



Hawksbill hatchling swimming away from the beach, Pearl Cays Wildlife Refuge, Nicaragua. Photo: V. Huertas/WCS

**FINAL REPORT**

**Prepared By**

**Cynthia J. Lagueux, Cathi L. Campbell, Víctor Huertas and William A. McCoy  
Nicaragua Sea Turtle Conservation Program**

**April 2013**

**WILDLIFE CONSERVATION SOCIETY  
Pearl Lagoon, Región Autónoma Atlántico Sur (RAAS)  
Nicaragua**

## **ABSTRACT**

The Wildlife Conservation Society (WCS) monitored nesting activity of hawksbill turtles, *Eretmochelys imbricata*, during the 2012 nesting season in the Pearl Cays Wildlife Refuge (PCWR), Nicaragua. We recorded a total 280 clutches, the second highest number of clutches since conservation activities began in 2000. Over the 13 years of applied conservation measures there has been an average annual increase of 6.4% in the number of clutches laid, however, poaching activities continue to be a reason for concern. In 2012, the poaching rate was 13.2% which was slightly lower than the 15.1% reported in 2011. The greatest number and percent of poaching occurred on cays used primarily by fishers and where *acopios* (lobster buying stations) are established, however, poaching also occurred on all cays where nesting occurred, including cays permanently inhabited by caretakers, such as Baboon, Crawl, Grape, Lime and Water. In 2012, we observed a higher frequency of unregulated sea cucumber diving activities within the PCWR. Although this fishing activity has been observed previously, increased egg poaching activity observed on some cays, e.g., Wild Cane, could be related to the increased presence of sea cucumber divers in 2011 and 2012. Hatching and emergence success for clutches where at least one egg hatched were 69.4% and 68.0%, respectively. We estimated that at least 22,032 hatchlings were produced. The Pearl Cays area is a regionally important nesting site for hawksbills and its feeding grounds are visited by hawksbills from throughout the Caribbean. A juvenile hawksbill we tagged in the Pearl Cays in 2000 was encountered nesting 12 years later and more than 2,400 km away in Guadeloupe (far eastern Caribbean). Despite the importance of protecting hawksbills in the region, between May 2012 and February 2013, fishers in the RAAS and RAAN killed at least five adult hawksbill females, nine juvenile hawksbills and four juvenile loggerheads. Alteration and/or destruction of hawksbill nesting and developmental habitats continued within the boundaries of the PCWR, and unregulated and uncontrolled coastal development was the principal cause. Removal of dune vegetation, maintaining areas denude of vegetation, uncontrolled construction, artificial beach lighting during nesting and hatching seasons, presence of domestic and/or exotic fauna, and pollution resulting from increased human presence in the PCWR are negatively impacting hawksbill reproduction, threatening not only this regionally important hawksbill nesting population but also economically valuable marine resources in the area. To date, little institutional regulation of human activities or law enforcement has been enacted against environmental law violators in the area. More than two years after the declaration of the protected area, protection remains essentially non-existent. We provide recommendations to reduce human threats, including the regulation of development and construction activities, prohibiting the presence of domestic or exotic animals, prohibiting the destruction of beach and dune habitats, promoting the restoration of native beach vegetation, restricting the use of artificial lights during nesting and hatching seasons, and restricting human activities that may be detrimental to hawksbill nesting and reproductive efforts.

## **REPORT SUMMARY**

- a) Since 2000 there has been an overall 73.6% increase in nesting levels. In 2012, we recorded the second highest number of clutches laid since the beginning of our conservation efforts. However, although this encouraging trend continues to indicate an overall increase in nesting activity over the last 13 years, long-term monitoring is necessary to detect real changes in this segment of a sea turtle population.

- b) Egg poaching decreased slightly and killing of adults (especially reproductively mature females) and juveniles, although reduced since prior to initiation of conservation efforts, continues to inhibit population recovery. Due to the high migratory behavior of all sea turtles, enforcement of existing laws and conservation efforts need to be conducted along the entire Caribbean coast of Nicaragua, not just in the Pearl Cays Wildlife Refuge (PCWR); otherwise, hawksbills protected at the nesting beach will continue to be killed when they migrate to their foraging grounds away from the Pearl Cays and are captured by local divers and fishers, which has been confirmed repeatedly by our tag recovery efforts.
- c) Unregulated human activities on the cays continue to challenge conservation efforts and result in negative impacts to the cays, hawksbill reproductive efforts and other marine resources. Preventing removal of native dune vegetation and restricting the presence of domestic or exotic animals, among others, are necessary to mitigate these impacts.
- d) Uncontrolled and unregulated coastal development on the cays poses an immediate and serious threat to the Pearl Cays hawksbill nesting colony and the fragile ecosystems of the area by altering and/or destroying crucial nesting and developmental habitats for this species, as well as other species that contribute to the economy of local human populations and biodiversity of the area (e.g., lobster, shrimp, and finfish).
- e) Donations of live turtles to the Wildlife Conservation Society's program to be tagged and released was again very high this year, and is a positive sign of increased interest in conserving sea turtles in the Pearl Cays area; however more work is needed along the entire coast to attain 100% compliance with existing laws protecting all species of sea turtles.
- f) A juvenile hawksbill we tagged in the Pearl Cays in 2000 was encountered nesting in Guadeloupe in 2012. This information underscores the importance of the PCWR not only as a regionally important nesting site for hawksbills but as an equally important developmental site for hawksbills from throughout the Caribbean. This example clearly demonstrates the need to enforce laws that protect this critically endangered species in Nicaragua, enact strong conservation measures, and the need for regional collaboration.
- g) Activities to raise awareness should continue to be a priority to strengthen and enhance positive attitudes towards conservation of natural resources and increase collaboration with conservation efforts.

## ***INTRODUCTION***

The hawksbill turtle, *Eretmochelys imbricata*, is listed as critically endangered on the IUCN Red List (Mortimer and Donnelly, 2008) and on Appendix I of CITES (UNEP-WCMC, 3 January 2013). On Nicaragua's Caribbean coast, hawksbill turtles nest in the Pearl Cays Wildlife Refuge (PCWR), at El Cocal, and sporadically along the mainland; and all size classes forage in offshore coastal waters (Lagueux et al., 2003; Lagueux and Campbell, 2005; Lagueux et al., 2012; Lagueux and Campbell, unpubl. data). The Pearl Cays rookery is believed to be the largest remaining nesting population in the west-central Caribbean (Lagueux et al., 2003; Campbell et

al., 2012) and as such, has been identified as an important index site within the greater Caribbean region for long-term population monitoring (see <http://www.cites.org/eng/prog/hbt/dialogue2/E-HT2-8.PDF>). The PCWR also provides important foraging and developmental habitats for hawksbill turtles from the Pearl Cays and from across the wider Caribbean, with more than 20 genetic haplotypes identified thus far (Lagueux et al., 2001; Campbell and Lagueux, unpubl. data).

Hawksbill turtles on Nicaragua's Caribbean coast are severely threatened by decades of uncontrolled killing of nesting females and taking of their eggs, and by the opportunistic capture of foraging juveniles and adults (Nietschmann, 1981; Lagueux, 1998; Lagueux et al., 2003; Lagueux and Campbell, 2005; Campbell et al., 2012; Lagueux et al., 2012). In 1999, the Wildlife Conservation Society (WCS) conducted the first systematic surveys of the Pearl Cays and discovered that nearly 100% of the clutches laid were taken by local fishers for personal consumption, and nesting females were often killed for their meat and scutes (Lagueux et al., 2003). In 2000, a community and government approved project to protect nesting females and their eggs was implemented by WCS. In addition, WCS implemented a "Donate A Live Turtle" program that provides an incentive to local fishers and inhabitants on the cays to voluntarily donate live turtles to the project to be tagged and released (including males and juveniles, as well as green, *Chelonia mydas*, and loggerhead, *Caretta caretta*, turtles) that otherwise would be killed for their meat and/or scutes. This volunteer program is conducted throughout the year and not only helps save turtles directly but also provides an opportunity to educate local residents and engage them in sea turtle conservation activities.

Both the Donate a Live Turtle Program and the Pearl Cays Hawksbill Conservation Project have been highly successful at reducing hawksbill mortality in the PCWR. For example, there has been a steady increase in the number of clutches laid, and although variable, a decrease in the number and percent of clutches poached since initiation of the nesting beach project (Lagueux et al., 2003, 2006, 2009, 2011; Campbell et al., 2007, 2008, 2010, 2012). In addition to protecting females and eggs, we have increased efforts to collect data on the reproductive ecology of females to better understand nesting ecology and habitat needs of hawksbills in the Pearl Cays. For example, data collected during the 2005 nesting season indicate that hawksbills have a strong preference for nesting among beach vegetation (Lagueux et al., 2006), a behavior commonly observed at other hawksbill nesting sites (e.g., Horrocks and Scott, 1991; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998; Kamel and Mrosovsky, 2006).

The Pearl Cays hawksbill population is currently facing destruction of its nesting and feeding habitats from increasing human presence in the area. The construction of permanent houses and/or the installation of lobster buying stations, *acopios*, on 12 of 16 cays used by nesting hawksbills are negatively affecting nesting behavior, as well as indirectly affecting reproduction from the destruction and alteration of nesting habitat (e.g., sand mining, clearing of upper beach vegetation, and structures built on nesting areas). Other factors negatively affecting hawksbill reproductive biology and survival include the presence of domestic or exotic animals, and artificial lighting of nesting beaches. In addition, fishing activities in the Pearl Cays such as the lobster, shark and sea cucumber fisheries add to these threats. In addition to the lack of affective management to mitigate negative human affects, these activities increase human presence on the cays and in surrounding waters, which in turn increases pressure on other marine resources. Furthermore, sharks, lobsters, and sea cucumbers play vital roles in marine ecosystems and a

reduction in their populations in the Pearl Cays area will undoubtedly have detrimental effects on other resources and habitat quality.

The conservation of hawksbill turtles in the PCWR is important for both the regional and global recovery of hawksbills. In this 13<sup>th</sup> year of monitoring, conservation and research efforts, the WCS program has made great strides towards the recovery of this important hawksbill nesting and feeding ground, and engaging local stakeholders in better natural resource use management practices. In this report we provide results from our conservation and research efforts during the 2012 nesting season, as well as some of the long-term trends.

## Objectives

Objectives for the 2012 nesting season were to:

1. assist local communities to continue and expand conservation of marine turtles through sustainable turtle watching,
2. quantify nesting activity spatially and temporally on 14 of the cays,
3. document human activities daily on the cays during the nesting season,
4. maintain or increase survival of egg clutches and nesting females,
5. determine hatching and emergence success,
6. continue the collection of reproductive and biometric data on nesting females,
7. continue to monitor beach and nest temperatures to assess trends in incubation temperatures,
8. promote conservation through the media and education,
9. build technical capacity at the local and regional levels,
10. improve local collaboration and increase government involvement in conservation activities,
11. raise awareness of lobster and sea cucumber divers at lobster purchasing stations, *acopios*, and discourage the killing of marine turtles, particularly hawksbills, and
12. provide tangible incentives to local fishers to donate live marine turtles of any species for tag and release.

