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Nesting and Conservation of the Hawksbill Turtle, *Eretmochelys imbricata*, in the Pearl Cays, Nicaragua

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ABSTRACT. – **Results are reported from nesting beach surveys and egg protection activities for hawksbill turtles, *Eretmochelys imbricata*, on the Pearl Cays, Nicaragua, from 1999 to 2002. A total of 154, 158, and 155 clutches were recorded in 2000, 2001, and 2002, respectively, between April and November with peak nesting in July. The majority of nesting activity occurred on Wild Cane, Crawl, Grape, Lime, and Water Cays. Prior to the implementation of nest protection activities in 2000, almost 100% of the egg clutches laid were taken, as well as any females encountered on the beach. Mean clutch size was 138.4 eggs. Over the three years, 44.9% (n = 175) of the clutches were relocated to protect against human predation and 55.1% (n = 215) were left *in situ*. Overall hatching and emergence success of nests in which at least one egg hatched was 68.7 and 65.6% for relocated clutches, and 75.5 and 74.6% for clutches left *in situ*, respectively. For those clutches that had at least one egg hatch, overall hatching and emergence success was 72.5 and 70.7%, respectively. For all clutches, overall hatching and emergence success was 66.2 and 64.6%, respectively. The nesting population of hawksbills on the Pearl Cays of Nicaragua is probably one of the largest remaining in the central-western Caribbean. We estimate the Pearl Cays population to be between 85 and 165 nesting females. It is important that the protection of females and their eggs continues so that the population can begin to recover from many years of overexploitation. Current threats to nesting hawksbills, their eggs, and habitat in the Pearl Cays area include the construction of houses and docks, clearing and burning of upper beach vegetation and clearing of mangroves, artificial lights, an increased presence of humans and dogs, and poaching of females and eggs. A management plan for the Pearl Cays is needed to regulate development, promote conservation, and minimize threats to hawksbills and their habitat. Development of a plan should include the participation of all stakeholders to ensure the recovery of the hawksbill foraging and nesting populations and the long-term health of natural resources in the area.**

KEY WORDS. – **Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; sea turtle; nesting; reproduction; hatching success; conservation; community-based; Pearl Cays; Nicaragua; Central America**

The hawksbill turtle, *Eretmochelys imbricata*, occurs in circum-tropical regions of the world. Throughout its range, the hawksbill is considered to be Critically Endangered with most populations in serious decline (King, 1982; Groombridge and Luxmoore, 1989; Meylan, 1989, 1999; Meylan and Donnelly, 1999; Hilton-Taylor, 2000). In a recent review of their status in the wider Caribbean, Meylan (1999) reported that hawksbill populations were declining or depleted in 22 of the 26 geopolitical units for which some status and trend information were available. Only populations in the Yucatán, Mexico, and on Mona Island, Puerto Rico, were considered to be increasing (Meylan, 1999).

In Nicaragua, major threats to all sea turtle populations include the direct and indirect take of animals from the water and the harvest of females and their eggs from nesting beaches by local inhabitants for income and protein (Nietschmann, 1973, 1979, 1981; Carr et al., 1978; Lagueux, 1998; Campbell et al., 2002). Although hawksbills are harvested primarily for their shell, which is sold to local artisans who fashion it into various types of jewelry, their meat is also consumed. On the Caribbean coast of Nicaragua, hawksbill populations are severely reduced according to local fishers. Nietschmann (1981) reported approximately 1000 to 1200 hawksbills were harvested annually from Nicaragua's Caribbean coast in the early 1970s. Currently, a minimum of 80 hawksbills are captured and/or harvested annually from the Caribbean coast (Lagueux, 1998), although recent observations suggest that many more, possibly 100–200 more, are being harvested (CJL and CLC, *pers. obs.*). This decrease in the annual harvest of from 1000 turtles down to several hundred is likely due more to a decrease in the size of the hawksbill population than a decrease in the demand for hawksbill products (Lagueux, 1998).

Until recently, relatively little was known about the status of hawksbill nesting populations along the Caribbean coast of Nicaragua. Nietschmann (1971) reported major hawksbill nesting beaches were located at El Cocal, Set Net Peninsula, Set Net Cays (also known as the Pearl Cays), and the Kings Cay area, and that nesting occurred from June to November with peak nesting in July and August

(Nietschmann, 1971, 1979, 1981). He also reported between 90 and 95% of the clutches laid in 1971 and 1972 had been harvested; however, no data were provided regarding the number of nests or animals nesting (Nietschmann, 1981). Incer (1984) estimated 25 females nesting in 1981, but does not provide information on how the estimate was derived or where nesting occurred. Regardless, this limited information is more than 20 years old and thus does not give insight into the current status of hawksbill populations on the Caribbean coast of Nicaragua. It is important to determine the status of hawksbill populations in view of their threatened status and the growing concern for the long-term survival of populations around the world.

In 1998, CJL and CLC conducted a reconnaissance of several of the Pearl Cays, located in the nearshore waters off the central Caribbean coast of Nicaragua. These surveys revealed that the beaches of the Pearl Cays are still visited by nesting hawksbills. The survival of these remaining hawksbills and their eggs, however, is threatened by continued opportunistic harvest by local fishers for local consumption and for income from the sale of tortoiseshell (Lagueux, 1998; Campbell et al., 2002). To determine the annual number of hawksbill egg clutches laid and reproductive success in the Pearl Cays we conducted beach surveys during each reproductive season from 1999 to 2002. To address threats to the survival of the Pearl Cays hawksbill population we initiated a conservation project in 2000, in collaboration with several local communities, to protect nesting hawksbills and their eggs. We also conducted nocturnal beach patrols to encounter nesting females to study their nesting ecology.

METHODS

Surveys. — During the hawksbill nesting season from 1999 to 2002 we conducted early morning surveys of the Pearl Cays in Nicaragua (Fig. 1). A survey was defined as any time a cay was checked for nesting activity. In 1999, we conducted beach surveys between one and four times per month, whenever logistics and weather permitted, on 11 of the 18 Pearl Cays (Baboon, Bottom Tawira, Columbilla, Crawl, Grape, Lime, Maroon, Top Tawira, Vincent, Water, and Wild Cane). In 2000, nesting beach surveys were conducted daily on four cays (Baboon, Crawl, Grape, and Wild Cane), at least every other day on an additional five cays (Bottom Tawira, Lime, Maroon, Vincent, and Water), and, as often as possible on Black Mangrove and Columbilla. In 2001 and 2002, nesting beach surveys were conducted daily on eight cays (Baboon, Crawl, Grape, Lime, Maroon, Vincent, Water, and Wild Cane), and as often as possible but at least once per week on Botton Tawira and Columbilla. After 2000, surveys were discontinued on Black Mangrove and Top Tawira Cays because little to no nesting occurred. Of the remaining seven Pearl Cays, hawksbill nesting occurs on Askill and Buttonwood, however, these were not surveyed because of their distance from our primary research area. Hawksbill nesting is not known to occur on Crow Cam, Rocky Boar, Savanna, and Seal Cays, probably due to their rocky substrate and lack of appropriate nesting habitat.

Initiation and duration of surveys differed each year. In 1999, periodic surveys were conducted from 14 April to 28 August. In 2000, the first survey was conducted on 27 May

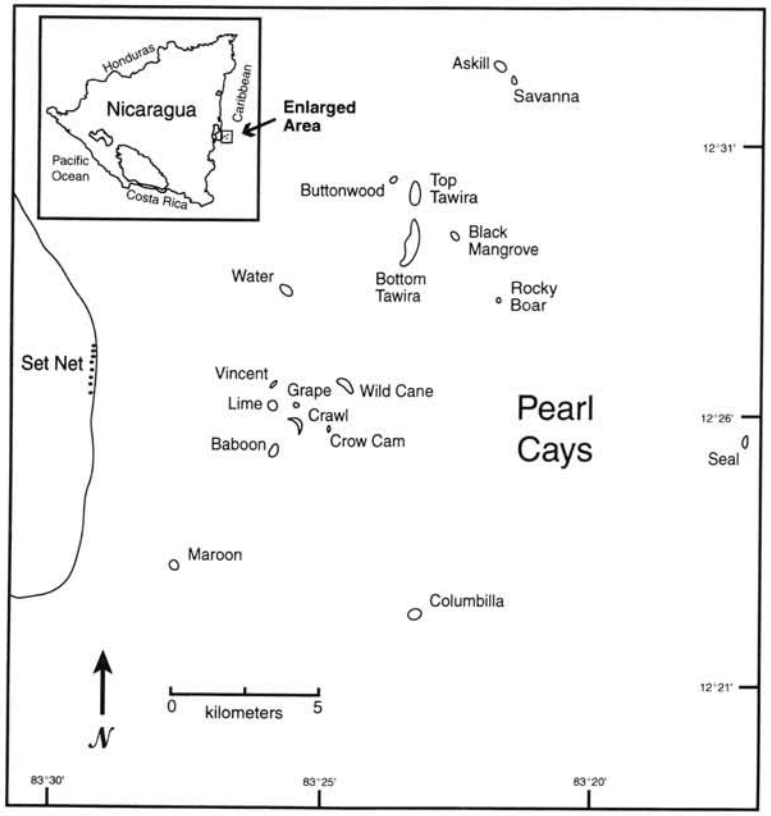

Figure 1. The Pearl Cays, located off the central Caribbean coast of Nicaragua, Central America.

and daily surveys began on 14 June. Beach surveys continued on six of the cays until 4 October. However, beach surveys were interrupted in mid-September 2000 on the other five cays (Baboon, Crawl, Vincent, Water, and Wild Cane) and they were not surveyed again until late October. In 2001, the first survey was conducted at the end of April, and at least weekly until daily surveys began on 10 June. Daily surveys continued until 2 October when they were suspended due to concern for the safety of team members. The cays were again surveyed periodically between 24 November and 18 December 2001 when nest excavations were conducted. In 2002, the first survey was conducted at the end of May and periodically throughout June on Bottom Tawira, Columbilla, and Maroon Cays. Private guards on the remaining cays provided information on nesting activity in June until the daily surveys began on 3 July and continued until 15 October 2002. Nesting beach surveys were also conducted periodically in October, November, and December 2002, and January 2003 when nest excavations were conducted.

