per year. Using reproductive data (Fig. 2) and the extent of annual historical harvests in each Zone (Carrillo et al., 1998a), Zone A was estimated to contribute 65% of the annual nesting effort in Cuba (Moncada et al., 1998a). On this basis, nesting in Cuban waters can be estimated to be in the range of about 1700–3400 nests per year.

Monitoring. — The cost of surveying and monitoring nesting throughout the year on all known nesting beaches in Cuba is prohibitive. From a management point of view, the key question to be answered is whether the nesting population is increasing, decreasing, or remaining stable. At Doce Leguas, nesting on 10 selected beaches is now being monitored in a more systematic fashion, while nesting at other sites is being examined opportunistically (see Table 2). These 10 beaches were selected on the basis of accessibility during the main part of the nesting season (August–March; Fig. 3). Seasonal fluctuations in nesting effort, as recorded elsewhere for other species of marine turtle, and other factors (e.g., physical changes to nesting beaches) can be expected to occur, so population trends as indicated by these "nesting indices" may only become clear from longer-term data. Reproductive data from *E. imbricata* taken at the two traditional harvest sites in Cuba (see Carrillo et al., 1998c; Republic of Cuba, 1998) provide an additional index of whether the population of *E. imbricata* in Cuban waters is increasing, decreasing, or stable.

Acknowledgments

We wish to express our thanks to the Centro de Investigaciones Pesqueras, through which these studies were undertaken, to the Japan Bekko Association for their support, and to the numerous sea turtle fishermen and other people who contributed to this work. We are grateful to Grahame Webb and Charlie Manolis (Wildlife Management International Pty. Limited) for their ongoing assistance and encouragement, and to Rene Márquez for assistance with nesting surveys over many years.

LITERATURE CITED

Bjorndal, K.A., Bolten, A.B., and Chaloupka, M.Y. 1998. Green turtle growth rates: evidence for a density-dependent effect and Caribbean-Pacific differences. In: Memoria de Resúmenes, 18th International Sea Turtle Symposium, Mazatlán, Mexico, 3-7 March 1998, p. 32.

Bjorndal, K.A., Carr, A., Meylan, A.B., and Mortimer, J.A. 1985. Reproductive biology of the hawksbill *Eretmochelys imbricata* at

Tortuguero, Costa Rica, with notes on the ecology of the species in the Caribbean. Biological Conserv. 34:353-368.

CARRILLO, E.C., AND CONTRERAS, J. 1998. Annex 2. Cuba and its marine environments. Rev. Cub. Inv. Pesq. 22(1):61-68.

CARRILLO, E.C., MONCADA, F.A., ELIZALDE, S.R., NODARSE, G.A., PEREZ, C.P., AND RODRIGUEZ, A.M. 1998a. Annex 4. Historical harvest, trade and sampling data. Rev. Cub. Inv. Pesq. 22(1):75-88.

CARRILLO, E.C., PEREZ, C.P., OHTAISHI, N., KOBAYASHII, M., MONCADA, F.A., MANOLIS, S.C., TSUBOUCHI, T., AND WEBB, G.J.W. 1998b. Annex 7. Population size. Rev. Cub. Inv. Pesq. 22(1):117-134.

CARRILLO, E.C., PEREZ, C.P., MONCADA, F.A., NODARSE, G.A., RODRIGUEZ, A.M., MENESES, A., AND MANOLIS, S.C. 1998c. Annex 9. Management program and procedures - traditional wild harvest. Rev. Cub. Inv. Pesq. 22(1):151-156.

CHALOUPKA, M. 1998. Sea turtle growth dynamics: a review. In: Memoria de Resúmenes, 18th International Sea Turtle Symposium, Mazatlán, Mexico, 3-7 March 1998, p. 28.

DÍAZ-FERNÁNDEZ, R., OKAYAMA, T., UCHIYAMA, T., CARRILLO, E., ESPINOSA, G., MÁRQUEZ, R., DIEZ, C., AND KOIKE, H. 1998. Genetic sourcing for the hawksbill turtle, *Eretmochelys imbricata*, in the northern Caribbean region. Chelonian Conservation and Biology 3(2):296-300.

GARDUÑO, M.A. 1998. Growth of hawksbill turtle *Eretmochelys imbricata* off Rio Lagartos, Yucatan, Mexico. In: Memoria de Resúmenes, 18th International Sea Turtle Symposium, Mazatlán, Mexico, 3-7 March 1998, p. 31.

GARDUÑO, M.A., AND MÁRQUEZ, R. 1994. Tagging and returns of hawksbill sea turtles in Las Coloradas, Yucatan, Mexico. In: Proceedings, International Workshop on the Management of Marine Turtles '94, Tokyo, 28-30 March 1994.

GIL HERNANDEZ, R.A., MIRANDA RUELAS, E., AND VAZQUEZ DEL VALLE, R. 1991. Protección e investigación de la tortuga carey, *Eretmochelys imbricata*, (Linnaeus, 1766), en Isla Holbox, Quintana Roo, temporada 1990. In: Frazier, J. (Ed.). Rep. of the IV Reg. Wkshp. Conserv. Prog. Sea Turt. Yucatan Pen., 11-13 March 1991, Merida, Yucatan, Mexico, pp. 143-158.

HIRTH, H.F. 1971. Synopsis of biological data on the green turtle *Chelonia mydas* (Linnaeus) 1758. FAO Fisher. Synops. 85, 75 pp.