## Study Area

The Pearl Cays are located from 3 to 22 km east of the mainland, off the central Caribbean coast of Nicaragua (Figure 1), and encompass an area of approximately 700 km<sup>2</sup>. The study area is comprised of 14 of the 22 Pearl Cays; they are Baboon, Black Mangrove, Bottom Tawira, Buttonwood, Columbilla, Crawl, Grape, Lime, Maroon, Vincent, Water and Wild Cane, and two additional cays that have only recently had nesting activity, Maria Crow Cam (nesting activity first observed in 2009) and Seal (nesting activity first reported in 2007). Cays range in size from 0.04 ha to 18.4 ha; although the size of the cay is not necessarily related to the amount of available nesting habitat (Table 1). Although rare, hawksbill nesting also occurs in the northern Pearl Cays on Askill and Little Savanna; however, these cays were not included in the regularly surveyed area because of their distance from our primary study area and infrequency of nesting, e.g., no nesting activity has been reported on either cay since 2007. No nesting occurs on Top Tawira, Esperanza, Savanna, Walter, and two unnamed cays due to a lack of appropriate nesting habitat. Cays where no nesting occurs are comprised primarily of mangroves and/or coral rubble along their shorelines.

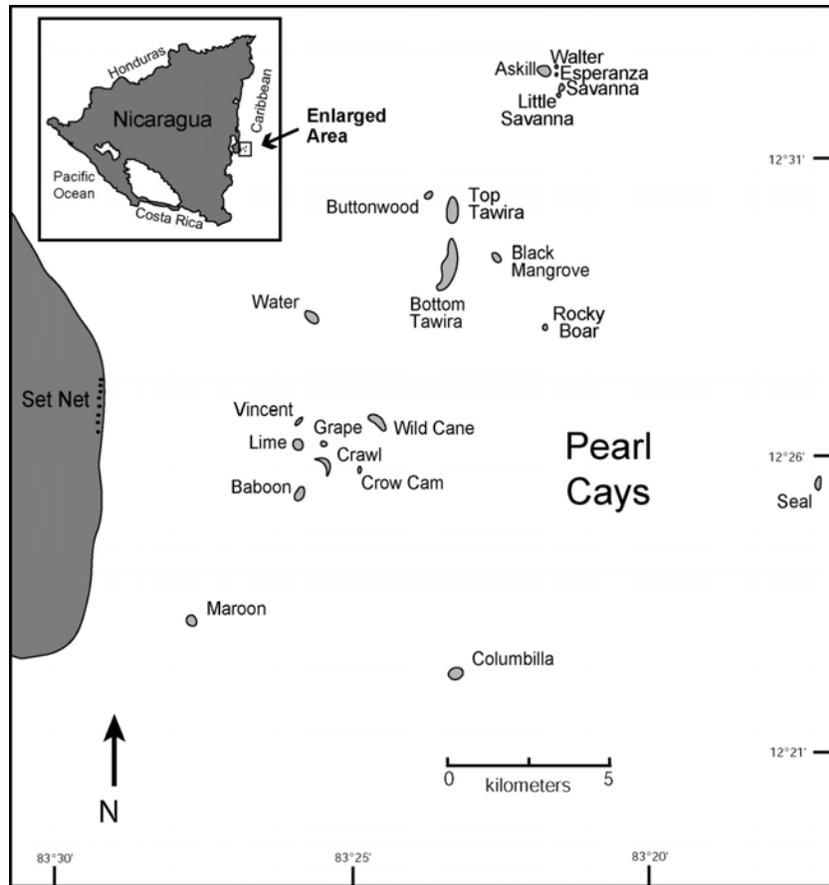


Figure 1. Map of the Pearl Cays, Nicaragua.

Table 1. Area and cumulative nesting beach length for each of the cays regularly monitored in the study. Data is based on a mapping survey conducted in October 2009 (Campbell and Lagueux unpubl. data).

Cay	Area (ha)/ Nesting Beach Length (m)	Cay	Area (ha)/ Nesting Beach Length (m)	Cay	Area (ha)/ Nesting Beach Length (m)
Baboon	4.61 / 310	Columbilla	3.02 / 113	Maroon	0.2 / 132
Black Mangrove	0.67 / 7.5	Crawl	1.80 / 590	Vincent	0.04 / 169
Bottom Tawira	18.4 / 310	Grape	0.46 / 120	Water	4.69 / 460
Buttonwood	0.22 / 226	Lime	3.5 / 393	Wild Cane	7.47 / 517

## **METHODS**

### **Nesting Beach Surveys**

During the 2012 nesting season, nesting beach surveys were conducted regularly on 13 of the Pearl Cays, where the majority of hawksbill nesting occurs, and periodically on Askill and Little Savanna cays. No surveys were conducted on Seal Cay because no nesting has been observed there since 2007 and due to its distance from the principal nesting beaches; however, informal

interviews with local fishers who reside on the cay were conducted opportunistically throughout the season regarding nesting activity. Surveys were carried out by one of two, four-person WCS field teams who worked alternate weeks from the end of June to mid-November. Field team members received classroom and field training by experienced WCS personnel in sea turtle biology, nesting ecology, and in conducting nesting beach surveys, data collection, and clutch relocation methods. Of 15 candidates (selected out of 31 applicants) who attended the one-day training workshop, eight (six men and two women) were selected to work with the hawksbill project. As in previous years, selection of team members included a mixture of people from as many local communities as possible, some with previous project experience and some without. Team members included Alex Allen, Harvey Antonio, Kanrod Cayasso, Nelborth Douglas, Claudia Forbes, Kessey Johnson, Roanie Julio, and Dorian McCoy (Photo 1), representing five local communities of the Pearl Lagoon basin (Brown Bank, Haulover, Marshall Point, Orinoco and Pearl Lagoon). William McCoy (Field Supervisor) and Víctor Huertas (Project Coordinator) supervised and assisted with team activities, data collection, and management.

Two Nicaragua National Police accompanied project staff on nesting beach surveys. Police from the Bluefields station were assigned to the project, rotating personnel every two weeks, throughout the survey period. Prior to their shift out to the Pearl Cays, each Police received an orientation which included a presentation about basic sea turtle biology, conservation needs of hawksbill turtles and the Pearl Cays, overview of hawksbill project activities and results, and the living conditions in the temporary base camp.

To determine the onset of the nesting season and to protect clutches laid early in the season, nesting beach surveys were initiated on 27 April, when the first nest of the season was encountered. Subsequently, surveys were conducted approximately every three to five days until 23 June when our temporary base camp was established and surveys were then conducted daily until 20 November. Additional surveys were conducted periodically, between 21 November 2012 and 10 February 2013, when hatched nests were excavated.

During each cay-survey (defined as each time a cay was surveyed), data on nesting and non-nesting emergences were recorded, as well as the status and location (using GPS) of each nest. For the purposes of locating the nest after hatchling emergence, each nest was referenced by marking a nearby object (e.g., a tree) and recording the distance and compass bearing from that object to the nest. Clutches were left *in situ* unless survey teams deemed it necessary to relocate them to protect them from would-be poachers or if nest site conditions were inadequate for incubation, e.g., located too close to the high tide line or in areas prone to inundation. Relocation involved the excavation of a nest chamber of similar depth, at a site usually within a few meters of the original nest site, careful removal of each egg into a bucket, transport of the bucket to the new site, careful placement of the eggs into the new nest chamber, always maintaining the eggs in their original vertical orientation, and covering the eggs. The new site was minimally disturbed and then camouflaged to hide the clutch from would-be poachers.

Several parameters were measured for each nest. Clutch size was based on egg counts of relocated clutches because it is more precise than eggshell counts. Clutch counts with suspected errors were not included in the analysis. Nest depths were measured in the original nest cavity, from the bottom of the nest cavity to the beach surface, at the time clutches were relocated, thus, nest depths were not measured for clutches left *in situ*. Nest depths of artificial cavities were

measured when clutches were excavated post-emergence. Crawl length was measured along the track from the most recent high tide to the center of the nest chamber, as well as to any incomplete nest chambers excavated during an emergence. Nest location in relation to the water's edge was measured in a straight-line, perpendicular to the shore, from the most recent high tide line to the center of the nest cavity, as well as to any incomplete nest chambers excavated during an emergence. Also recorded, was the location of the nest on the cay (i.e., beach, on the dune, or behind the dune) and the general habitat type where the nest was located (i.e., among vegetation, area naturally without vegetation (e.g., open beach or rocky), area where vegetation has been altered or removed, or transition area between beach and vegetation ("border")). In addition, a fresh eggshell was collected from each recently laid clutch for a genetic study.

Poaching activity was categorized as completely or partially poached (some eggs removed but the remainder of the clutch was left to incubate) based on evidence found by the survey team at the nest site or during nest excavations. Completely poached clutches were those nests where all (or almost all) eggs were removed from the nest chamber, and often broken eggshell(s) were present in or around the nest chamber. Partially poached were those clutches where evidence of disturbance to the nest chamber was observed, such as the appearance of eggs missing at the top of the clutch combined with obvious signs of human presence at the nest site, e.g., human footprints in the sand or evidence of poking in the sand with a stick; or when there was a difference of more than 20 eggs between clutch count at excavation and the original clutch count by the teams at relocation. However, before assigning a clutch as partially poached we also took into account the cay, whether or not there was full-time human presence and if they cooperated with the project, and consistency of field staff to accurately make clutch counts. We did not assume that small clutch sizes were partially poached nests; rather we included nests as partially poached only if there was evidence of human disturbance and/or apparently missing eggs from the clutch.

### **Temperature Loggers**

We continued to monitor sand and nest temperatures at mid-clutch depth. Nineteen temperature data loggers were inserted in clutches, and as a control an accompanying temperature logger was placed in the sand one meter from the center of the nest at a depth of 35 cm. In addition, 30 temperature data loggers were buried at 35 cm depth in known nesting areas on seven cays. Loggers in nests were placed approximately in the center of the clutch after temporarily removing 50-75 eggs. Once the logger was in place the removed eggs were returned immediately to the nest chamber and covered. At all times the original vertical orientation of the eggs was maintained. Loggers in nests were only inserted in clutches left to incubate *in situ* and were retrieved from clutches post-emergence, along with the accompanying control logger. The 30 separate temperature loggers were retrieved in December, near the end of the hatching season.