During each survey the amount and type of emergence and number of clutches left *in situ*, relocated, poached, or destroyed and cause, when it could be determined, were recorded for each cay. Emergence types were based on Mortimer and Bresson (1999) and included: "LAID" when eggs were deposited, "Did Not Lay (DNL)" when some digging of the nest cavity occurred but no eggs were deposited, and "Half Moon (HM)" when a track was present but no digging occurred. Any clutch encountered for the first time was either left *in situ* or relocated to a nearby site (within 6 m) on the same beach. For clutches left *in situ*, the track and nest site were smoothed-over attempting to camouflage the area. Sand excavated during construction of nest cavities for relocated clutches was placed on a plastic sheet and care was taken not to crush or disturb ground vegetation. The original nest cavity of relocated clutches was left open to give the appearance the clutch had already been poached.

Protection Activities. — Prior to the 2000 nesting season we met with nine communities whose fishers use the Pearl Cays area (Awas, Corn Island, Haulover, Kakabila, Marshall Point, Orinoco, Pearl Lagoon, Raitipura, and Set Net). The purpose of the meetings was to present results from the 1999 surveys, provide background information on sea turtle biology, discuss the current status of hawksbills in the area, propose actions to protect nesting hawksbills and their eggs during future nesting seasons, and to obtain the support of the communities to initiate a hawksbill conservation project. Community members in support of the conservation project were asked to sign a petition. A presentation was also made to the government council of the Región Autónoma del Atlántico Sur (RAAS) regarding the status of hawksbill nesting in the Pearl Cays. Prior to, and during the 2001 and 2002 nesting seasons a radio announcement or several three-minute radio spots, produced by community members, were broadcast in three languages, several times a week, informing people that the Pearl Cays Hawksbill Conservation Project was beginning and to remind people to protect hawksbills and their eggs.

Each year, six men were hired from nearby communities to conduct the daily surveys and protection activities. Team members were trained in conducting the surveys, clutch excavation, relocation methods, and data collection (Boulon, 1999; Miller, 1999; Mortimer, 1999). Given the number of cays and beaches where nesting occurs and their lack of proximity to each other, it was not always feasible to relocate clutches within the recommended time frame of 6 to 12 hrs of deposition. Although leaving the clutch *in situ* is the preferred conservation measure to use, based on 1999 results we knew that if egg clutches were not relocated in 2000, with the aim of decreasing the need to relocate egg clutches in subsequent years, they would be poached and therefore, have zero probability of producing hatchlings. Thus, we decided that more clutches would incubate to term by relocating them in 2000, even though not all nests could be moved within the recommended time-frame, and some would not be moved for as much as 24–30 hrs after deposition. In 2001 and 2002, however, private guards were resident on four and six cays, respectively. Thus, with the cooperation of the private guards it was not necessary to relocate clutches on those cays but only on cays where neither guards, the survey team, or Nicaraguan police were resident; or in cases where egg clutches were laid in areas susceptible to high tides, beach erosion, or ants.

Relocated clutches were moved to within 6 m of the original nest site and reburied. To disguise the new location, disturbance to the site of the relocated clutch was minimized. Care was taken in selecting the new nest site so that it was in a similar location as the original site (e.g., distance from high tide, height above the water table, similar coverage of shade and ground vegetation, except when the original site was susceptible to inundation or erosion). For all clutches, a plastic garden label approximately 6 cm in length bearing the nest number and date was placed in each nest cavity to provide confirmation on nest number when excavations were conducted. For *in situ* clutches the label was placed on top of the clutch of eggs and for relocated clutches it was placed in the bottom of the relocated nest cavity. Nest number and date were also placed on flagging tape tied to nearby vegetation. Compass bearing and distance from the flagging tape to the egg clutch were recorded. For relocated clutches, the original nest cavity was left open to suggest to any would-be poachers that the eggs had already been taken. If available, the following data were recorded: date, nest number, cay, general and specific information on clutch location, and egg count.

When daily surveys were initiated, team members received instruction and hands-on training for three to seven days. In addition, data books were reviewed at least weekly and training was on-going as teams were supervised throughout the nesting season.

Subsequent to hatchling emergence, nest contents were evaluated to determine hatching and emergence success. We attempted to find, as soon as possible, all previously marked nests. In 2000 and 2001, however, project activities were interrupted near the end of each nesting season for five and

seven weeks, respectively, due to attempts to impede project activities and/or concern for the safety of project staff. Thus, we were unable to evaluate all post-emerged egg clutches as soon as we would have liked.

To determine hatching and emergence success, clutch contents were removed, separated into categories, and counted. Categories used are adapted from Miller (1999) and include: shells (S, number of empty shells > 50 % intact), undeveloped eggs (UD, unhatched eggs with no obvious embryo), unhatched eggs (UH, unhatched eggs with obvious embryo smaller than full- term), unhatched term eggs (UHT, unhatched eggs with an apparently full-term embryo), unknown state (UNK, stage of embryo development could not be determined due to excessive decomposition or unhatched eggs were not examined), killed by excavation team (KT, unhatched eggs that were accidentally destroyed by the excavation team when attempting to locate the clutch), live hatchlings in the nest (L, encountered in the nest cavity), and dead hatchlings in the nest (D, completely pipped). In addition, signs of nest depredation were recorded. To improve consistency in evaluation of nest contents, all but 13 clutches in 2000 and 29 clutches in 2002 were evaluated by the same individual (CJL). These 42 clutches were evaluated by one individual (WAM) but divided only into four categories (S, UNK, L, and D). Any live hatchlings found in the nest cavity and determined to be unable to emerge by themselves (e.g., inactive, not enough sand to allow them to reach the surface, or no evidence of yolk sac) or in potential danger (i.e., presence of dogs on cay) were removed from the nest cavity and released on the beach between dusk and dawn and observed until they entered the water and were no longer visible. Shell counts were not attempted for nests in which egg shells were in small fragments.

Hatching and emergence success were calculated for all intact egg clutches in which nest contents could be counted, and separately for only those clutches where at least one egg hatched. Hatching success is the percent of hatchlings that hatch out of the egg shells and emergence success is the percent of hatchlings that reach the beach surface. In 2000, some nests were excavated prior to hatchling emergence, thus we assumed any live hatchlings encountered in the nest cavity would probably have emerged on their own and were not included in the "L" category. Hatching and emergence success for clutches where at least one egg hatched were determined separately for egg clutches that were relocated or for those left *in situ*. Hatching and emergence success were adapted from Miller (1999) and were calculated as follows:

$$\text{Hatching success (\%)} = \frac{S}{S + UD + UH + UHT + UNK + KT} \times 100$$

$$\text{Emergence success (\%)} = \frac{S - (L + D)}{S + UD + UH + UHT + UNK + KT} \times 100.$$

Clutch counts made at the time of nest excavation were used because some of the original clutch counts from relocated nests differed from the counts at excavation or because clutch counts were not conducted on clutches left *in situ*. Reasons for the discrepancy between pre- and post-incubation clutch counts are likely due to counting errors and because some eggs are believed to have been removed from the nest subsequent to relocation. For 1999, hatching and emergence success could not be determined because nearly 100% of the clutches laid were poached. From 2000 to 2002, overall hatching and emergence success were calculated by using the sum of each category for the years combined.

RESULTS

Local Support. — During meetings in nine coastal communities we received the support of several hundred people through signed petitions. We also received the unanimous support of the regional government council for the RAAS (Región Autónoma del Atlántico Sur) to conduct nesting beach surveys and conservation activities for hawksbills on the Pearl Cays. Because the regional council meetings were broadcast live on radio throughout the region many people were informed about the status of hawksbill nesting, threats to their survival, our proposed conservation activities, and the council's unanimous support. In addition, people were informed about the permanent closed season for killing hawksbill turtles and their eggs established in 1999 by the government, Ministerio del Ambiente y los Recursos Naturales (MARENA, Ministerial Resolutions 007-99 and 023-99).

Nesting Activity. — A summary of the beach surveys and hawksbill nesting activity are presented in Table 1. For 1999, the number of surveys conducted and emergences recorded are much lower than for subsequent years of the project because surveys were conducted only one to four times each month and concluded prior to completion of nesting activity. In addition, the majority (93.2%, $n = 110$) of emergences were inferred to have resulted in egg deposition (LAID), and thus, might have been overestimated and DNL underestimated because poaching occurred prior to our surveys leaving little evidence to confirm if egg deposition occurred. From 2000 to 2002, females made an average of 1.6 emergences for each egg clutch laid resulting in 154

Table 1. Summary of nesting beach surveys and hawksbill nesting activity encountered on the Pearl Cays, Nicaragua, from 1999 to 2002.

	Number (%)			
Survey Period	1999[1] mid-Apr to late-Aug	2000[2] late-May to mid-Nov	2001[2] late-Apr to mid-Dec	2002[2] late-Apr to mid-Jan 03
Cays Surveyed	11	11	10	10
Surveys Conducted	122	755	1081	1010
Emergences[3]	118	271	239	228
LAID	110 (93.2)	154 (56.8)	158 (66.1)	155 (68.0)
DNL	7 (5.9)	81 (29.9)	48 (20.1)	54 (23.7)
HM	1 (0.8)	36 (13.3)	33 (13.8)	19 (8.3)

[1] Surveys were conducted one to four times each month during the specified period.
[2] Surveys were conducted daily throughout the majority of the specified period.
[3] Emergence types were categorized as: LAID = when eggs were deposited, DNL (Did Not Lay) = when some digging of the nest cavity occurred but no eggs were deposited, and HM = when a track was present but no digging occurred, categories from Mortimer and Bresson (1999).