HIRTH, H.F., AND ABDEL LATIF, E.M. 1980. A nesting colony of the hawksbill turtle *Eretmochelys imbricata* on Seil Ada Kebir Island, Saukin Archipelago, Sudan. Biol. Conserv. 17:125-130.

HORROCKS, J.A., AND SCOTT, N.M. 1991. Nest site location and nest success in the hawksbill turtle *Eretmochelys imbricata* in Barbados, West Indies. Mar. Ecol. Prog. Ser. 69:1-8.

HOYLE, M., AND RICHARDSON, J. 1993. The Jumby Bay hawksbill project: survivorship, mortality and reproductive biology and behavior of adult female hawksbill sea turtles *Eretmochelys imbricata* nesting at Pasture Bay, Long Island, Antigua, 1987-1992. Technical Report, Georgia Sea Turtle Cooperative, Institute of Ecology, University of Georgia, Athens, 76 pp.

LIMPUS, C.J. 1980. Observations on the hawksbill turtle (*Eretmochelys imbricata*) nesting along the Great Barrier Reef. Herpetologica 36:265-271.

LIMPUS, C.J. 1992. The hawksbill turtle, *Eretmochelys imbricata*, in Queensland: population structure within a southern Great Barrier Reef feeding ground. Wildl. Res. 19:489-506.

LIMPUS, C.J., AND MILLER, J.D. 1996. Australian hawksbill turtle population dynamics project. Unpublished Project Report for Year 1, Queensland Department of Environment.

LIMPUS, C.J., MILLER, J.D., BAKER, V., AND MCLACHLAN, E. 1983. The hawsbill turtle, *Eretmochelys imbricata* (L.), in north-eastern Australia: the Campbell Island rookery. Aust. Wildl. Res. 10:185-197.

LOOP, K.A., MILLER, J.D., AND LIMPUS, C.J. 1995. Nesting by the hawksbill turtle (*Eretmochelys imbricata*) on Milman Island, Great Barrier Reef, Australia. Wildl. Res. 22:241-252.

MANOLIS, C., CARRILLO, E.C., WEBB, G.J.W., KOIKE, H., DIAZ, R., MONCADA, F., MENESES, A.P., NODARSE, G., ESPINOSA, G., AND BAKER, B. 1998. Research update on the Cuban hawksbill turtle program. In: Memoria de Resúmenes, 18th International Sea Turtle Symposium, Mazatlán, Mexico, 3-7 March 1998.

MÁRQUEZ, R. 1990. FAO species catalogue. Vol. 11. Sea turtles of the world. An annotated and illustrated catalogue of sea turtle species known to date. FAO Fish. Synop. 125: 81 pp

MCKEOWN, A. 1977. Marine Turtles of the Solomon Islands. Honiara: Fisheries Division, Ministry of Natural Resources. 47 pp.

MEYLAN, A.B. 1984. Biological synopsis of the hawksbill turtle (*Eretmochelys imbricata*). In: Bacon, P., et al. Proceedings of the Western Atlantic Turtle Symposium 1:112-117.

MONCADA, F. 1998. Impact of regulatory measures on Cuban marine turtle fisheries. In: Memoria de Resúmenes, 18th International Sea Turtle Symposium, Mazatlán, Mexico, 3-7 March 1998.

MONCADA, F., AND NODARSE, G. 1994. Length composition and size of sexual maturation of hawksbill turtle in the Cuban platform. In: Study of the Hawksbill Turtle in Cuba (I). Havana: Ministry of Fishing Industries, pp. 19-25.

MONCADA, F., CARDONA, R., AND NODARSE, G. 1987. Comportamiento reproductivo de los quelonios marinas en el archipiélago cubano. Resúmenes 1er Congreso de Ciencias del Mar, pp. 58.

MONCADA, F.A., PEREZ, C.P., NODARSE, G.A., ELIZALDE, S.R., RODRIGUEZ, A.M., AND MENESES, A. 1998a. Annex 6. Reproduction and nesting of *E. imbricata* in Cuba. Rev. Cub. Inv. Pesq. 22(1):101-116.

MONCADA, F.A., KOIKE, H., ESPINOSA, G., MANOLIS, S.C., PEREZ, C.P., NODARSE, G., TANABE, S., SAKAI, H., WEBB, G.J.W., CARRILLO, E.C., DIAZ, R., AND TSUBOUCHI, T. 1998b. Annex 8. Movement and population integrity. Rev. Cubana Inv. Pesq. 22(1):135-150.

NODARSE, G.A., MENESES, A., MANOLIS, S.C., WEBB, G.J.W., CARRILLO, E.C., AND PELEGRIN, E. 1998. Annex 10. Management program and procedures - ranching program. Rev. Cubana Inv. Pesq. 22(1):157-165.

REPUBLIC OF CUBA. 1998. An annotated transfer of the Cuban population of hawksbill turtles (*Eretmochelys imbricata*) from Appendix I to Appendix II of CITES. Rev. Cubana Inv. Pesq. 22(1):1-58.

THURSTON, J., AND WIEWANDT, T. 1976. Management of sea turtles at Mona Island. Appendix I. Mona Island Management Plan. San Juan, Puerto Rico: Department of Natural Resources, 20 pp.

WITZELL, W.N. 1983. Synopsis of biological data on the hawksbill turtle *Eretmochelys imbricata* (Linnaeus, 1766). FAO Fish Synop. 137:1-78.

Received: 5 August 1998
Reviewed: 3 November 1998
Revised and Accepted: 12 December 1998