### **Population Size Study**

In 2012, we received permission from the Ministerio del Ambiente y los Recursos Naturales (MARENA) to collect one fresh eggshell from each clutch encountered for a population genetic study. Genetic analysis of the shells will allow us to identify a larger proportion of nesting females, and increase our understanding of the status of the rookery and its nesting ecology by

providing a more accurate estimate of population size, the average renesting and remigration intervals, and nest site fidelity during subsequent nesting events. Better understanding of demographic parameters will aid managers in addressing the needs of this critically endangered species in order to ensure effective protection measures.

### **Nest Excavations**

After 70 days of incubation, or sooner, if evidence of hatchling emergence was observed, nests were excavated to determine hatching and emergence successes. Once the nest cavity was relocated, clutch contents were removed, separated into categories, and counted. In order to ensure consistency in categorizing and counting nest contents, excavations have been conducted by the same individual (CJL) since the beginning of the Hawksbill Project in 2000; however, during the 2012 season both CJL and VH excavated nests, with VH excavating approximately 78% of the nests. Nest content categories were modified from Miller (1999) and include: shells (S, empty shells greater than 50%), undeveloped (UD, unhatched eggs with no obvious embryo), unhatched (UH, unhatched eggs with obvious embryo smaller than full-term), unhatched term (UHT, unhatched eggs with an apparently full-term embryo or pipped hatchling), unhatched with unknown stage of embryo (ENS, unhatched eggs with embryo, but stage could not be determined due to excessive decomposition), unknown state (UNK, it could not be determined whether or not there was an embryo present), live hatchlings in the nest (L, encountered in the nest cavity), and dead hatchlings (D, completely pipped hatchlings encountered in the nest cavity). Clutches that had not hatched when checked were left to complete incubation. If hatchlings were active and already emerging, however, they were counted and released. If the number of hatchlings found in the nest cavity was greater than the shell count at excavation, we used the hatchling count in the hatching and emergence success calculations since it provided a more precise estimate of hatched eggs. Clutches that were partially poached were not included in the calculations of hatching or emergence success because we did not know the extent to which the clutch was disturbed when eggs were removed by poachers.

### **Night Surveys**

To collect reproductive and biometric data on individual females, night surveys were conducted during most of the nesting season (from 25 June to 4 November). Although the WCS teams initiated night surveys on 25 June; a local collaborator inhabiting one of the cays assisted the project by donating a nesting female captured on 27 May. Night surveys consisted of patrolling the beach at least every hour from approximately 1900 h to sunrise in search of nesting females. Field staff were trained by experienced WCS personnel to conduct night patrols and in methods for locating, observing, and capturing nesting females. During encounters with nesting females, care was taken not to disturb the female or the nesting process. Once the female began laying eggs or once the nesting attempt was abandoned, a field staff member approached the turtle to check for flipper tags and determine whether or not biometric data needed to be collected. Individual females were measured only once during the nesting season; therefore, females that had already been encountered by field staff in 2012 were released immediately after being identified. Turtles that were encountered for the first time in 2012 were held on their backs on the upper beach platform until early morning when project supervisors could collect the appropriate data on each individual. Females not bearing tags were tagged with Inconel #681 metal tags (National Band & Tag Co., Newport, Kentucky, U.S.A.) on the trailing edge of each

front flipper, proximal to the first scute. In addition, passive integrated transponder (PIT) tags (12mm, 125kHz or 134kHz) were inserted into the left front flipper of each turtle not previously tagged to minimize loss of data on individuals from metal flipper tag loss. Biometric data were collected from each turtle on her first encounter for the season, and a small tissue sample was obtained for genetic analysis from a rear flipper of females not previously sampled.

### **Incentive Program - Donation of Live Turtles**

Throughout the 2012 nesting season, we continued our incentive program, which encourages fishers and other people on the cays to donate live marine turtles to the project for tag and release (Photo 2), by providing them with a specially designed T-shirt for each turtle donated. Each T-shirt bears the message, “I’m a Volunteer in the Caribbean Nicaragua Sea Turtle Tagging Program”, “I’m Helping Our Turtles, Are You?” in Spanish, English, and Miskitu. To further encourage donations of live turtles we offer a lifejacket for every 15<sup>th</sup> live turtle donated by an individual. Each lifejacket is painted on the back with a turtle silhouette and the slogan, “Donating Turtles Saves Lives, Protect Our Resources, Nicaragua Sea Turtle Conservation Program, Wildlife Conservation Society”.

### **Data Analysis**

A Mann-Whitney U test was used to compare crawl length (CL) and straight-line distance from the high tide line (HTL) in relation to habitat type where clutches were located, and also to compare hatch (HS) and emergence (ES) success for clutches left *in situ* vs. relocated clutches. After completing a preliminary analysis we found that data were skewed and transformations were unsuccessful at reducing skewness in both cases. Hence, we used a non-parametric test that does not assume normality. Data were analyzed using StatPlus (AnalystSoft, 2009). One standard deviation (SD) is provided with means.

## **RESULTS**

### **Nesting Beach Surveys**

From 27 April 2012 to 10 February 2013, a total of 1,528 cay-surveys were conducted on 13 of the Pearl Cays. Based on periodic visits and/or informal interviews no nesting was observed on Askill, Little Savanna or Seal cays. We recorded 145 non-nesting emergences and 280 egg clutches, resulting in a ratio of non-nesting to nesting emergences of 0.52:1. Of the 261 clutches where month laid was known, 50.7% were laid during two months, i.e., July (26.8%) and August (23.9%) (Figure 2).

Wild Cane Cay had the greatest number of clutches with 74 (26.4%) followed by Crawl and Water cays, each with 39 clutches (13.9%), and Lime with 34 clutches (12.1%) (Figure 3). These four cays represented 66.3% of all clutches laid throughout the season. No clutches were recorded on Black Mangrove or Maria Crow Cam cays. Of the 280 clutches laid, 53.2% (149 clutches) were left *in situ*, 6.8% (19 clutches) were left *in situ* but approximately 50% of the eggs were temporarily removed to insert a temperature logger (see Methods section), 36.4% (102 clutches) were relocated to a site near the original nest location, and the remaining ten clutches (3.6%) were completely poached prior to encounter by a survey team.

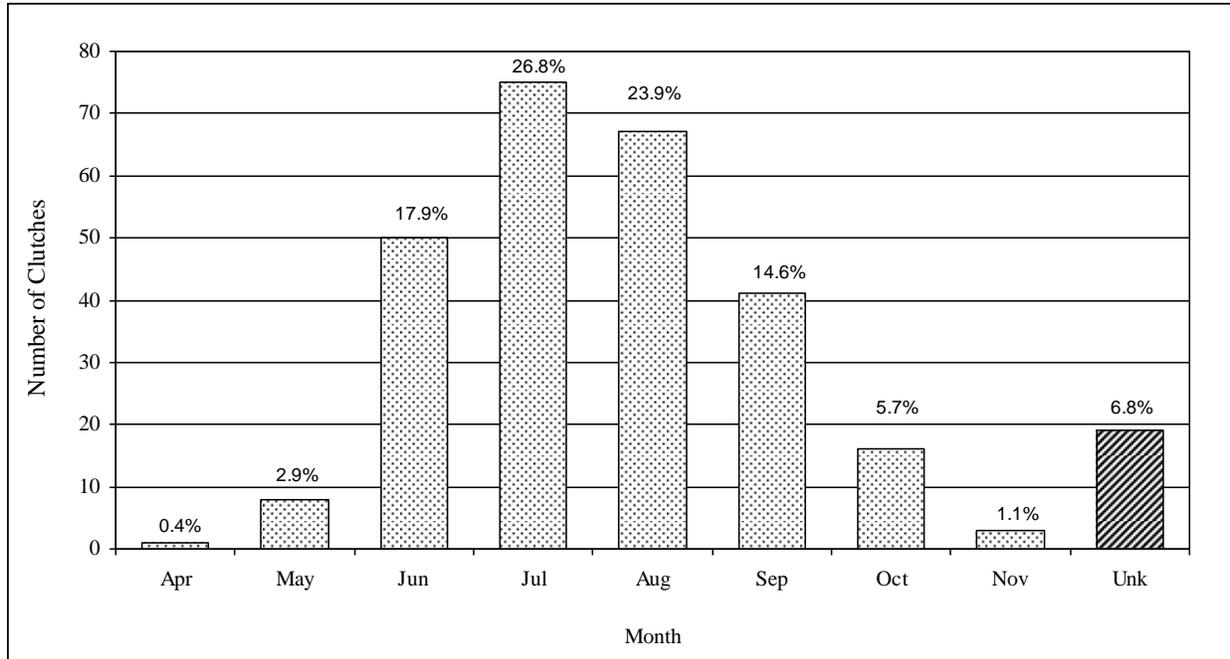


Figure 2. Temporal distribution of hawksbill clutches laid in the Pearl Cays Wildlife Refuge, from April to November 2012 (n=280). Unk = clutches where month laid is unknown.

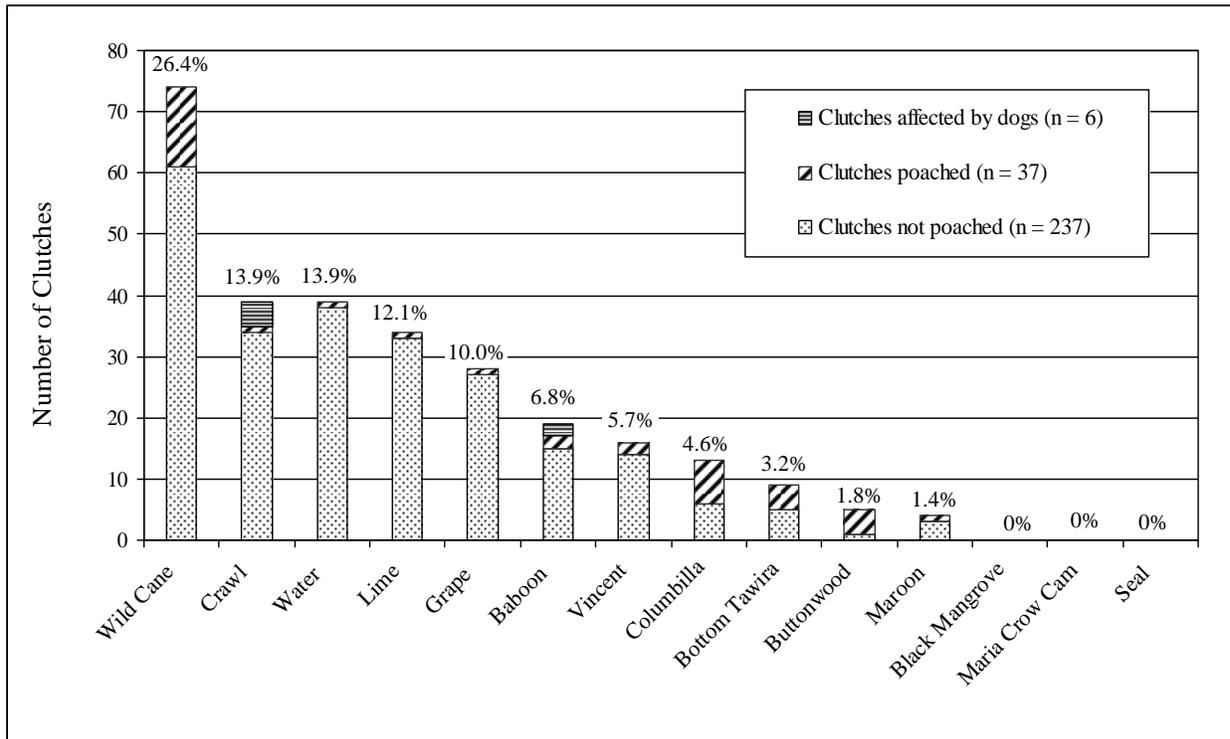


Figure 3. Spatial distribution of hawksbill nests in the Pearl Cays Wildlife Refuge during the 2012 nesting season. Bars show total number of clutches laid by cay separated into clutches not poached, clutches affected by poaching (partially or completely), and clutches dug up by dogs. Numbers above bars indicate percent of total clutches laid for each cay.