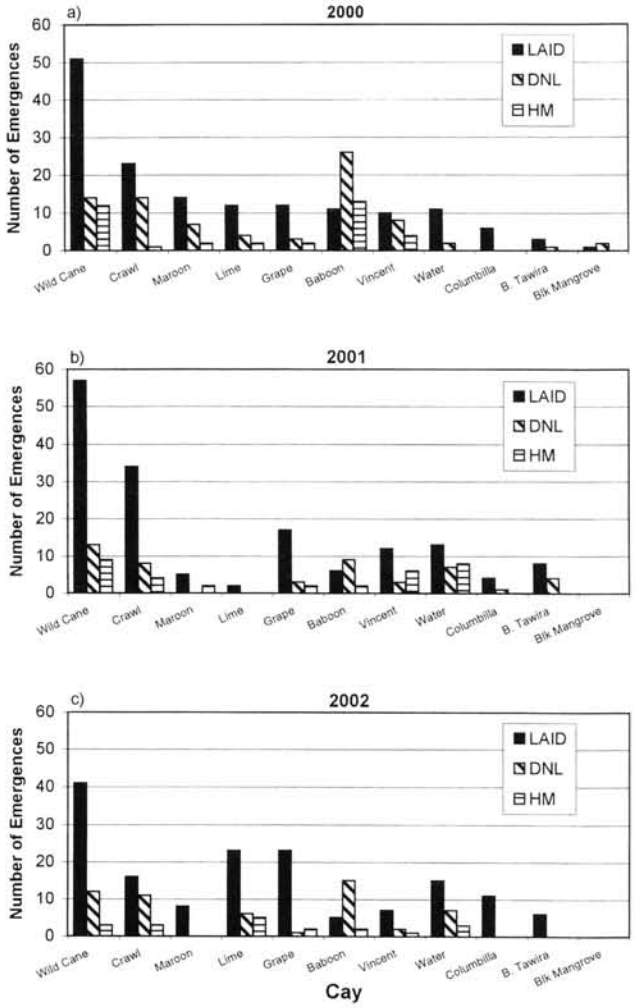

Figure 2. Distribution of hawksbill emergences in the Pearl Cays, Nicaragua on a) 11 cays from May to November 2000, b) 10 cays from April to December 2001, and c) 10 cays from mid-May 2002 to January 2003. LAID = emergence during which eggs were deposited, Did Not Lay (DNL) = emergence during which digging occurred but no eggs found, Half Moon (HM) = emergence in which a track was present but no digging occurred, categories from Mortimer and Bresson (1999). Black Mangrove Cay was not surveyed in 2001 and 2002. B = Bottom and Blk = Black.

to 158 egg clutches each year. On all cays except Baboon and Black Mangrove, emergences were more likely to result in egg deposition (Fig. 2). On Baboon Cay, more emergences resulted in either DNL or HM than in LAID. The number of clutches laid on each cay varied among the years.

In 1999, of the 110 clutches recorded, almost 94% were poached prior to the arrival of the team to conduct the daily surveys (Table 2). We encountered only 7 nests during the 1999 surveys that had not been poached. From 2000 to 2002, 154, 158, and 155 egg clutches were recorded, respectively (Table 2). In 2000, a little over 21% of the egg clutches were poached but in 2001 and 2002, just under 13% were poached each year (Table 2). Dogs destroyed 0.6 to 1.3% of clutches in each of the three years (Table 2).

Seasonal Distribution of Nesting Emergences. — Hawksbill nesting in the Pearl Cays occurs primarily from May to October with peak nesting occurring, for most years, in July (Fig. 3). For all years combined, the majority (67.8%)

Table 2. Condition of hawksbill nests or clutches as initially encountered by project personnel from 1999 to 2002, Pearl Cays, Nicaragua.

	Number of Nests/Clutches (%)			
	1999[a]	2000[b]	2001[b]	2002[b]
Intact outside daily survey period	N/A	14[c] (9.1)	12 (7.6)	18 (11.6)
Poached outside daily survey period	N/A	17 (11.0)	12 (7.6)	13 (8.4)
Destroyed outside daily survey period	N/A	0	0	2 (1.3)
Intact during daily survey period	7 (6.4)	105 (68.2)	125 (79.1)	115 (74.2)
Poached during daily survey period	103 (93.6)	16 (10.4)	8 (5.1)	7 (4.5)
Destroyed during daily survey period	N/A	2 (1.3)	1 (0.6)	0
Total	110 (100)	154 (100)	158 (100)	155 (100)

[a] Nesting beach surveys were conducted 1 to 4 times per month.
[b] Nesting beach surveys were conducted daily on some cays, every other day on other cays, or at least once per week for two cays.
[c] These clutches were laid prior to initiation of daily surveys ($n = 2$), missed during the daily surveys ($n = 7$), or were laid between mid-September and late-October ($n = 5$) when our access to five of the cays was interrupted.

of clutches were laid in July and August, and a smaller but almost equal number of clutches were laid in June and September, 16.4 and 12.0%, respectively. The remaining 3.8% of clutches laid were distributed among April, May, October, and November. An additional 17 clutches were encountered for which a month could not be assigned. Seven of these clutches were laid between June and mid-September, and 10 were laid between mid-September and late-October.

Spatial Distribution of Nesting Emergences. — Spatial distribution of nesting emergences on the cays surveyed varied among the years (Fig. 2). Data from 1999 were not included because we were unable to confirm that a clutch had been laid for each nest cavity encountered. For each of the three years, from 2000 to 2002, the largest number of clutches were laid on Wild Cane Cay, 51, 57, and 41, respectively (Fig. 2). In 2000, a near majority, and in 2001,

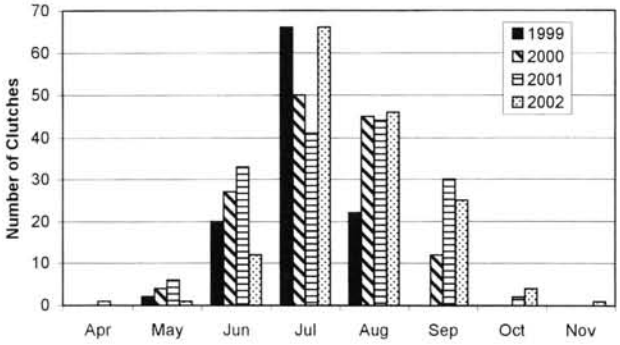

Figure 3. Seasonal distribution of hawksbill clutches laid on 11 of the Pearl Cays, Nicaragua in 1999 (n = 110) and 2000 (n = 138), and on 10 cays in 2001 (n = 157) and 2002 (n = 155). No surveys were conducted after August in 1999, during April 2000, from mid-September to late- October 2000, from October to mid- November 2001, or during April 2002. No nesting occurred in April 1999, and November 2000 and 2001 based on limited surveys.

the majority of clutches were laid on Wild Cane and Crawl Cays combined, 48.0 and 57.6%, respectively. In 2002, the majority (56.1%) of clutches were laid on Wild Cane, Lime, and Grape Cays combined.

Nesting Females. — From 1999 to 2002, at least five nesting females were killed for their scutes and meat by laborers or fishers; one each from Baboon, Bottom Tawira, and Water Cays, and two from Buttonwood Cay (not included in our surveys but one of the Pearl Cays). In 2001 and 2002, on at least 18 separate occasions, females aborted nesting attempts because they were disturbed by dogs that were allowed to roam freely at times during the nesting season on Baboon, Crawl, Lime, Vincent, Water, and Wild Cane Cays. From one to three dogs were present on these cays at any one time. In 2001, on Water Cay, for 7 of 8 consecutive nights a female emerged but abandoned her nesting attempt because she was disturbed by a dog that was abandoned on the cay. In 2002, on Baboon Cay, females were deterred from nesting by a dog at least 10 times during a 1.5 mo period until mid-August when the dog died. On Crawl and Vincent Cays, dogs were left loose on the cays when guards were absent.

From 2000 to 2002, a total of 22 females nesting on six different cays were tagged, measured, and released. Egg deposition was confirmed for 15 of these females. Mean minimum straight-line carapace was 79.8 cm (SD = 3.2, range = 70.5–85.3, n = 21). In 2000, a female we satellilte tagged after laying on Wild Cane Cay returned in 2002 and laid on Grape Cay, a straight-line distance between cays of 1.25 km. However, in 2000, she was released from Grape Cay and not Wild Cane Cay, thus we cannot be sure that we did not influence her change in cays, although it seems unlikely. Another female, originally tagged by the Caribbean Conservation Corporation (CCC) in 1999 at Tortuguero, Costa Rica, renested twice on Grape Cay, Nicaragua, in 2002 at a 15-day interval. Although this female was originally encountered and tagged on the beach at Tortuguero, she did not lay eggs the one time she was observed there (CCC, unpubl. data).

Nest Protection. — The number of clutches poached has decreased since initiation of conservation activities in 2000 (Fig. 4), resulting in a decreased need to relocate clutches from 84.7% in 2000 to 14.8% in 2002. In 1999, prior to project initiation, only seven non-poached nests were encountered during the surveys (Table 2). Two of these were left *in situ* and the beach surface camouflaged to protect against would-be poachers, but both were subsequently poached. The other five clutches were relocated in proximity to the original nest site, but two of these were subsequently poached. Thus, only 3 of the 110 clutches laid in 1999 incubated to term and 97.3% were poached (Figs. 4 and 5).

In 2000, of the 154 clutches recorded for the season, 102 (66.2%) were left to incubate to term, 46 (29.9%) were poached, and 6 (3.9%) were destroyed, 2 prior to and 4 subsequent to being relocated or camouflaged by the survey teams (Fig. 5). Of the 46 that were poached, 17 were taken outside of the daily survey period (prior to mid-June or after mid- September), and 29 were taken during the daily survey period. These 29 clutches poached during the daily survey period were taken from a total of 130 clutches laid during that time, thus 22.3% of the clutches laid while the surveys were being conducted were poached, and 101 (77.7%) were left to incubate to term. Of the 29 clutches that were poached, 55.2% were taken before the survey team arrived to conduct the survey, this most often occurred on the cays which were not monitored daily. The remaining 13 clutches were poached subsequent to being relocated or camouflaged. Twenty-two of 154 clutches were laid before or after the daily survey period, of these, 17 (77.3%) were poached and 5 (22.7%) were left to incubate to term.

In 2001, of the 158 clutches recorded for the season 114 (72.2%) were left to incubate, 40 (25.3%) were poached, and 4 (2.5%) were destroyed, 1 prior to and 3 subsequent to being relocated or camouflaged by the survey teams (Fig. 5). Of the 40 that were poached, 12 (30.0%) were taken outside of the daily survey period (all prior to 11 June when daily surveys were initiated), and 28 (70.0%) were taken during the daily survey period. These 28 clutches poached during the daily survey period were taken from a total of 135 clutches laid during that time, thus 20.7% of the clutches laid while the surveys were being conducted were poached, and 107 (79.3%) were left to incubate to term. Of the 28 clutches that were poached, 8 (28.6%) were taken from two cays (Bottom Tawira and Water) before the survey team arrived to conduct the survey. Seven of these eight clutches were taken from Bottom Tawira which was not monitored daily and has a permanent presence of local fishers. The remaining 20 (71.4%) clutches were poached subsequent to being relocated or camouflaged from six cays, of which 70.0% were taken from three cays that also had a permanent human presence (Bottom Tawira, Crawl, and Wild Cane). Twenty-four of the 158 clutches were laid outside the daily survey period, of which 50% were left to incubate to term and the remainder were poached.

In 2002, of the 155 clutches recorded for the season, 119 (76.8%) were left to incubate, 32 (20.6%) were poached, and 4 (2.6%) were destroyed, 2 prior to and 2 subsequent to being camouflaged by the survey teams (Fig. 5). Of the 32 that were poached, 13 were taken outside of the daily survey

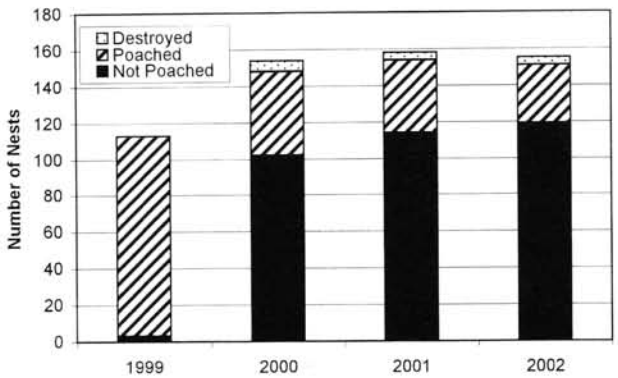

Figure 4. Number of hawksbill clutches not poached, poached, or destroyed as initially encountered by project personnel from 1999 to 2002 on the Pearl Cays, Nicaragua.

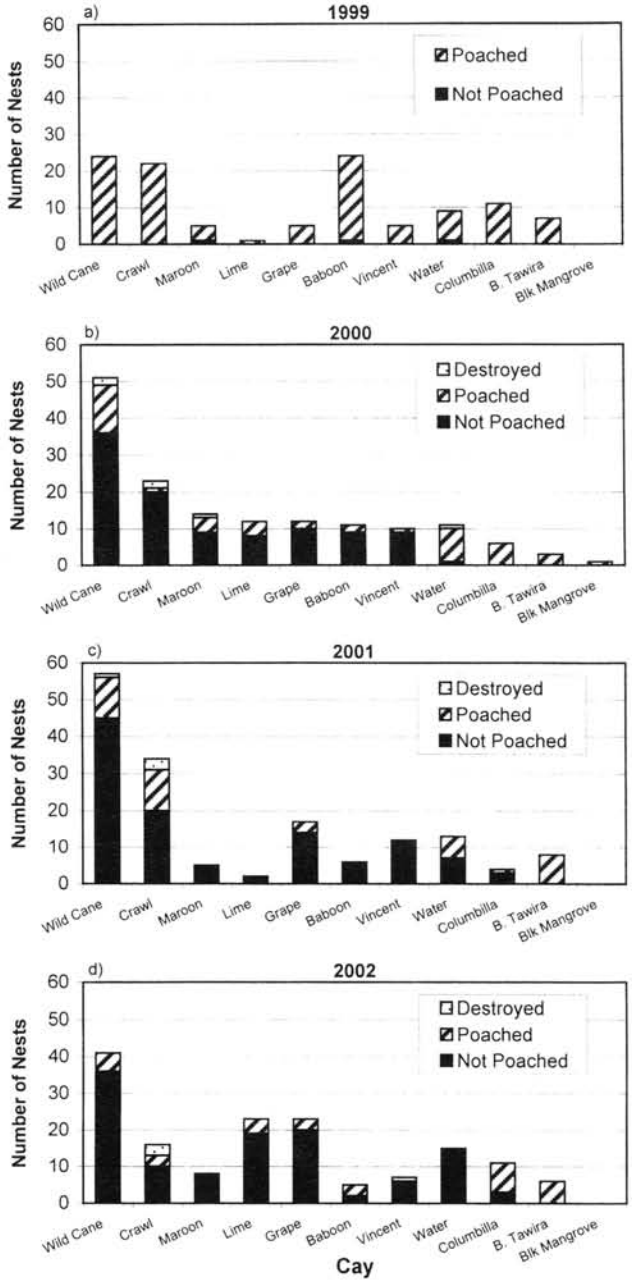

Figure 5. Spatial distribution of hawksbill clutches as initially encountered by project personnel on 11 of the Pearl Cays, Nicaragua in a) 1999 and b) 2000, and on 10 of the cays in c) 2001 and d) 2002. Black Mangrove Cay was not surveyed in 1999, 2001 and 2002, and Top Tawira Cay was not surveyed after 1999. B = Bottom and Blk = Black.

period (prior to early July or after mid-October), and 19 were taken during the daily survey period. These 19 clutches poached during the daily survey period were taken from a total of 122 clutches laid during that time, thus only 15.6% of the clutches laid while the surveys were being conducted were poached, and 103 clutches (84.4%) were left to incubate to term. Of the 19 clutches that were poached, 7 (36.8%) were taken from three cays (Baboon, Bottom Tawira, and Columbilla) before the survey team arrived to conduct the survey. Five of these seven clutches were taken from Columbilla which was not monitored daily, nor does it have

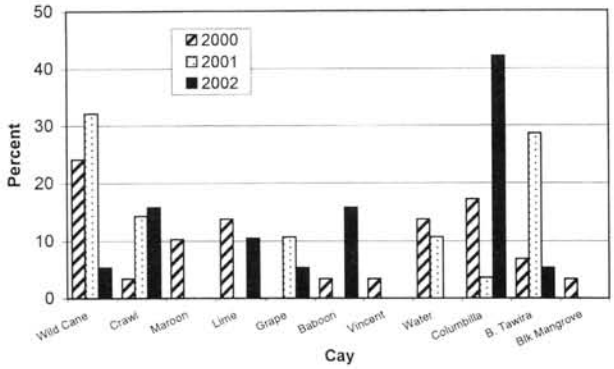

Figure 6. Distribution of the percent of known poached hawksbill clutches laid during the daily survey period on 11 of the Pearl Cays, Nicaragua in 2000 (n = 29 clutches), and on 10 of the cays in 2001 (n = 28 clutches) and 2002 (n = 19 clutches). Black Mangrove Cay was not surveyed in 2001 and 2002. B = Bottom and Blk = Black.

a permanent human presence. The remaining 12 (63.2%) clutches were poached from six cays subsequent to being relocated or camouflaged, of which 66.7% of the clutches were taken from four cays that had a permanent human presence during the hawksbill nesting season (Baboon, Crawl, Lime, and Wild Cane). Thirty-three of the 155 clutches were laid outside of the daily survey period, of these 18 (54.5%) were left to incubate, 13 (39.4%) were poached, and 2 (6.1%) were destroyed by dogs.

Poaching of egg clutches occurred during all four years to varying degrees on the cays monitored (Fig. 5). In 1999, almost all egg clutches were poached from every cay surveyed with only three clutches incubating to term. Although the overall percent of clutches poached has decreased considerably since the initiation of project activities in 2000, the percent of clutches poached from some cays remains high. From 2000 to 2002, all clutches laid on Bottom Tawira and Black Mangrove (only surveyed in 2000), and 71% of those laid on Columbilla were poached. On some cays (Baboon, Crawl, Grape, and Lime) the number of clutches poached has fluctuated, while on other cays (Maroon, Vincent, Water, and Wild Cane) poaching has decreased since the initiation of project activities.

From 2000 to 2002, during only the daily survey period, the percent of clutches poached varied among the cays from 0 to 42% (Fig. 6). The highest percent of clutches poached in 2000 and 2001 occurred on Wild Cane Cay (24.1 and 32.1%, respectively) and in 2002 on Columbilla (42.1%). No clutches were poached during some years from Baboon, Grape, Lime, Maroon, Vincent, and Water Cays (Fig. 6). There were additional clutches each year that were not found by the excavation teams and thus may have also been poached (see Clutch Success). In 2000, an additional 8 clutches (from Baboon, Crawl, Lime, and Wild Cane Cays) were never found. In 2001, an additional 22 clutches (from Columbilla, Crawl, Grape, Vincent, and Wild Cane Cays) were never found. In 2002, an additional 14 clutches (from Columbilla, Crawl, Grape, Water, and Wild Cane Cays) were never found.

Clutch Size. — Mean clutch size was not significantly different among the years from 2000 to 2002 (One-Way

Table 3. Fate of hawksbill clutches encountered intact from 2000 to 2002, Pearl Cays, Nicaragua.

	Number of Clutches (%)			
	2000	2001	2002	Overall
Hatched (at least one egg hatched)	85 (71.4)	67 (48.9)	92 (69.2)	244 (62.7)
Not found after the incubation period	8 (6.7)	22 (16.1)	14 (10.5)	44 (11.3)
Poached	13 (10.9)	19 (13.9)	12 (9.0)	44 (11.3)
Did not hatch - unknown cause	7 (5.9)	11 (8.0)	5 (3.8)	23 (5.9)
Washed away	2 (1.7)	8 (5.8)	6 (4.5)	16 (4.1)
Destroyed	4 (3.4)	3 (2.2)	2 (1.5)	9 (2.3)
Unknown	0	7 (5.1)	2 (1.5)	9 (2.3)
Total	119 (100)	137 (100)	133 (100)	389 (99.9)

ANOVA, $p = 0.113$). For all years combined mean clutch size was 138.4 eggs (SD = 27.9, range = 50–229, $n = 173$). During the three years, 49 yolkless eggs were observed in 21 clutches with a maximum of 17 yolkless eggs in one clutch. Due to the inexperience of some survey team members, however, it is possible that the number of yolkless eggs was greater than reported.

Clutch Success. — For the years from 2000 to 2002 combined, a minimum of 62.7% of the clutches encountered and either relocated or left *in situ* had at least one egg hatch (Table 3). Some clutches were never located by the excavation team, thus additional clutches may have hatched. Clutch success ranged from 48.9 to 71.4%. From 2000 to 2002, overall, 23.6% did not hatch (this includes clutches that were poached, destroyed, washed away, or died from unknown causes), 11.3% of the original clutches were never found again by the excavation team, and the hatch status of 2.3% of the clutches could not be determined (Table 3).

Of the 92 clutches that did not have at least one egg hatch, 47.8% were poached, 25.0% died from unknown causes, 17.4% washed away, and 9.8% were destroyed (Table 3). Forty-four clutches were poached from nine cays, with the highest percent (38.6%) from Wild Cane, followed by Crawl (18.2%) and Lime (13.6%). Less than 10% of the egg clutches were poached from each of the remaining six cays. The majority (56.3%) of the clutches that were washed away were located on Vincent Cay and the remaining 43.7% were distributed among five other cays (Columbilla, Grape, Maroon, Water, and Wild Cane). Of the 9 (2.3%) clutches destroyed, 5 were destroyed on Crawl Cay, 3 on Wild Cane Cay, and 1 on Vincent Cay. At least 4 of these nests were destroyed by dogs (on Crawl Cay), while the cause could not be determined for the other 5 nests, dogs were the most likely predator since they were often allowed to roam free (see Nesting Females).