Hawksbill nest parameters for 2012 are summarized in Table 2. Mean clutch size, based only on clutches that were relocated was 154.0 eggs (SD=36.9, n=94). Twenty-one yolklless eggs were observed in 15 clutches, ranging from 1 to 5 yolklless eggs in a clutch. Due to the inexperience of some survey team members, however, it is possible that the number of yolklless eggs was underreported. Overall mean crawl length for females that successfully nested was 8.34 m (SD=6.55, range=1.35-47.00, n=237); however, on at least 13 occasions (5.5%) females crawled more than 20 m before laying their clutch. Overall mean straight-line distance from the most recent high tide line to the center of the nest was 4.56 m (SD=3.43, range= 0.50-18.85, n=253).

Table 2. Hawksbill nest parameters in the Pearl Cays for 2012. CL = crawl length measured along the crawl from most recent high tide to the center of the nest, HTL = distance of the nest to the most recent high tide measured perpendicular to the coast. Only 4a and 4b, and 5a and 5b were tested for differences between their distributions. Parameters with the same superscript are significantly different.

Nest Parameters	Mean	Standard Deviation	Range	n
1. Clutch size based on relocated clutches only	154.0	36.9	46-252	94
2. Nest depth – original nest cavity (measured at time of clutch relocation) (cm)	42.0	5.5	30.0-60.0	97
3. Nest depth – artificial nest cavity (measured at excavation) (cm)	37.9	5.3	25.0-50.0	82
4. CL to nest (m) - for all nests combined	8.34	6.55	1.35-47.00	237
<i>a) Unaltered vegetation<sup>1</sup></i>	7.42	5.56	1.95-47.00	161
<i>b) Vegetation altered/removed<sup>1</sup></i>	13.37	9.79	2.60-36.40	32
<i>c) No Vegetation (naturally clear)</i>	8.58	5.40	2.30-25.80	39
<i>d) Border</i>	3.81	2.90	1.35-8.30	5
5. HTL to nest (m) - for all nests combined	4.56	3.43	0.50-18.85	253
<i>a) Unaltered vegetation<sup>2</sup></i>	4.24	3.17	0.50-18.85	174
<i>b) Vegetation altered/removed<sup>2</sup></i>	6.62	4.22	1.85-18.00	34
<i>c) No Vegetation (naturally clear)</i>	4.46	3.32	1.00-13.23	40
<i>d) Border</i>	2.41	2.24	0.75-5.70	5

Crawl lengths (CL) for clutches laid in areas where ground vegetation had been removed (Table 2, 4b) were longer than for clutches that were laid in areas with ground vegetation present (Table 2, 4a) (Mann-Whitney  $U=3,607$ ,  $Z=3.57$ ,  $p=0.0004$ ). Similarly, straight-line distances from the most recent high tide line (HTL) to the center of nests laid in areas where vegetation was removed (Table 2, 5b) were also significantly longer than in areas where ground vegetation was present (Table 2, 5a) (Mann-Whitney  $U=4,193$ ,  $Z=3.85$ ,  $p=0.0001$ ). Because individual females nest more than once during a nesting season and we were not able to identify every nest to individual turtles, there is a possibility of lack of independence of the data, however, the p-values are sufficiently small to suggest that a significant difference would still exist between the groups even if possible lack of independence were accounted for.

A correlation analysis was conducted to evaluate the overall trend in nesting. As in previous years, we found a significant positive relationship between the number of clutches recorded on

the Pearl Cays and the number of years since initiation of the hawksbill project in 2000 ( $r = 0.892$ ,  $p < 0.001$ , Figure 4). Since 2000, there has been an overall 73.6% increase in nesting levels, with an annual average increase of 6.4% from 2000 to 2012. Data prior to 2000 are not available for the entire nesting season.

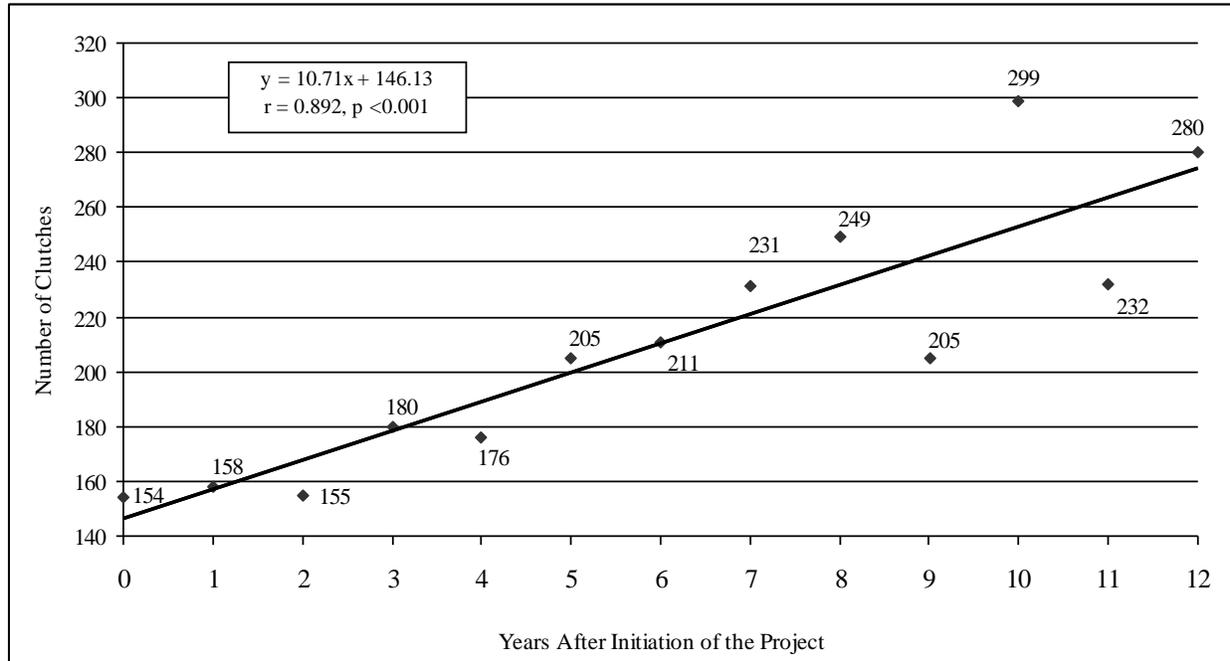


Figure 4. Trend in hawksbill nesting in the Pearl Cays Wildlife Refuge since project initiation in 2000 (year 0) to 2012 (year 12).

### Population Size Study

Survey teams collected 255 fresh eggshells. Samples need to be processed and analyzed. Results of the study will be shared when they become available.

### Nest Excavations

Of the 280 clutches laid, 267 were left to incubate either *in situ* or at a nearby relocation site, the remaining 13 were either completely ( $n=10$ ) or partially ( $n=3$ ) poached prior to being encountered by a WCS survey team. Of the 267 clutches left to incubate, 24 were affected by poaching activities (10 clutches were completely poached and 14 were partially poached). Fourteen of the 16 partially poached clutches had at least one egg hatch. Of the remaining 243 clutches not affected by poaching, 211 hatched, 11 had no eggs hatch, 7 were completely washed-out, 1 was partially washed out and none hatched, 1 was inundated and none hatched, 8 were partially destroyed (six were dug into by dogs, one was partially destroyed by crabs and another by ants), and 4 clutches could not be located post-emergence. In total, 234 clutches had at least one egg hatch.

Overall estimated poaching rate, regardless of when or if an entire clutch was poached, was 13.2% and occurred on all cays where nesting occurred (Table 3, Figure 3). Of the 37 clutches

affected by poaching, the largest proportion (83.8%, n=31) occurred on cays used by fishers or where *acopios* were permanently established (Table 3). In addition, poaching activities also occurred on Baboon, Crawl, Grape, Lime, and Water cays, which were inhabited permanently by caretakers, and some were also temporarily inhabited by sea cucumber divers (see Human Activities section below). Poaching activity was highest on Wild Cane, and when combined with Columbilla, Buttonwood and Bottom Tawira, represents more than 75% of all poaching events.

Table 3. Human presence, and number and percent of clutches affected by poaching in 2012, Pearl Cays.

Cay	Type & Duration of Human Occupants	Total Clutches Laid	Number and (%) Poached (partially or completely)
Wild Cane	Sea cucumber divers & Fishers, Frequent	74	13 (17.6)
Columbilla	Fishers, Frequent	13	7 (53.8)
Buttonwood	Fishers, Permanent <sup>1</sup>	5	4 (80.0)
Bottom Tawira	<i>Acopio</i> (fishers), Permanent	9	4 (44.4)
Vincent	Fishers, Sporadic	16	2 (12.5)
Baboon	Caretakers, Permanent <sup>1</sup>	19	2 (10.5)
Maroon	Fishers, Occasional	4	1 (25.0)
Grape	Caretaker, Permanent	28	1 (3.6)
Lime	Caretakers, Permanent <sup>1</sup>	34	1 (2.9)
Crawl	Caretakers/WCS team <sup>2</sup> , Permanent	39	1 (2.6)
Water	Caretakers, Permanent	39	1 (2.6)

<sup>1</sup> Also inhabited periodically by sea cucumber divers.

<sup>2</sup> WCS field staff were not present permanently, but camped on the cay from 23 June to 20 November.