Forty-four (11.3%) of the previously marked clutches could not be located because the flagging tapes were not found after the incubation period (Table 3). In 2000, five of these egg clutches had been laid on Crawl Cay, where much of the woody vegetation in the primary nesting area was cut down and burned during the nesting season. The other three clutches that were not found were laid on three other cays (Baboon, Lime, and Wild Cane). Also in 2000, on Baboon Cay, a small house was built on the beach during the nesting season in close proximity to one of the relocated clutches that could not be found, possibly having been destroyed during construction of the house. In 2001, the highest percent (16.1%) of clutches could not be found after the incubation period probably due to the intentional removal of flagging tape from six of the cays by a family of foreigners residing on one cay during the nesting season. It is also possible that some or all of the 44 clutches that were not found had been poached.

Hatching and Emergence Success. — Results from nest content evaluations for the 2000 to 2002 seasons are presented in Table 4. Percent eggs hatched, for all egg clutches, ranged from 58.3 to 73.2%. For only those clutches where at least one egg hatched, percent eggs hatched ranged from 68.3 to 77.3%. In 2000, the stage of embryonic death could not be determined (unknown category) for almost 9% of the eggs and increased to almost 15% in both 2001 and 2002 because some unhatched eggs had begun to decompose due to delayed evaluation of nest contents. In 2002, the increase in the percent of the unknown category was in part because whole eggs in 29 clutches were not examined to determine stage at embryonic death. Excluding nest contents for these 29 clutches decreases the unknown category to 11.2% for all clutches and 8.1% for clutches where at least one egg

Table 4. Fate of hawksbill eggs for clutches laid from 2000 to 2002, Pearl Cays, Nicaragua.

	All Clutches Number (%)				At Least One Egg Hatched Number (%)			
	2000 $n = 87$	2001 $n = 69$	2002 $n = 94$	Overall $n = 250$	2000 $n = 79$	2001 $n = 59$	2002 $n = 89$	Overall $n = 227$
Hatched eggs[1]	7511 (64.0)	4908 (58.3)	9750 (73.2)	22,169 (66.2)	7511 (69.6)	4908 (68.3)	9750 (77.3)	22,169 (72.5)
Undeveloped eggs	1482 (12.6)	1594 (18.9)	810 (6.1)	3886 (11.6)	909 (8.4)	852 (11.9)	598 (4.7)	2359 (7.7)
Unhatched eggs	1107 (9.4)	477 (5.7)	609 (4.6)	2193 (6.6)	1017 (9.4)	442 (6.1)	543 (4.3)	2002 (6.5)
Unhatched term embryos	566 (4.8)	180 (2.1)	164 (1.2)	910 (2.7)	392 (3.6)	166 (2.3)	74 (0.6)	632 (2.1)
Killed accidentally	22 (0.2)	3 (0.04)	0	25 (0.1)	8 (0.1)	3 (0.04)	0	11 (0.04)
Unknown	1045 (8.9)	1252 (14.9)	1992 (14.9)	4289 (12.8)	956 (8.9)	817 (11.4)	1641 (13.0)	3414 (11.2)
Total Eggs	11,733 (99.9)	8414 (99.9)	13,32 5 (100)	33,472 (100)	10,793 (100))	7188 (100)	12,606 (99.9)	30,587 (100)

[1]One count of clutch contents was based on the number of hatchlings emerged because the egg shells were not intact.

Table 5. Percent hatching and emergence success for hawksbill clutches that were relocated or left *in situ*, where at least one egg hatched, from 2000 to 2002, Pearl Cays, Nicaragua.

	Relocated (number of clutches)				*In Situ* (number of clutches)			
	2000 (65)	2001 (22)	2002 (9)	Overall (96)	2000 (13)	2001 (32)	2002 (81)	Overall (126)
Hatching Success (%)	66.9	69.1	80.0	68.7	80.6	68.4	77.1	75.5
Emergence Success (%)	62.7	68.6	78.9	65.6	80.5	68.0	76.0	74.6

Table 7. Percent hatching and emergence success for all hawksbill clutches and for those clutches where at least one egg hatched, from 2000 to 2002, Pearl Cays, Nicaragua.

	All Clutches (number of clutches)				At Least One Egg Hatched (number of clutches)			
	2000 (86)	2001 (69)	2002 (96)	Overall (251)	2000 (79)	2001 (59)	2002 (90)	Overall (228)
Hatching Success (%)	64.0	58.3	73.2	66.2	69.6	68.3	77.3	72.5
Emergence Success (%)	60.9	58.0	72.1	64.6	66.2	67.8	76.2	70.7

hatched. In 2000 and 2001, a small percentage (0.2 and 0.04 %, respectively) of the embryos were killed by the excavation team when prematurely checking nest contents prior to hatching (Table 4). No embryos were killed by team members in 2002.

Overall mean hatching success where at least one egg hatched was 68.7% ($n = 96$) for relocated clutches and 75.5% ($n = 126$) for *in situ* clutches (Table 5). Overall mean emergence was 65.6% ($n = 96$) for relocated clutches and 74.6% ($n = 126$) for *in situ* clutches (Table 5). Differences between percent hatched and percent emerged were small for relocated clutches (0.5 to 4.2%) and even smaller for *in situ* clutches (0.1 to 1.1%) (Table 5). Five dead albino embryos were observed in clutches laid on four different cays, four were from 2000 and one was from 2002. During nest excavations, 731 eggs from 32 clutches were encountered full of sand. The shells were intact but were perforated with small, circular holes. Many of these same nest cavities were infested with ants at the time of excavation. Whether or not ants killed the embryos or scavenged the egg contents after the embryos died could not be determined. For all years combined, a total of 547 pipped hatchlings were encountered in the nest cavity, the majority (56.5%) were alive and released (Table 6). The number of hatchlings found alive in the nest cavity has decreased from 283 in 2000 to 8 in 2002. This is probably due to a decrease in the percent of clutches relocated each year and an increase in the amount of time elapsed prior to excavation. The total number of pipped hatchlings found dead in the nest cavity was variable with a range of 14 to 130 hatchlings (Table 6). For all clutches, overall hatching success was 66.2% and emergence success was 64.6% (Table 7). Hatching success ranged from 58.3 to 73.2%, and emergence success ranged from 58.0 to 72.1%. For those clutches that had at least one egg hatch, overall hatching success was 72.5% and emergence success was 70.7% (Table 7). Hatching success ranged from 68.3 to 77.3%, and emergence success ranged from 66.2 to 76.2%. The highest hatching and emergence success occurred in 2002 for all clutches and for those that had at least one egg hatch (Table 7). In 2000, 2001, and 2002 an additional 6, 38, and 12 clutches, respectively, were excavated, however, nest contents were excluded because accurate shell counts could not be made.

Table 6. Status of hatchlings encountered during evaluation of nest contents for hawksbill clutches laid from 2000 to 2002, Pearl Cays, Nicaragua.

	Number (%)			
	2000	2001	2002	Overall
Live in nest and released	283 (75.1)	18 (56.3)	8 (5.8)	309 (56.5)
Dead in nest - unknown cause	86 (22.8)	14 (43.8)	130 (94.2)	230 (42.0)
Depredated by ants	8 (2.1)	0	0	8 (1.5)
Total	377 (100)	32 (100.1)	138 (100)	547 (100)

DISCUSSION

Nesting Activity. — These are the first systematic nesting beach surveys conducted throughout the principal nesting season for hawksbills in the Pearl Cays of Nicaragua. The main nesting season begins in May and continues into October with peak nesting in July and/or August, although hawksbills have been observed nesting in other months of the year, e.g., April, November, and January. Nietschmann (1981) reported similar results for the east coast of Nicaragua for the early 1970s. Temporal distribution of nesting in the Pearl Cays also coincides with reports for other rookeries in the Caribbean (Witzell, 1983; Horrocks, 1992; van Dam, 1997; Moncada et al., 1999; Richardson et al., 1999). Although there has been a change in the distribution of nesting emergences among the cays surveyed during the past three years in the Pearl Cays the most important for hawksbill nesting are Wild Cane, Crawl, Grape, Lime, and Water Cays. In the early 1970s, Nietschmann (1971) reported Top and Bottom Tawira Cays as the most important sites for hawksbill nesting in the Pearl Cays. Today, however, Top Tawira is comprised mainly of mangrove forest with little to no nesting habitat and no nesting activity was recorded on this cay in 1999. Bottom Tawira Cay has accounted for 6% or less of the nesting emergences for each year from 1999 to 2002, and has only a few small areas that may be suitable for nesting. This apparent shift in the principal nesting locations is likely due to a decrease in suitable nesting habitat on the Tawira Cays.

Population Size. — This study provides new information on the current state of the Pearl Cays nesting hawksbill population. Preliminary estimates can be made using data from the 2000 to 2002 nesting seasons and from long-term studies of hawksbill populations elsewhere in the Caribbean

(data from 1999 season is excluded because surveys were conducted weekly and may have undercounted the number of egg clutches laid). Based on a mean number of 2.6 to 4.5 clutches laid per female per season (Richardson et al., 1989; Hillis and Phillips, 1996; Richardson et al., 1999), and assuming the number of clutches laid in this area from 2000 to 2002 is typical, there are an estimated 34 to 61 females nesting each year on the Pearl Cays. Based on a mean remigration interval of 2.5 to 2.7 years (Richardson et al., 1999) the nesting population of hawksbills in the Pearl Cays is estimated at 85 to 165 adult females. Although no population trend data are available, the survival outlook for the population has been dismal for the last several decades. Nietschmann (1971) reported for July 1971 the harvest of approximately 50 adult hawksbills, of which 30 were females, from an area between Pearl Lagoon bar to the Kings Cays. In 1971 and 1972, 90 to 95% of the clutches laid were harvested, although how this was calculated was not provided (Nietschmann, 1981). In 1999, the pattern was the same as in the early 1970s with nearly 100% of the eggs poached from the Pearl Cays. In the past 28 years, annual harvest levels of hawksbills of all size classes from Nicaragua's Caribbean coast have decreased 92% (Lagueux, 1998). This decrease was attributed to a decline in the hawksbill population rather than a decrease in demand for hawksbill products. The continued harvest of all size classes and eggs of hawksbills poses a serious threat to this population.