For all clutches where clutch contents could be evaluated, hatching (HS) and emergence (ES) successes were 65.5% and 64.2% (n=199), respectively. For those clutches where at least one egg hatched, HS and ES were 69.4% and 68.0% (n=187), respectively. For clutches left *in situ*, HS and ES were 69.6% and 68.2% (n=114), respectively; and for relocated clutches HS and ES were 57.4% and 56.0% (n=72). Additionally, HS and ES for nests with temperature loggers inserted were 76.3% and 75.8% (n=13), respectively. HS and ES for relocated clutches were significantly lower than clutches left *in situ* (Mann-Whitney  $U=3,015$ ,  $Z=3.04$ ,  $p=0.002$ ; and Mann-Whitney  $U=3,039.5$ ,  $Z=2.98$ ,  $p=0.003$ , respectively); however, no significant difference was found between clutches left *in situ* and clutches with temperature loggers (Mann-Whitney  $U=772$ ,  $Z=0.25$ ,  $p=0.52$ ; and Mann-Whitney  $U=781.5$ ,  $Z=0.32$ ,  $p=0.75$ , respectively), although this result may be biased due to a low sample size for clutches with temperature loggers. As previously stated, because individual females nest more than once during a nesting season and our teams were not able to identify every nest to individual turtles, there is a possibility of lack of independence of the data, however, the distributions for HS and ES were similar and the p-values for differences between relocated and *in situ* clutches for HS and ES were low, thus, the conclusion of differences between groups is justified.

Based on shell counts, we estimated a minimum 22,032 hatchlings were produced. The exact number of hatchlings cannot be determined because i) four nests were not located at excavation,

ii) clutches washed out post-hatching but prior to excavation, or iii) in some cases, eggshells were too fragmented to count.

### Night Surveys

From 25 June through 4 November, a total 67 cay-night surveys (defined as each night a cay was patrolled) were conducted on seven cays to encounter nesting females. Cays selected for monitoring each night were based on our assessment of the likelihood of encountering a returning nesting female or on cays that had consistently high nesting activity, e.g., Wild Cane. In addition, nesting females were donated to the Project by fishers and other inhabitants from two additional cays. In total, nesting females were encountered on 48 occasions of which 28 (58.3%) successfully nested and 20 (41.7%) were non-nesting emergences. Of the 48 encounters, we sighted 32 individual females and the remaining 16 encounters were resightings of those same females. Of the 32 individual females encountered, 10 showed no evidence of having been previously tagged (referred to as “recruit”), and hence, all 10 were tagged and measured for the first time. The remaining 22 females (referred to as “remigrant”) were previously tagged by project staff in the Pearl Cays prior to 2012 (Table 4).

Table 4. Number of female hawksbills newly tagged and number of remigrants observed each nesting season by year when they were originally tagged in the Pearl Cays Wildlife Refuge, Nicaragua.

Year Tagged	Number of Females Tagged	Number of Remigrants by Year										
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
1999	1 <sup>a</sup>		1						1		1	
2000	4	1	2		1		2		1		1	
2001	1		1		1		1		1		1	
2002	17			9		2	2	5	3	2		3
2003	34				10	2	8	5	4	6	2	3
2004	14					1	5	3	2	7	3	1
2005	13						3	3	3	2	3	2
2006	5							2	1	2	1	2
2007	20								3	10	7	1
2008	29									8	6	4
2009	20										2	2
2010	22											4
2011	20											
2012	10											
Total	210	1	4	9	12	5	21	18	19	37	27	22

<sup>a</sup> Female was originally captured in-water and tagged, and was encountered nesting in the Pearl Cays four years later.

Of the 32 individuals encountered, 20 females (62.5%) were observed nesting once, and 4 (12.5%) were observed nesting twice. The remaining eight females (25.0%) were observed only during non-nesting emergences. Of four females encountered nesting more than once, three

(75.0%) used two different cays, and one female used the same cay for each nesting event. Females had an average renesting interval of 16.3 days (SD=2.5, range=14-19, n=3) however, this is based on a very small sample size. A fourth female was observed renesting after 34 days, however, this observation was not included in the calculations since it is likely that a nesting event for this female was missed due to incomplete coverage of nesting beaches.

Remigration intervals (defined as the # of years prior to 2012 a previously tagged female was last seen in the Pearl Cays) ranged from two to four years with a mean interval of 2.5 yr (SD=0.7, n=22), with 63.6% exhibiting a 2-yr interval, 27.3% a 3-yr interval, and 9.1% exhibiting a 4-yr interval. As in previous years, changes in remigration intervals by individual females were also observed in 2012. For example, two females switched from a three-year to a two-year interval; however, six females did not change their remigration interval whether it had previously been a two or three year interval. Since we began a concerted effort to tag nesting females in 2002, the ratio of remigrants to recruits over the past eleven years has varied (Table 5), and is related to both night patrol effort and the number of turtles in the population that have been previously tagged, and thus increasing the probability of encountering a “remigrant” turtle. As in 2010 and 2011, we observed a higher proportion of remigrants during the 2012 season than prior to the 2010 season.

Table 5. Proportion of remigrants (tagged during a previous nesting season by project staff) to recruits (no evidence of having been previously tagged) encountered each year on nesting beaches in the Pearl Cays Wildlife Refuge.

Year	Recruits Tagged	Remigrants Encountered	Ratio of Remigrants:Recruits	Effort (cay-night surveys)
2002	17	1	0.1:1	73
2003	34	4	0.1:1	93
2004	14	9	0.6:1	165
2005	13	12	0.9:1	169
2006	5	5	1.0:1	65
2007	20	21	1.1:1	284
2008	29	18	0.6:1	369
2009	20	19	1.0:1	407
2010	22	37	1.7:1	468
2011	19	27	1.4:1	512
2012	10	22	2.2:1	67

### Human Activities and Habitat Alteration/Destruction

Human presence on the cays was monitored throughout the nesting season in order to identify and better understand the impacts of human activities on hawksbill nesting, and their foraging and nesting habitats in the Pearl Cays (Tables 6 and 7). Seven of the thirteen cays monitored were permanently inhabited during the 2012 nesting season. Bottom Tawira had the highest density with a mean 10.1 (SD=5.6) people/day on the cay during the nesting season. Approximately 40% of the time Bottom Tawira was occupied by >10 people/day. Crawl Cay followed with a mean 9.1 (SD=5.2) people/day (including caretakers, tourists, and WCS personnel), however, due to diurnal visits by tourists, as many as 60 people were observed on

Crawl Cay at one time. The WCS survey team (6-8 people) camped on Crawl Cay from 23 June to 20 November, when the camp was dismantled and all materials removed. Despite its smaller size, Buttonwood had a comparatively high mean number of inhabitants with 6.1 (SD=5.9) people/day, but as many as 19 people at one time (primarily lobster trap and dive fishers). Columbilla was inhabited by green turtle fishers during at least 50.0% of the hawksbill nesting season. Vincent and Maria Crow Cam cays remained uninhabited throughout the nesting season. In 2012, no caretaker was present on Wild Cane Cay; however, sea cucumber divers installed a camp in an important nesting area on the cay and operated frequently in the area. Sea cucumber divers were also observed several times staying on Baboon and Lime cays during the nesting season. Seal Cay was not surveyed in 2012 but fishers using the cay were interviewed throughout the season regarding the occurrence of nesting activity and none was reported.

Table 6. Summary of human presence by cay in the Pearl Cays Wildlife Refuge where hawksbill nesting occurs. SCD=sea cucumber divers.

Cay <sup>1</sup>	Occupants	Mean # People (SD)	Range	# Observations
Bottom Tawira	Fishers	10.1 (5.6)	1-20	117
Crawl	Caretakers/WCS team/Tourists	9.1 (5.2)	1-60	166
Buttonwood	Fishers/SCD	6.1 (5.9)	0-19	73
Columbilla	Fishers	3.5 (4.9)	0-18	74
Lime	Caretakers/SCD	2.3 (1.3)	0-7	166
Water	Caretakers	2.7 (1.7)	0-10	160
Baboon	Caretakers/SCD	1.8 (1.3)	1-12	163
Grape	Caretaker/Tourists	1.4 (2.2)	0-13	165
Wild Cane	Fishers/SCD	1.2 (3.3)	0-20	165
Maroon	Fishers (occasionally)	0.4 (1.7)	0-12	67
Vincent	Fishers (sporadically)	0	-	163

<sup>1</sup>Black Mangrove, Maria Crow Cam and Seal cays are not included because nesting and/or human presence was occasional and/or sporadic.

Vegetation on the upper beach platform was altered, removed, or maintained cleared on several cays during the nesting season (Table 7). Cutting or clearing mangrove trees and/or ground vegetation, or raking was observed on seven cays (Baboon, Columbilla, Crawl, Grape, Lime, Water and Wild Cane cays). Large areas on Baboon, Crawl, Grape, and Lime cays continue to be periodically raked, maintaining areas devoid of vegetation and preventing the regeneration of native plants that help secure the substrate. Additionally, a nesting area on the southeast point of Wild Cane was cleared of vegetation.

The use of artificial lights at night on the cays was monitored from 23 June to 20 November 2012. During the nesting season, artificial lighting was only observed three nights on Grape Cay, and one night on each of Bottom Tawira and Crawl cays. However, use of artificial lights is probably underreported due to severely reduced night surveys. Nevertheless, it is important to continue monitoring this serious threat to nesting hawksbills and their hatchings, and work to mitigate future lighting on the cays.

Domestic and/or exotic animals were present during the nesting season on 10 of the 13 cays monitored, e.g., dogs, cats, chickens, and rats (*Rattus* sp.) (Table 7). Dogs were observed on 9 of the 13 cays where hawksbill nesting occurs. As many as 6 dogs were present at one time on Bottom Tawira. A total of six clutches were partially destroyed by dogs: four on Crawl Cay and two on Baboon Cay. Occasionally, dogs were brought to Columbilla Cay by green turtle fishers. In addition, one domestic cat resides on Crawl Cay, and one feral cat was observed on Lime Cay. A wild cat (probably a margay, *Leopardus wiedii*, or ocelot, *L. pardalis*) that had been observed on Wild Cane Cay in previous seasons was removed from the cay by a group of fishers and brought to the community of Kahkabila, where it escaped captivity. Although no rats were observed by our teams, they were reported by residents on Water Cay during the 2012 season and their presence has been reported previously on Crawl, Lime, Vincent, Water and Wild Cane cays. No domestic pigs were observed on the cays.

There was very little new construction on the cays during the 2012 nesting season (Table 7), but that may be due, in large part, to the number of permanent structures already present. On some cays, sections of the nesting beaches continue to be used to store lobster traps and/or fishing materials, and/or piled-up dead vegetation, such as coconut husks, fallen branches and driftwood, and later burned. Small nesting areas on Bottom Tawira and Buttonwood cays were, on occasion, covered with lobster traps during the nesting season, rendering the areas unusable by nesting hawksbills. The extraction of sand (sand mining) on nesting beaches was observed on Crawl Cay on one occasion at the beginning of the nesting season.