In the Caribbean, only a few reasonably sized hawksbill nesting populations still exist. The largest known is found on the Yucatán Peninsula, Mexico (Garduño-Andrade, 1999; Garduño-Andrade et al., 1999) where thousands of clutches are laid annually. Mona Island, Puerto Rico, is probably the second largest with 475 and 537 nests recorded in 1997 and 1998, respectively (Diez et al., 1996, 1998), with indications the population has been increasing (Meylan, 1999). Other noteworthy populations include Belize which is reported to have between 200–250 nests/yr (Smith et al., 1992), and on the Doce Leguas Archipelago, Cuba, where 100–300 nests/yr were reported from 1994 to 1997 (Moncada et al., 1999).

In the central-western Caribbean, the population of nesting hawksbills in the Pearl Cays, although not large, is probably one of the largest remaining. In Guatemala, nesting of hawksbills on the Caribbean coast appears low to sparse (Carr et al., 1982; Rosales-Loessener, 1984; Meylan, 1999). In Honduras, hawksbill populations on the Caribbean coast are severely depleted (Carr et al., 1982; Marin, 1984; Cruz and Espinal, cited in Groombridge and Luxmoore, 1989; Meylan, 1999). At Tortuguero, Costa Rica, there has been a continuous decline in the number of hawksbills nesting on the northern 8 km of beach from 1956 to 2002 with fewer than 15 nests per year in the last 26 years, except in 2001 when 22 nests were encountered (Carr et al., 1966; Carr and Stancyk, 1975; Bjorndal et al., 1993; Meylan, 1999; CCC, unpubl. data) and a significant decrease in carapace length of nesting females from 1955 to 1977 has been reported (Bjorndal et al., 1985). At Chiriquí Beach, Panama, the nesting population of hawksbills was once considered to be the largest in the Caribbean (Carr, 1956) but for the past several decades only a small number of females can be found nesting each year (Carr et al., 1982; Arosemena, 1984; Meylan, 1989, 1999).

The current number of hawksbill clutches laid per year in the Pearl Cays is within the range reported from 1987 to 1998 for both Jumby Bay, Antigua (77–154 clutches/yr) and Buck Island, U.S. Virgin Islands (73–135 clutches/yr) where intensive monitoring of nesting beach activity occurs (Hillis, 1994a; Meylan, 1999; Richardson et al., 1999). The overall declining or depleted status of hawksbill populations throughout the Caribbean makes the remnant population in the Pearl Cays important to their overall regional recovery, particularly in the central-western region. Thus, it is important that the protection of females and their eggs continues on the Pearl Cays so that the population can begin to recover from many years of overexploitation. Protection measures also should continue to be evaluated by monitoring annual nesting levels and foraging populations.

Nesting Ecology. — It is not uncommon for nesting hawksbills to emerge more than once before depositing a clutch of eggs. From 2000 to 2002, the ratio of the average number of emergences made to each egg clutch laid in the Pearl Cays was 1.6, similar to ratios reported at other hawksbill nesting locations, such as Buck Island, U.S. Virgin Islands (1.3 emergences/clutch - pre-Hurricane Hugo, Hillis, 1994a), Cousin Island, Seychelles (1.8 emergences/clutch, Mortimer and Bresson, 1999), and Milman Island, Australia (1.3 emergences/clutch, Dobbs et al., 1999). The relationship of average number of emergences to each clutch laid can be an important index used when estimating total number of clutches laid in a season. An increase over time in this ratio may be an indicator of an increase in disturbance of nesting females or a decrease in the quality of nesting habitat. Based on data presented by Hillis (1994a) for Buck Island, U.S. Virgin Islands, we calculated that females emerged on average 1.3 times for every clutch laid prior to Hurricane Hugo and 2.3 times after Hurricane Hugo. Hurricanes can negatively impact nesting beaches by increasing erosion, thereby changing the slope of the berm, decreasing the depth of nesting substrate, destroying vegetation and exposing roots on the upper beach platform, and felling trees (Hillis, 1994a,b; Richardson et al., 1999). Habitat destruction by development can cause similar problems by changing the upper beach platform and layer of ground vegetation which can increase the vulnerability of nesting beaches to erosion. An increase in the emergence to nest ratio means females are expending more energy to successfully lay a clutch of eggs which could result in decreased energy availability for reproductive output and offspring development. Also, the more often females emerge to nest increases their exposure to natural and human predators, and has the potential to increase mortality rates of nesting females.

Mean clutch size (138.4 eggs) for hawksbills nesting in the Pearl Cays from 2000 to 2002 was similar to those reported for other populations in the Caribbean (Horrocks, 1992; Hillis, 1994a; Hillis and Phillips, 1996; Moncada et

al., 1999; Richardson et al., 1999). The occurrence of yolkless eggs has been reported from several locations around the world at low incidence (Witzell, 1983; Hillis and Phillips, 1996; Dobbs et al., 1999) and thus their occurrence and incidence in clutches laid in the Pearl Cays does not appear abnormal.

Protection Efforts. — Results from this project have exceeded our expectations in terms of hawksbill conservation and local participation and cooperation. This is the first local community and government supported sea turtle conservation project for the Caribbean coast of Nicaragua. From 2000 to 2002, only five nesting females, to the best of our knowledge, were killed when encountered on nesting beaches in the Pearl Cays and almost 83.3% (389 of 467) of the clutches were encountered by the project teams. Of these, 88.7% were left intact to incubate. In contrast, 53% of the clutches laid in the absence of project activities were poached, and nearly 100% of the clutches laid in previous years, including 1999, were harvested (Nietschmann, 1981; this study). Regardless, the quantity of clutches poached outside the project period of activities has decreased during the three years of the project from 77% in 2000 to 39% in 2002. Even though 76 clutches were poached during the daily survey periods from 2000 to 2002, almost one-half of the clutches (47.4%) were poached from cays that were not surveyed daily. Relocating egg clutches was fairly effective against poaching since only 12.9% were poached after being relocated, although improved concealment of the new nest site is needed. When clutch relocation is necessary, relocation near the original nest site is preferred to relocating clutches to a hatchery because it is the least manipulative and poses the least risk to the embryos and the hatchling imprinting process (Blanck and Sawyer, 1981; Boulon, 1999; Miller, 1999; Mortimer, 1999; Witherington, 1999).

In 2000, hatching success of clutches left *in situ* was 13.7% higher than for relocated clutches. In general, hatching success of relocated clutches is lower than for *in situ* clutches (Boulon et al., 1996; Boulon, 1999). However, in 2001 and 2002, hatching success of relocated eggs was slightly higher than for clutches left *in situ* by 0.7 and 2.9%, respectively. The similarity in hatching success for both relocated and *in situ* clutches could be due to improved care by project personnel in moving the relocated clutches due to experience working on the project in previous seasons. Seventy-one percent of the 2002 field crew have worked all three years of the project. Overall emergence success for *in situ* clutches on the Pearl Cays (74.6%, Table 5) was higher than the emergence success reported for *in situ* clutches in Cuba (69.2%) (Moncada et al., 1999). Emergence success on the Pearl Cays, for all clutches (64.6%) and for those that had at least one egg hatch (70.7%), are both higher than emergence success reported in Brazil, where emergence success ranged from 38 to 63% for *in situ* and relocated clutches combined (Marcovaldi et al., 1999).

The lower hatching success in 2000 for relocated eggs compared to clutches left *in situ* (Table 5) can be attributed, in part, to inexperience and lack of understanding by survey team members of the care needed in handling recently-laid eggs. Another reason for the lower hatch rate was because some clutches probably were moved > 24 hrs after egg deposition. Also, several clutches were destroyed by dogs, lost to beach erosion, and possibly by ant invasion into the nest cavity. Although the overall hatching success for relocated clutches was not as high as for clutches left *in situ*, many more clutches would have been poached based on our experience in 1999 when attempting to only camouflage the original nest site resulted in clutches being subsequently poached. Other researchers have reported similar results from trying to camouflage nest sites from poachers (Sato and Madriasau, 1991). Thus, whenever it is necessary for survey teams to relocate clutches they will need to do so but with greater care and closer to time of egg deposition. There was a decrease in the need to relocate clutches in 2001 and 2002 due in large part to the increased presence of private security on the cays willing to cooperate with protection efforts. In contrast, regular presence of local fishers on some cays (Bottom Tawira and Columbilla) has resulted in high levels of poaching. In either case, this increased presence of humans living on the cays has resulted in new threats to the conservation of hawksbill turtles in the Pearl Cays.

Threats to Conservation Activities and Nesting Population. — Starting in 2000, there has been uncontrolled and unregulated activities on eight (Baboon, Bottom Tawira, Crawl, Grape, Lime, Vincent, Water, and Wild Cane) of the Pearl Cays which threatens this hawksbill nesting population. Within a 12-mo period in 2000, six small to relatively large houses were built on five of the cays. By the end of 2002, 18 structures were built on the eight previously mentioned cays. All of the houses were constructed on hawksbill nesting beaches or in direct view of the beach. During the 2000 nesting season, one house was constructed on the beach among incubating clutches. One nest site within 7 m of the house had a low hatch rate which may be attributed to sand compaction and disturbance to the nest site by construction workers. Another clutch on this same cay was never found, possibly because the house was constructed on top of the nest site. On another cay, sand was excavated from the nesting beach for the production of cement to construct a house. Two fish purchasing stations were established on another cay from which local fishers conduct their fishing activities, construct lobster traps, and have introduced domestic pigs and dogs that are allowed to roam freely on the cay. The absence of appropriate authorities in the area results in a lack of awareness and cooperation of existing regulations by foreigners and nationals which can impede conservation activities. In 2000, access to five of the cays was denied to the survey team by a foreigner for five weeks during the nesting season. In 2001, daily nesting surveys were terminated two weeks prematurely and nest excavations were interrupted for almost two months. Fortunately, in both years the authorities eventually intervened and access was regained to continue conducting research and conservation activities, although poaching occurred and valuable biological information was lost during the interim.

In 2002, although project activities were initiated three weeks late we were accompanied by Nicaragua National Police during all project activities and as a result no activities were suspended or terminated prematurely.