### **Mortality of Hawksbills and Loggerheads**

Based on tag recoveries and informal reports we estimate that at least five reproductively mature hawksbills from the Pearl Cays rookery, a minimum of nine juvenile hawksbills, and four juvenile loggerheads were killed between 1 May 2012 and 28 February 2013. All these turtles were captured and killed by fishers in the RAAN and RAAS. We believe hawksbill mortality is highly underrepresented because our data is based almost entirely on tag recoveries and because of reports that some fishers inhabiting the northern Pearl Cays continue killing juvenile hawksbills. In 2012, our project field staff visited the northern cays (Askill, Esperanza, Little Savanna, Savanna, and Walter) on 14 occasions (on average one visit every 11 days) during the nesting and hatching seasons to discourage the killing of juvenile hawksbills by lobster and sea cucumber divers, lobster trap and green turtle fishers, and to talk with *acopio* residents about the need for sea turtle conservation, and to continue providing an incentive to donate live turtles for tag and release (see Incentive Program).

### **Incentive Program - Donation of Live Turtles**

We continue to encourage fishers and divers to donate live turtles in exchange for a specially designed T-shirt, or a lifejacket for every 15<sup>th</sup> donation by the same individual (Photo 2). Donated turtles are then tagged and released. Although some fishers continue killing hawksbills and loggerheads, we believe the Incentive Program has resulted in an overall decrease in the mortality of both species, as well as small green turtles in the Pearl Cays. During the 2012 hawksbill nesting season (June to December) there were 95 live sea turtle donations, of which 5 were green turtles, 15 were loggerheads, and 75 were hawksbills. Green turtles were small to large juveniles ranging in size from 26.7 cm to 50.1 cm SCLmin (mean=34.0 cm, SD=9.65, n=5)

Minimum straight carapace length (SCL<sub>min</sub>) was measured as a straight-line from the nuchal scute along the midline to the posterior notch between the supracaudal scutes. Loggerheads were captured in nets by green turtle fishers and were large juvenile to adult in size, ranging from 54.2 cm to 79.2 cm SCL<sub>min</sub> (mean=66.2 cm, SD=6.72, n=14). Of the 75 hawksbills donated to the project, 14 were nesting females captured on a cay by fishers, watchmen, or others residing on the cays. The remaining 61 hawksbills were captured in the water, ranging from 21.2 cm to 73.3 cm SCL<sub>min</sub> (mean=41.9 cm, SD=12.9, n=60). Of these, 53 were captured by lobster and/or sea cucumber divers and 8 were captured in green turtle or gill nets.

Table 7. Summary of human activities and habitat alteration/destruction observed during the 2012 hawksbill nesting season, Pearl Cays Wildlife Refuge.

Cay	Side of Cay Where Most Disturbance Occurred	Human Habitation	Domestic and/or Exotic Animals Present	Use of Artificial Lights <sup>1</sup>	Sand Mining	Erosion of Coastline Observed	Construction Activities &/or Obstruction of Nesting Area	Vegetation Alteration
Baboon	North	Permanent	Dog and chickens	No	No	Northeast, North, Northwest, West	None observed.	Periodically raked north & west sides of cay to maintain large area denude of all vegetation (dune & inland), including nesting area. Burned piles of dead vegetation inland.
Black Mangrove	Entire cay	Periodic	Dogs	No	No	No	None observed.	None observed.
Bottom Tawira	West & South	Permanent	Dogs and chickens	Yes (1 night)	No	No	One small wooden house constructed on west side of cay.	None observed.
Buttonwood	Entire cay	Permanent	Dogs and chickens	No	No	North, west & Southwest	None observed.	None observed.
Columbilla	North & East	Frequent	Dogs (sporadically)	No	No	Northwest, North & Northeast	None observed.	Dune vegetation cut on east & north sides. Vegetation cleared on north side (inland). Dune vegetation burned on west side.
Crawl	West, Center and East	Permanent	Dogs, cat, and chickens	Yes (1 night)	Yes, East	North & East	Minor construction work on large cement building continued for a short period during the nesting season.	Vegetation routinely cut in the center and south. Piled-up dead vegetation on dune was burned on north, east and west sides. Large area on east, center, and west sides of cay periodically raked to maintain area denude of all vegetation.
Grape	Entire cay	Permanent	White-faced capuchin monkey and parrot	Yes (3 nights)	No	All	None observed.	Vegetation cut on north side (dune & inland) and center. Garbage burned on dune on north side. Almost entire cay periodically raked to maintain most of the cay denude of vegetation.
Lime	South	Permanent	Dogs, cat, and chickens	No	No	North, West & South	None observed.	Burned piles of dead vegetation inland on the north side and on the dune on south side. Periodically raked south side and center to maintain area denude of vegetation.
Maria Crow Cam	None	Uninhabited	None observed	No	No	No	None observed.	None observed.
Maroon	East	Occasional	None observed	No	No	All	None observed.	None observed.
Vincent	None	Sporadic	None observed	No	No	All (Severe) <sup>2</sup>	None observed.	None observed, very little vegetation remaining.
Water	West & Center	Permanent	Dogs, chickens, 2 rabbits & rats	No	No	North, West, & South	None observed.	On one occasion cut grass & native dune vegetation on west side.
Wild Cane	North & South Point	Frequent	Dog (sporadically) & Small wild cat (probably a margay or ocelot)	No	No	North, West, South, Southeast Pt.	Large wood framed house on north side was almost entirely dismantled by the onset of the nesting season. Additional materials were taken during the nesting season. Sea cucumber divers established a small camp on the nesting beach on the southeast point.	Mangroves cut on south side, behind nesting beach. Cut & cleared vegetation on southeast point, and periodically raked the area to maintain it denude of all vegetation, including nesting area. Burned piles of dead vegetation on south side

<sup>1</sup>Use of artificial lights is probably underreported this season because night surveys during the 2012 season were highly reduced.<sup>2</sup>Severe coastal erosion due to clearing of vegetation has almost eroded away the entire cay (see Photo 5).

## **National Police Collaboration**

In total, 20 Police collaborated with the project during the 2012 nesting season (Photo 3). Police were effective in acting as deterrents to egg poaching and killing of all sizes of hawksbill turtles. In addition, they provided an authoritative presence on the cays when the WCS team was conducting surveys and intervened to confiscate eggs or hawksbill and loggerhead turtles that would otherwise have been killed.

## **Development of Sustainable Alternative Livelihoods**

In 2012 we initiated an ecotourism pilot project with the Miskitu community of Kahkabila. This pilot project aims to provide green turtle fishers with an alternative source of income through a sustainable, non-extractive use of sea turtles and the marine environment. SOLIMAR was contracted to develop a business plan for conducting hawksbill nesting and reef snorkeling tours. In addition, SOLIMAR provided training to WCS Program Facilitator, Rodolfo Chang, in business development and operations management, and they provided an introductory course on offering tourism services to the community. In addition, participants of the project received classroom and field training on basic sea turtle biology and conservation from WCS Hawksbill Project Coordinator, Víctor Huertas. The course was held in Kahkabila and included a field trip to the cays where participants received training on how to conduct night patrols for nesting sea turtles, with a simulated nesting event.

## **Awareness and Outreach**

During the nesting season, a mid-term progress report on project activities and preliminary results was distributed to 22 Nicaraguan authorities, including: the Ministry of the Environment (Ministerio del Ambiente y los Recursos Naturales, MARENA), National Police, Attorney General for the Environment, Navy, the south autonomous regional government (Consejo Regional, RAAS), Bluefields Indian & Caribbean University (BICU), Pearl Lagoon municipality, Territorial Authority representing 10 indigenous and ethnic communities that use the Pearl Cays, and the U.S. Embassy. Two radio updates were also compiled and broadcast on Caribbean Pearl Radio in Pearl Lagoon during the nesting season. These radio updates were broadcast by local WCS project staff.

Several presentations were given during the 2012 season to increase awareness and promote support for sea turtle conservation on the Caribbean coast of Nicaragua. At the end of the nesting season, presentations on the results of the season, hawksbill biology, and hawksbill conservation issues were given to the WCS field staff, local and regional authorities, and to members of the Nicaragua National Police. Additionally, Víctor Huertas, was interviewed by the Bluefields Radio Station “La Costeñísima”. Mr. Huertas gave a summary of project results for the 2012 nesting season and answered questions regarding the factors that threaten hawksbill survival in the region. The interview ended with a call for increased protection for hawksbill turtles in Nicaragua. Rodolfo Chang participated in a panel regarding the “Environment and Use of Natural Resources of the Pearl Lagoon Basin” organized by FADCANIC (Fundación para la Autonomía y el Desarrollo de la Costa Atlántica de Nicaragua, Foundation for the Autonomy and Development of the Atlantic Coast of Nicaragua). Mr. Chang’s presentation addressed the challenges for achieving sustainable resource use and management, and included two case studies: i) the conservation status of hawksbill turtles in the Pearl Cays Wildlife Refuge, and ii)

the difficulties to manage the green turtle fishery on the Caribbean coast of Nicaragua. The forum was attended by local authorities, students and other community members. Finally, WCS personnel gave a presentation about our conservation activities in Nicaragua to a group of five U.S. university students in Pearl Lagoon.

This spring, Pearl Lagoon hosted the 62nd Annual Atlantic Nicaragua Baseball Series. This event attracts people from the Caribbean coast of Nicaragua, as well as from the Pacific coast, and thus provides an excellent opportunity for outreach to a large public audience. In order to increase sea turtle conservation awareness we commissioned the painting of two murals on the inside of the outfield wall at the Harry and Maggie Taylor Municipal Stadium. The message of one mural was: “Our Resources, Our Culture, Our Future, Let’s Take Care Of It” and the second mural depicted a swimming sea turtle saying “Eat more chicken!” (Photo 4).

## ***DISCUSSION AND CONCLUSIONS***

In 2012, 280 clutches were laid, the second highest number of clutches laid in a single season since 2000, and more than 22,032 hatchlings were produced in the Pearl Cays Wildlife Refuge (PCWR). The high level of nesting is consistent with the positive trend in hawksbill nesting observed in the Pearl Cays since the inception of project activities in 2000. The stronger fluctuations observed since 2008 are probably a result of variable remigration intervals because annual fluctuations in hawksbill nesting levels are not uncommon and have been reported for many sea turtle nesting populations (e.g., Tortuguero, Costa Rica, Bjorndal et al., 1999). These fluctuations are likely due, in large part, to changes in environmental factors, which can influence food quality and availability, in turn affecting reproductive condition of females and ultimately remigration intervals. Continued long-term monitoring is necessary to more accurately assess population trends and effects of management actions.