Additional threats to nesting hawksbills, their eggs, and habitat in the Pearl Cays area include the continued take of animals from the foraging grounds and eggs from the beaches; construction of docks, septic tanks, and wells; clearing and burning of ground vegetation and secondary growth and clearing of mangroves; an increased presence of dogs; and an increased incidence of lights from campfires, brush fires, and generators. Potential threats include an increase in sewage and waste that may decrease subsurface water quality on the cays, as well as increase sediment runoff that could degrade nearshore water quality, and an increase in human traffic. Decrease in water quality can severely degrade seagrass beds and coral reef ecosystems which are critical habitat for green and hawksbill turtles, as well as other economically important marine resources. Both of these habitats are located in nearshore waters surrounding most of the beaches of the Pearl Cays. Witherington (1999) and Gibson and Smith (1999) provided excellent reviews of the threats facing sea turtles and their nesting and foraging habitat. Witherington (1999) described how sand mining disrupts vegetation that stabilizes the beach which can exacerbate erosion leading to the elimination of nesting habitat. He recommended that construction should not occur within approximately 50 m of mean high tide. Richardson et al. (1999) reported a decrease in emergence success for hawksbill eggs at Jumby Bay, Antigua, because clutches were more susceptible to storms and poaching due to an increase in clearing of native vegetation and beach development. Protecting and maintaining vegetation on the upper beach platform is not only important for retaining an integral and stable coastline but important for providing quality hawksbill nesting habitat. Female hawksbills prefer to nest under ground vegetation on the upper beach platform (Schroeder and Murphy, 1999). The increase in the number of hatchlings found dead in the nest cavity may be due to an increase in nest temperature due to the clearing of ground vegetation from the upper beach platform on six of the cays. Moncada et al. (1999) suggested that clutches incubating in the open (not under ground vegetation) may have increased mortality due to overheating. Fowler (1979) determined that dogs caused the most damage to incubating green turtle nests at Tortuguero, Costa Rica. Dogs are no longer allowed on the beach in Tortuguero National Park during the nesting season and park guards are authorized to shoot any dogs encountered on the beach (S. Troëng, *pers. comm.*). On the Pearl Cays, dogs allowed to roam freely have deterred females from laying their eggs, resulting in increased energy expenditure and vulnerability to predators (see Nesting Ecology), and have destroyed clutches already laid. The effects of artificial lighting on reducing nesting activity and increasing the mortality of females and hatchlings is well documented (McFarlane, 1963; Philibosian, 1976; Mortimer, 1982; Witherington, 1991, 1992, 1999; Witherington and Bjorndal, 1991; Witherington and Martin, 1996). In general, artificial lights (including campfires, flashlights, and electrically produced light) deter females from the nesting beach, but hatchlings are attracted to artificial light sources as they emerge from the nest cavity, thus increasing their risk of mortality. Witherington and Martin (1996) and Witherington (1999) provided many practical solutions to reducing and eliminating negative impacts of artificial lights on nesting sea turtles and their hatchlings.

In conclusion, we attribute the success of the hawksbill conservation project from 2000 to 2002 to conducting community meetings prior to initiation of the project, direct local participation of community members in nest protection, and the low economic value of hawksbill eggs to local inhabitants. Community meetings and local participation provided an opportunity for the resource users to learn more about this resource and how they could contribute to its recovery, thus increasing their cooperation with the project. The low economic value of hawksbill eggs is probably a result of relatively few nests available each year and thus, no one is dependent on eggs as a source of income. This of course works to the benefit of the conservation project in that there is little economic incentive for people to continue collecting eggs and less resistance to changing their behavior. Although poaching of clutches continues to occur, it has decreased each year since project initiation and we are confident that cooperation by local inhabitants to protect nesting hawksbills and their eggs will continue to improve, as long as conservation efforts continue.

Recommendations and Future Conservation Activities

We recommend the following activities to improve conservation of hawksbills in the Pearl Cays in the coming years.

1. Continue educating local inhabitants about sea turtles in general, and hawksbills in particular, through the development and use of educational materials appropriate to Nicaragua coastal inhabitants.

2. Present weekly and final results of each nesting season through radio broadcasts and in the communities involved in the project.

3. Increase local involvement in the recovery of hawksbill populations by increasing the direct participation of community residents and university students in hawksbill conservation activities.

4. Provide additional experience to project personnel that may improve their skills and knowledge of conservation issues and increase the survival of hawksbill eggs, hatchlings, and adults.

5. Improve nesting and hatching success by initiating beach surveys earlier in the season and conducting them more frequently, and taking more diligent care with eggs, nest site selection, and nest cavity construction.

6. Minimize destruction and degradation of hawksbill nesting and developmental habitat by working closely with

local, regional, and national government agencies to develop regulations and sanctions for non-compliance to mitigate impacts to hawksbills and to establish a protected area in the Pearl Cays that includes both important terrestrial and marine habitats.

7. Increase our knowledge of hawksbill reproductive ecology in the Pearl Cays by conducting studies to determine parameters such as renesting and remigration intervals, nest site fidelity, movements, survival rates, population genetic structure, and morphometrics.

Conservation and management practices in Nicaragua must also include the protection of all hawksbill nesting populations (e.g., at El Cocal) and the foraging aggregations of adults (e.g., area off the north-central coast) and juveniles (e.g., found among many fringing and patch reefs located throughout the shallow area of the Pearl Cays) throughout Nicaragua's coastal waters. Towards this end, in 1999, MARENA established a system of partial and complete closed seasons for fauna in the country. Hawksbills and their products are protected by a year-around closed season. However, no penalties have been established for violators. Rigorous enforcement of the closed season also needs to be implemented. In addition, the sale of hawksbill products, which still occurs in local shops and at national and international airports in Nicaragua, should be strictly prohibited and enforced to lessen the demand for hawksbills. As a signatory of CITES since 1977 (Hemley, 1994), it is particularly disconcerting that Nicaraguan authorities allow the sale of hawksbill products at the international airport where they can be readily exported illegally.

We are encouraged by the support the project has received from the fishers, local communities, and government agencies, but disappointed to have encountered new threats to the nesting population. It is crucial that habitat alteration and degradation be regulated and controlled to minimize their impact on hawksbills and other wildlife. We strongly recommend that a management plan be developed for the Pearl Cays area and a permitting process be established for proposed land-use and water-based activities accompanied by strict enforcement and strong sanctions for violators. All stakeholders, including the ethnic and indigenous communities, local, regional, and central government authorities, scientists, and private citizens need to play active and constructive roles in the development of a management plan.

RESUMEN. – Se muestran resultados de censos en playas de anidación y actividades de protección de huevos de tortuga carey, *Eretmochelys imbricata*, en Cayos Perlas, Nicaragua, de 1999 a 2002. Se registró un total de 154, 158, y 155 nidadas en 2000, 2001, y 2002 respectivamente, entre abril y noviembre, teniendo el pico de anidación en julio. La mayor parte de la actividad de anidación ocurrió en los Cayos Wild Cane, Crawl, Grape, Lime, y Water. Antes de la implementación de las actividades de protección de nidos en 2000, casi el 100% de las nidadas depositadas eran tomadas, así como tantas hembras como eran encontradas en la playa. El tamaño de nidada promedio fue de 138.4 huevos. Durante los tres años, el 44.9% (n = 175) de las nidadas fueron reubicadas para protegerlas contra la depredación humana y el 55.1% (n = 215) fueron dejadas *in situ*. El éxito total de eclosión y emergencia para los nidos en que por lo menos un huevo eclosionó fue de 68.7 y 65.6% para nidadas reubicadas, y 75.5 y 74.6% para nidadas *in situ*, respectivamente. Para aquellas nidadas que tuvieron por lo menos un huevo eclosionado, el éxito global de eclosión y emergencia fue de 72.5 y 70.7%, respectivamente. Para todas las nidadas, el éxito global de eclosión y emergencia fue de 66.2 y 64.6%, respectivamente. La población anidadora de tortuga carey en los Cayos Perlas en Nicaragua es probablemente una de las más grandes que quedan en el Caribe Centro-Occidental. Estimamos que la población de Cayos Perlas tiene entre 85 y 165 hembras anidadoras. Es importante que la protección de hembras y huevos continúe de manera que la población pueda recuperarse de muchos años de sobreexplotación. Las actuales amenazas para las careyes anidadoras, sus huevos y el hábitat en el área de Cayos Perlas incluyen la construcción de casas y muelles, tala y quema de la vegetación en la parte alta de la playa y la tala de manglares, iluminación artificial, un incremento en la presencia de personas y perros, y saqueo de hembras y huevos. Se necesita un plan de manejo para los Cayos Perlas para regular el desarrollo, promover la conservación y disminuir las amenazas para las careyes y su hábitat. El desarrollo de dicho plan debe incluir la participación de todos los involucrados en el problema para asegurar la recuperación de las poblaciones en las áreas de forrajeo y anidación, así como la salud a largo plazo de los recursos naturales en dicha zona.

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LITERATURE CITED

AROSEMENA, D. 1984. The national report for the country of Panama. In: Bacon, P., Berry, F., Bjorndal, K., Hirth, H., Ogren, L., and Weber, M. (Eds.). Proceedings of the Western Atlantic Turtle Symposium. Vol. 3. RSMAS Printing, Miami, FL, pp. 344-348.

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. Biol. Conserv. 34:353-368.

BJORNDAL, K.A., BOLTEN, A.B., AND LAGUEUX, C.J. 1993. Decline of the nesting population of hawksbill turtles at Tortuguero, Costa Rica. Conservation Biol. 7(4):925-927.

BLANCK, C.E. AND SAWYER, R.H. 1981. Hatchery practices in relation to early embryology of the loggerhead sea turtle, *Caretta caretta*, (Linné). J. Exp. Mar. Biol. Ecol. 49:163-177.

BOULON, R.H., JR. 1999. Reducing threats to eggs and hatchlings: *in situ* protection. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 169-174.

BOULON, R.H., JR., DUTTON, P.H., AND MCDONALD, D.L. 1996. Leatherback turtles (*Dermochelys coriacea*) on St. Croix, U.S. Virgin Islands: fifteen years of conservation. Chelonian Conservation and Biology 2(2):141-147.

CAMPBELL, C.L., LAGUEUX, C.J., AND MCCOY, W.A. 2002. Hawksbill (*Eretmochelys imbricata*) nesting on the Pearl Cays of Nicaragua. Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memor. NMFS-SEFSC-477, pp. 246-247.

CARR, A. 1956. The Windward Road: Adventures of a Naturalist on Remote Caribbean Shores. Alfred A. Knopf, Inc., New York, pp. 258.

CARR, A. AND STANCYK, S. 1975. Observations on the ecology and survival outlook of the hawksbill turtle. Biol. Conserv. 8:161-172.

CARR, A., HIRTH, H., AND OGREN, L. 1966. The ecology and migrations of sea turtles, 6. The hawksbill turtle in the Caribbean Sea. Am. Mus. Novitates 2248:1-29.

CARR, A., CARR, M.H., AND MEYLAN, A.B. 1978. The ecology and migrations of sea turtles, 7. The west Caribbean green turtle colony. Bull. Am. Mus. Nat. Hist. 162(1):1-46.