Hatching success for all clutches was lower than for previous years. Hatch rate for relocated clutches improved slightly compared to the 2011 season, however, it still remains relatively low. Several factors may have contributed to this relatively low hatch rate, however, poor handling of eggs when clutches were relocated was likely the principal cause. Although it is also possible we’re beginning to see the effect of global warming and rising sea levels on the microclimate of the nest cavity. Nevertheless, in future nesting seasons, we will continue to emphasize the need for proper egg handling during training and increase oversight of field teams in an effort to ensure greater hatching success for relocated clutches.

Poaching activity in 2012 was slightly lower than the previous year, and it may be even lower than reported due to possible clutch count errors made by field staff since 66.7% (n=10) of the clutches found “partially” poached had no other sign of poaching other than a clutch count discrepancy greater than 20 eggs between clutch count during relocation and at excavation. Since 2006, when diving for sea cucumbers was first observed in the Pearl Cays (Campbell et al., 2007), the fishery occurred sporadically until 2011, when several groups of fishers were observed operating in the area, suggesting an increase in demand. By April 2012, sea cucumber divers had built a camp on the southeast point of Wild Cane Cay and camped on the cay throughout most of the nesting season. The presence of sea cucumber divers in the protected area may be contributing to the increased poaching of hawksbill clutches observed in 2011 and 2012,

highlighting the need for increased vigilance. In fact, 13 clutches were found poached on Wild Cane during the 2012 season, and this is likely the result of the combination of the presence of divers and the lack of vigilance on that cay. Additionally, poaching still persists on Bottom Tawira, Buttonwood, Columbilla and Maroon cays, which are inhabited either permanently or temporarily by local fishers who are involved in the lobster, green turtle, shark or sea cucumber fisheries. Fishers on these cays continue to be particularly problematic with respect to improving nest protection, however, poaching activities within the PCWR were recorded on all the cays where nesting occurred. We believe the spread of the distribution of poaching in the Pearl Cays is the result of the lack of cooperation by a small number of fishers/divers, and the absence of law enforcement of existing regulations by local authorities; nevertheless, we continue to work with all local fishers to increase their cooperation.

Nesting females continue to exhibit similar patterns of inter- and intra- nesting intervals (primarily 2- or 3-yr and approximately 16 days, respectively), and are consistent with other hawksbill nesting populations in the region (Bjorndal et al., 1985; Hillis and Mackay, 1989; Richardson et al., 1999). In 2012, the ratio of remigrants to recruits was 2.2:1, although this ratio is biased due to the comparatively small amount of night work conducted during the 2012 nesting season. In July 2012, turtle researchers working on the far eastern Caribbean island of Marie-Galante, Guadeloupe encountered a nesting hawksbill turtle with flipper tags H4825 and H4826 (E. Delcroix pers. comm.). This individual had been originally captured in May 2000 as a juvenile in the Pearl Cays and donated to WCS for tag and release by local fisherman Sudlan McCoy. The turtle was measured, tagged and released back in the Pearl Cays. Based on information provided by our colleagues in Guadeloupe, we determined the turtle grew 38.7 cm, an average 3.2 cm per year, during this 12-year period. Thus, this hawksbill was born in Guadeloupe, traveled more than 2,400 km to the Pearl Cays and resided there for at least 12 years until it matured and traveled back to Guadeloupe, its birth place, to reproduce. This example underlines the fact that threats (or conservation) measures undertaken in Nicaragua can affect marine turtle resources in other nations, and vice versa, and clearly demonstrates the need to enforce laws that protect this critically endangered species, enact strong conservation measures, and the need for regional collaboration. Identifying individuals allows us to monitor mortality and recruitment into the reproductive population, evaluate population status, and to identify and mitigate threats. Tagging of individual turtles also provides data on turtle migrations and links to remote foraging and/or nesting grounds.

Killing of hawksbills continues to threaten hawksbill recovery, not only for the Pearl Cays rookery but also for hawksbills that migrate to Nicaragua's coastal waters from throughout the Caribbean. Hawksbills, like other sea turtles, have naturally high mortality rates at earlier stages of their life cycle and higher survival rates as they grow and reach maturity. A study conducted on Caribbean hawksbills found that annual survival of large juveniles and adults were the most important factor for population maintenance (Heppell et al., 1995). Although in Caribbean Nicaragua hawksbills are not targeted by set net fishers, both large juveniles and adults are often captured intentionally by lobster or sea cucumber divers, or incidentally in gill and green turtle nets. Since killing hawksbills is illegal and surveillance is low, most mortality is likely not reported; thus, our report of hawksbill mortality in Caribbean Nicaragua is the minimum number killed, and is likely a much more serious threat to already depleted populations in the region.

The PCWR is a key nesting site for hawksbills in the western Caribbean, and a recent publication suggests that the Pearl Cays rookery's importance as a potential source stock is likely greater

than previously thought (LeRoux et al., 2012). In addition, this area also includes reefs that provide important developmental habitat for foraging juvenile hawksbills from both the Pearl Cays rookery and throughout the Caribbean (e.g., Barbados, Costa Rica, Guadeloupe, U.S. Virgin Islands). International tag recoveries, satellite tracking, and genetic analysis highlight the importance of the Pearl Cays on a regional scale. Thus, actions of Nicaragua's fishers towards hawksbill conservation not only affect Nicaragua's resource, but those of many other nations. Despite declaration of the PCWR in November 2010 enforcement remains essentially non-existent and thus continuing outreach activities to raise awareness and increase collaboration of fishers (including incentives) with conservation activities along the Caribbean coast of Nicaragua will remain a priority of the Pearl Cays Hawksbill Project to aid in the recovery of hawksbills in the region.

Hawksbills prefer to nest within the upper beach vegetation (Horrocks and Scott, 1991; National Marine Fisheries Service and U.S. Fish and Wildlife Service, 1998; Kamel and Mrosovsky, 2006), and a study by Horrocks and Scott (1991) showed that nest sites with vegetation were less compacted than non-vegetated sites. Our data indicates that females crawl significantly longer distances and farther from the high tide line when clutches are laid in areas where vegetation has been altered and/or removed, suggesting that vegetated areas on the dune are the preferred nesting site for nesting hawksbills, and reduced crawling requires less vital energy stores needed for reproduction. Ground vegetation also plays an important role in reducing coastal erosion, however, removal of ground vegetation and sand from nesting beaches continues to occur in the Pearl Cays. Furthermore, large areas on Baboon, Crawl, Grape, and Lime are periodically raked to maintain those areas devoid of vegetation. Continued raking has an ever increasing impact on these small islands by destabilizing beaches, compacting the sand, and increasing erosion, as well as reducing quality nesting habitat for hawksbills.

The impact of vegetation removal from the dune and interior of the cays extends beyond the boundaries of the cays themselves by impacting reefs and seagrass beds in the surrounding waters from increased turbidity and sedimentation. From our observations, beach erosion is a significant threat to the cays (Photo 5), as is the resulting sedimentation in the surrounding waters to seagrass beds and coral reefs, as discussed in Lagueux et al. (2011). Overlaying sediment loads on coral reefs can suppress herbivory by reef fishes and other large grazers (e.g. green turtles and manatees), leading to further degradation of coral reef ecosystems (Bellwood and Fulton, 2008). Reefs in the PCWR continue to show signs of stress derived from increased human-induced beach erosion (Photo 6). Uncontrolled human activities that alter or destroy the Pearl Cays ecosystem is one of the greatest threats to hawksbills in the area. To date, no mitigation measures have been taken to reduce coastal erosion on the cays or nearby coastal areas.

Habitat destruction related to human activities in the PCWR caused the loss of important nesting areas. Since 2003, there has been little to no nesting activity on the north side of Wild Cane Cay (Lagueux and Campbell, unpubl. data). Prior to 2003, when the upper beach and forest were cleared and construction began on a large house and swimming pool, this area accounted for 23% of the nesting activity on this cay (Lagueux and Campbell, unpubl. data). Since 2003, the north side of Wild Cane Cay has been completely devoid of vegetation and no longer provides appropriate conditions for hawksbill nesting. Native plants on the dune reduce erosion, therefore their removal needs to be strictly prohibited, and measures to restore native vegetation should be implemented immediately.

Nest site fidelity to a particular cay (loyalty to nest on the same cay) has been high in previous years, however, our limited data on nesting turtles in 2012 shows lower nest site fidelity. Due to our limited coverage of nesting beaches during 2012, our encounters are too few to draw any conclusions on changes in nest site fidelity. It should also be noted that we normally do not have complete coverage of the cays for night patrols and we pre-select cays where hawksbills are expected to come ashore to lay, thus we are likely biasing our results towards females that do not change cays when they re-nest. Nevertheless, three of the four re-nesters encountered this year nested on different cays. Variability in nest site fidelity by females emphasizes the need for all potential nesting areas to be protected in order to provide the greatest possibility for reproductive success and population recovery.

It is well documented that females are deterred from nesting on beaches illuminated with artificial lights (although it does occur), and that hatchlings are attracted to lights visible from the beach (Witherington and Martin, 2000). When females are deterred from nesting it can result in them nesting in suboptimal habitat or releasing their eggs at sea, reducing their reproductive success and population recovery. In addition, the orientation of hatchlings towards artificial light sources compromises their ability to respond to natural orientation cues, usually resulting in their death by dehydration or depredation. For these reasons, artificial lights visible from nesting beaches should be prohibited during the nesting and hatching season (May through January, from 1900 h to 0500 h), unless using approved “turtle friendly” lighting. In addition, campfires visible on nesting beaches should be prohibited during the same period. Guidelines for “turtle friendly” lighting have been well established and should be used to help resolve artificial lighting problems in the Pearl Cays (see Witherington and Martin, 2000, many commercial options are now available). These guidelines include considerations for positioning and shading of lights, and types of lights that are less detrimental near turtle nesting beaches. Use of artificial lights on or near nesting beaches in the Pearl Cays was almost non-existent during the period included in this report due to reduced human presence on Grape Cay during the reproductive season; however, a project to develop a large tourist resort in the Pearl Cays area will pose a major threat to this critical hawksbill nesting population if this project is approved by the authorities.

WCS strongly supports economic and development opportunities for local communities and local governments through the expansion of new and/or existing activities. Tourism can offer a range of opportunities that provide local employment and improve livelihoods at a local scale. However, if tourism activities are not properly regulated, they have the potential to add pressure to the fragile habitats and natural resources in the area. The goal of the livelihoods project we have initiated in 2012 is to successfully reduce fishing pressure on endangered green turtles by facilitating the development of sustainable ecotourism activities for local green turtle fishers. The main activities of the ecotours are guided encounters with nesting hawksbills and reef snorkeling in the Pearl Cays. This project incorporates the development of a best practices protocol and an awareness program that targets local teachers, fishers, and other community members. We expect this project to become a model for sustainable alternative livelihoods that promote sea turtle conservation in the region.