CARR, A., MEYLAN, A., MORTIMER, J., BJORNDAL, K., AND CARR, T. 1982. Surveys of sea turtle populations and habitats in the western Atlantic. NOAA Tech. Memor. NMFS-SEFC-91, pp. 91.

DIEZ, C.E., VAN DAM, R., AND PARÉS, D. 1996. Hawksbill nesting on Mona Island, Puerto Rico: results for 1994. In: Keinath, J.A., Barnard, D.E., Musick, J.A., and Bell, B.A. (Eds.). Proceedings of the Fifteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memor. NMFS-SEFSC-387, pp. 76-77.

DIEZ, C.E., MARSHALL, K.A., AND VAN DAM, R.P. 1998. Assessment of hawksbill nesting activities and nest production on Mona Island, Puerto Rico, 1997. Final Report to U.S. Fish and Wildlife Service, pp. 16.

DOBBS, K.A., MILLER, J.D., LIMPUS, C.J., AND LANDRY, A.M., JR. 1999. Hawksbill turtle, *Eretmochelys imbricata*, nesting at Milman Island, Northern Great Barrier Reef, Australia. Chelonian Conservation and Biology 3(2):344-361.

FOWLER, L.E. 1979. Hatching success and nest predation in the green sea turtle, *Chelonia mydas*, at Tortuguero, Costa Rica. Ecology 60(5):946-955.

GARDUÑO-ANDRADE, M. 1999. Nesting of the hawksbill turtle, *Eretmochelys imbricata*, at Río Lagartos, Yucatán, Mexico, 1990-1997. Chelonian Conservation and Biology 3(2):281-285.

GARDUÑO-ANDRADE, M., GUZMÁN, V., MIRANDA, E., BRISEÑO-DUEÑAS, R., AND ABREU-GROBOIS, F.A. 1999. Increases in hawksbill turtle (*Eretmochelys imbricata*) nestings in the Yucatán Peninsula, Mexico, 1977-1996: data in support of successful conservation? Chelonian Conservation and Biology 3(2):286-295.

GIBSON, J. AND SMITH, G. 1999. Reducing threats to foraging habitats. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 184-187.

GROOMBRIDGE, B. AND LUXMOORE, R. 1989. The Green Turtle and Hawksbill (Reptilia: Cheloniidae): World Status, Exploitation and Trade. Lausanne, Switzerland: CITES, 601 pp.

HEMLEY, G. (Ed.). 1994. International Wildlife Trade: A CITES Sourcebook. Washington, DC: Island Press, 166 pp.

HILLIS, Z. 1994a. The first five years at Buck Island Reef National Monument - the hawksbill story. In: Schroeder, B.A. and Witherington, B.E. (Compilers). Proceedings of the Thirteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memor. NMFS-SEFSC-341, pp. 242-245.

HILLIS, Z. 1994b. The hawksbill turtles of Buck Island Reef National Monument: a shared resource of the Caribbean. In: Bjorndal, K.A., Bolten, A.B., Johnson, D.A., and Eliazar, P.J. (Compilers). Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memor. NMFS-SEFSC-351, pp. 59-61.

HILLIS, Z. AND PHILLIPS, B. 1996. 1994: the year of expanding, standardizing, and planning for the future of hawksbill turtle research at Buck Island Reef NM. In: Keinath, J.A., Barnard, D.E., Musick, J.A., and Bell, B.A. (Compilers). Proceedings of the Fifteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Tech. Memor. NMFS- SEFSC-387, pp. 136-139.

HILTON-TAYLOR, C. (compiler) 2000. 2000 IUCN Red List of Threat-

ened Species. IUCN, Gland, Switzerland, 61 pp.

HORROCKS, J.A. 1992. WIDECAST Sea Turtle Recovery Action Plan for Barbados. Eckert, K.L. (Ed.). CEP Technical Report No. 12. UNEP Caribbean Environment Programme, Kingston, Jamaica, pp. 61.

INCER, J. 1984. The national report for the country of Nicaragua. In: Bacon, P., Berry, F., Bjorndal, K., Hirth, H., Ogren, L., and Weber, M. (Eds.). Proceedings of the Western Atlantic Turtle Symposium. Vol. 3. RSMAS Printing, Miami, FL, pp. 337-343.

KING, F.W. 1982. Historical review of the decline of the green turtle and the hawksbill. In: Bjorndal, K.A. (Ed.). Biology and Conservation of Sea Turtles. Washington, DC: Smithson. Inst. Press, pp. 183-188.

LAGUEUX, C.J. 1998. Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends. Ph.D. Thesis, University of Florida, Gainesville.

MARCOVALDI, M.A., VIEITAS, C.F., AND GODFREY, M.H. 1999. Nesting and conservation management of hawksbill turtles (*Eretmochelys imbricata*) in northern Bahia, Brazil. Chelonian Conservation and Biology 3(2):301-307.

MARIN, M. 1984. The national report for the country of Honduras. In: Bacon, P., Berry, F., Bjorndal, K., Hirth, H., Ogren, L., and Weber, M. (Eds.). Proceedings of the Western Atlantic Turtle Symposium. Vol. 3. RSMAS Printing, Miami, FL, pp. 220-224.

MCFARLANE, R.W. 1963. Disorientation of loggerhead hatchlings by artificial road lighting. Copeia 1963:153.

MEYLAN, A. 1989. Status report of the hawksbill turtle. In: Ogren, L., Berry, F., Bjorndal, K., Kumpf, H., Mast, R., Medina, G., Reichart, H., and Witham, R. (Eds.). Proceedings of the Second Western Atlantic Turtle Symposium. NOAA Tech. Memor. NMFS-SEFC-226, pp. 101-115.

MEYLAN, A.B. 1999. Status of the hawksbill turtle (*Eretmochelys imbricata*) in the Caribbean region. Chelonian Conservation and Biology 3(2):177-184.

MEYLAN, A.B. AND DONNELLY, M. 1999. Status justification for listing the hawksbill turtle (*Eretmohelys imbricata*) as Critically Endangered on the 1996 IUCN Red List of Threatened Animals. Chelonian Conservation and Biology 3(2):200-224.

MILLER, J.D. 1999. Determining clutch size and hatching success. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 124-129.

MONCADA, F., CARRILLO, E., SAENZ, A., AND NODARSE, G. 1999. Reproduction and nesting of the hawksbill turtle, *Eretmochelys imbricata*, in the Cuban Archipelago. Chelonian Conservation and Biology 3(2):257-263.

MORTIMER, J.A. 1982. Factors influencing beach selection by nesting sea turtles. In: Bjorndal, K.A. (Ed.). Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington DC, pp. 45-51.

MORTIMER, J.A. 1999. Reducing threats to eggs and hatchlings: hatcheries. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 175-178.

MORTIMER, J.A. AND BRESSON, R. 1999. Temporal distribution and periodicity in hawksbill turtles (*Eretmochelys imbricata*) nesting at Cousin Island, Republic of Seychelles, 1971-1997. Chelonian Conservation and Biology 3(2):318-325.

NIETSCHMANN, B. 1971. The exploitation of hawksbill turtles, east coast of Nicaragua: results and recommendations from a preliminary study. Report to Departamento de Recursos Naturales Renovables, Ministerio Agricultura Ganadería, Managua, Nicaragua, pp. 12.

NIETSCHMANN, B. 1973. Between Land and Water: The Subsistence Ecology of the Miskito Indians, Eastern Nicaragua. Seminar Press Inc., NY, pp. 279.

NIETSCHMANN, B. 1979. Caribbean Edge: The Coming of Modern Times to Isolated People and Wildlife. The Bobbs-Merrill Co., Inc. NY, pp. 280.

NIETSCHMANN, B. 1981. Following the underwater trail of a vanishing species: the hawksbill turtle. National Geographic Society Research Reports 13:459-480.

PHILIBOSIAN, R. 1976. Disorientation of hawksbill turtle hatchlings, *Eretmochelys imbricata*, by stadium lights. Copeia 1976:824.

RICHARDSON, J.I., CORLISS, L.A., RYDER, C., AND BELL R. 1989. Demographic patterns of Caribbean hawksbills, Jumby Bay, Antigua. In: Eckert, S.A., Eckert, K.L., and Richardson, T.H. (Compilers). Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Tech. Memor. NMFS-SEFC-232, pp. 253-256.

RICHARDSON, J.I., BELL, R., AND RICHARDSON, T.H. 1999. Population ecology and demographic implications drawn from an 11-year study of nesting hawksbill turtles, *Eretmochelys imbricata*, at Jumby Bay, Long Island, Antigua, West Indies. Chelonian Conservation and Biology 3(2):244-250.

ROSALES-LOESSENER, F. 1984. The national report for the country of Guatemala. In: Bacon, P., Berry, F., Bjorndal, K., Hirth, H., Ogren, L., and Weber, M. (Eds.). Proceedings of the Western Atlantic Turtle Symposium. Vol. 3. RSMAS Printing, Miami, FL, pp. 201-208.

SATO, F. AND MADRIASAU, B.B. 1991. Preliminary report on natural reproduction of hawksbill sea turtles in Palau. Mar. Turt. Newsl. 55:12-14.

SCHROEDER, B. AND MURPHY, S. 1999. Population surveys (ground and aerial) on nesting beaches. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 45-55.

SMITH, G.W., ECKERT, K.L., AND GIBSON, J.P. 1992. WIDECAST Sea Turtle Recovery Action Plan for Belize. Eckert, K.L. (Ed.). CEP Technical Report No. 18. UNEP Caribbean Environment Programme, Kingston, Jamaica, pp. 86.

VAN DAM, R.P. 1997. Ecology of hawksbill turtles on feeding grounds at Mona and Monito Islands, Puerto Rico. Ph.D. Thesis, Universiteit van Amsterdam.

WITHERINGTON, B.E. 1991. Orientation of hatchling loggerhead turtles at sea off artificially lighted and dark beaches. J. Exp. Mar. Biol. Ecol. 149:1-11.

WITHERINGTON, B.E. 1992. Behavioral responses of nesting sea turtles to artificial lighting. Herpetologica 48(1):31-39.

WITHERINGTON, B.E. 1999. Reducing threats to nesting habitat. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). Research and Management Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 179-183.

WITHERINGTON, B.E. AND BJORNDAL, K.A. 1991. Influences of artificial lighting on the seaward orientation of hatchling loggerhead turtles *Caretta caretta*. Biol. Conserv. 55:139-149.

WITHERINGTON, B.E. AND MARTIN, R.E. 1996. Understanding, assessing, and resolving light-pollution problems on sea turtle nesting beaches. FMRI Technical Report TR-2. Florida Marine Research Institute, St. Petersburg, FL, pp. 73.

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

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