Since 1999, our incentive program has received 1,013 donations of live turtles from at least 263 individuals. More than half (51.2%) of these donations occurred since 2009. The increase in turtle donations is a result of increased presence and effort by project field staff to raise awareness of local fishers in the more northern Pearl Cays about hawksbill conservation needs. Even though these are positive indicators of increased awareness and cooperation, some fishers

continue to kill hawksbills, and thus, in addition to continuing our efforts to raise the awareness of all fishers, it is also important that the authorities increase their vigilance in order to prevent the ongoing killing of hawksbills, and other protected species. Likewise, a concerted effort to reduce the killing of hawksbill turtles by fishers in the Región Autónoma Atlántico Norte (RAAN) should be implemented and laws protecting hawksbills and their products should be enforced at markets, fairs, tourist destinations, and at the international and national airports to reduce the demand for hawksbill jewelry.

Quality nesting habitat is vital to providing appropriate conditions for critically endangered hawksbills to reproduce and their populations to recover, ensuring their long-term survival and allowing them to fulfill their ecological role in the marine ecosystems of the Caribbean. Without quality nesting habitat reproductive success will diminish, further reducing population size, and the ecosystems in which hawksbills play a vital role will continue to deteriorate. Furthermore, as a result of strong site fidelity to their natal beaches hawksbills, like most sea turtles, will not simply relocate to a different nesting location, and the use of degraded habitats will decrease hatch rates and reduce recruitment into the population, eventually resulting in the loss of individual populations such as the Pearl Cays hawksbill rookery. Thus, restoring and protecting nesting habitat in the PCWR is vital to the survival and recovery of this important rookery, and will improve conditions for other species as well.

The Pearl Cays ecosystem is unique and the cays, seagrass beds, coral reefs, and mangrove forests are highly susceptible to stressors from anthropogenic impacts. Development of any kind in this fragile system should only be done at a level that is ecologically sustainable and does not over burden the natural resources within it. The development project mentioned above raises a great concern. Our data suggests that such high-scale development is incompatible with the preservation of an area that was granted legal protected status by the Nicaragua government through the declaration of the Pearl Cays Wildlife Refuge. However, more than two years after the official creation of the PCWR no management plan or regulations have yet been put into place, and no vigilance or institutional oversight is conducted to enforce existing environmental laws and prosecute violators. The result of this lack of action is counter to the purpose of the protected area and will ensure that the cays and surrounding marine habitat will continue to be degraded, resulting in ecological and economic consequences that are certain to be experienced by local communities and local governments in loss of natural resources and revenues now and in the future. Immediate steps are needed to improve the future outlook of the PCWR and its valuable natural resources, such as the critically endangered hawksbill.

Education and outreach continue to be a priority in our program. Progress reports, radio broadcasts, presentations and visitors to the project provide opportunities to inform community members as well as government officials of project activities and threats occurring during the hawksbill nesting season. Furthermore, training workshops and hands-on experiences provided to community members and government officials through the WCS Pearl Cays Hawksbill Project contribute towards the conservation of hawksbill turtles and their eggs.

While the 2012 hawksbill nesting season was successful, a number of threats continue to jeopardize the recovery of this important hawksbill rookery. It is evident that more work needs to be focused on educating fishers and local community members about the current and potential benefits from using hawksbill turtles in a sustainable, non-consumptive manner, e.g., through ecotourism, as well as the benefits that a healthy hawksbill population provides to marine and

terrestrial habitats. Increased protection of nesting females and clutches have resulted in the significant increase in nesting activity observed on the Pearl Cays in recent years, however, human alteration of the cays and surrounding waters is damaging and reducing critical nesting and foraging habitats; hampering conservation efforts and disrupting the ecological balance of the fragile ecosystems in the Pearl Cays area. Nevertheless, we remain optimistic that as we continue to increase participation in conservation activities, increase awareness and continue educating local inhabitants, and as local communities observe first-hand the advantages of managing use of their natural resources sustainably, positive changes will continue and the Pearl Cays hawksbill population will gradually move towards recovery.

### **Recommendations for the Pearl Cays Wildlife Refuge**

Recommendations continue to be similar as in previous years because the needed measures have not yet been put into place. The cays themselves are decreasing in area, at least in part, due to unsustainable practices. Thus, for local communities to continue to benefit from the resources found in the Pearl Cays area it is imperative that a set of regulations be approved by local and regional authorities, and enforced. Although the following recommendations are not exhaustive, if implemented, they would substantially reduce negative human impacts to the fragile Pearl Cays ecosystem.

- a) Regulations already drafted with local community and government authorities to mitigate human impacts on the Pearl Cays, particularly on hawksbills, should be legally enacted as soon as possible, and mechanisms for enforcement put into practice.
- b) Buildings should not be constructed on or near hawksbill nesting areas; setbacks of at least 20 m from the upper beach (possibly farther depending on the circumstance) for approved structures should be imposed and enforced.
- c) Breakwater walls, cement docks, and other hard structures should not be permitted in the nearshore waters of the cays.
- d) Upper beach areas should be allowed to revegetate with native vegetation and should not be cut or cleared. Non-native plant species such as coconut trees should be removed from the upper beach platform to facilitate the restoration of native vegetation and improve the quality of nesting habitat, and decrease susceptibility of the coastline to erosion.
- e) Artificial lights (including electric lights, campfires, or flashlights without red filters) should be prohibited from illuminating nesting beaches during nesting and hatching seasons, 1900 h to 0500 h from May through January. Lights certified as “turtle friendly” may be used with the appropriate positioning and shields based on accepted guidelines and approval.
- f) Use of generators during the night should be limited during nesting and hatching seasons, and until the potential impact of substrate vibrations produced by generators on nesting hawksbills and clutches incubating can be evaluated.
- g) Domestic or exotic animals should not be permitted on the cays at any time.
- h) Human activity on nesting beaches during nesting and hatching seasons should be controlled. People should only be permitted to observe nesting turtles under the

supervision of experienced, trained, and permitted guides or permitted sea turtle biologists.

- i) Proper sewage systems and waste disposal should be installed on cays where humans are permitted to reside.

## ***ACKNOWLEDGEMENTS***

We would like to thank the survey, nocturnal, and excavation team members (Photo 1): Alex Allen, Harvey Antonio, Kanrod Cayasso, Nelborth Douglas, Claudia Forbes, Kessey Johnson, Roanie Julio, and Dorian McCoy for their dedication and commitment to hawksbill conservation in the Pearl Cays; Telia Narcisso for her efforts to ensure each team had their weekly supply of food, and Rodolfo Chang for valuable assistance throughout the nesting season. We also appreciate the interest and support of local community members of the Pearl Lagoon basin, as well as the Territorial Authority of Ten Indigenous and Afro-Descendant Communities of the Pearl Lagoon Basin (TIADCPLB), Mayor Robert Cuthbert and the Municipal Council of the Pearl Lagoon Municipality, President Vernadine López and the South Atlantic Autonomous Regional Council (CRAAS), Secretariat of Natural Resources (SERENA), and MARENA. This project is authorized by the Consejo Regional RAAS Resolution No. 192-02-04-00 and MARENA permits No. 012-102011 and No. 008-042012. The donation of live turtles to the project by local fishers and watchmen for tag and release adds considerably to our knowledge of hawksbills in the region and is greatly appreciated. We would also like to thank Silvio Reyes and Norwin Reyes for their in-kind support of reduced fuel costs. The assistance of the Nicaragua National Police was important to ensure the safety of team members and access to the cays to conduct research and conservation activities throughout the nesting season, and we are grateful for their assistance. We would like to thank: Comisionado Mayor E. Lee López, Comisionada Mayda Quiróz, and Subcomisionado G. Vargas. We are especially grateful to the police that accompanied the field teams in conducting daily surveys, they are: Subinspector E. Mairena, Suboficiales R. Ballesteros, J. Britton, B. Gómez, J. López, M. Martínez, N. Pineda and I. Rodas; and Policías de Línea X. Borge, S. García, A. González, D. Hodgson, M. Jiménez, W. Lewis, A. López, F. López, V. Marín, O. Romero, Yahaira Sosa and Yessenia Sosa.

We thank volunteer Kent McCoy (student, Pierre y Marie Curie Universal High School, Nicaragua), who accompanied us to the cays and/or assisted us during the nesting and hatching seasons. We are very grateful for financial support from the U. S. Fish & Wildlife Service - Marine Turtle Conservation Act, United Nations Environmental Program (UNEP), an anonymous donor, and the many individual donors through the WCS website.

**LITERATURE CITED**

- AnalystSoft, StatPlus:mac - statistical analysis program for Mac OS. Version 2009. See [www.analystsoft.com/en/](http://www.analystsoft.com/en/).
- Bellwood, D.R. and C.J. Fulton. 2008. Sediment-mediated suppression of herbivory on coral reefs: decreasing resilience to rising sea levels and climate change? *Limnology and Oceanography* 53(6):2695-2701.
- Bjorndal, K.A., A.F. Carr, A.B. Meylan, and J.A. Mortimer. 1985. Reproductive biology of the hawksbill *Eretmochelys imbricata* at Tortuguero, Costa Rica, with notes on the ecology of the species in the Caribbean. *Biological Conservation* 34: 353-368.
- Bjorndal, K.A., J.A. Wetherall, A.B. Bolten, and J.A. Mortimer. 1999. Twenty-six years of green turtle nesting at Tortuguero, Costa Rica: an encouraging trend. *Conservation Biology* 13(1):126-134.
- Campbell, C.L., C.J. Lagueux, S. Gautreau, and W.A. McCoy. 2008. 2007 Pearl Cays Hawksbill Conservation Project, Nicaragua. Final Report. Wildlife Conservation Society, Pearl Lagoon, RAAS, Nicaragua. 25 pp. (also available in Spanish).
- Campbell, C.L., C.J. Lagueux, and V. Huertas. 2007. 2006 Pearl Cays Hawksbill Conservation Project, Nicaragua. Final Report. Wildlife Conservation Society, Bronx, NY. 20 pp. (also available in Spanish).
- Campbell, C.L., C.J. Lagueux, V. Huertas and W.A. McCoy. 2012. 2011 Pearl Cays Hawksbill Conservation Project, Nicaragua. Final Report. Wildlife Conservation Society, Pearl Lagoon, RAAS, Nicaragua. 32 pp. (also available in Spanish).
- Campbell, C.L., C.J. Lagueux, and W.A. McCoy. 2010. 2009 Pearl Cays Hawksbill Conservation Project, Nicaragua. Final Report. Wildlife Conservation Society, Pearl Lagoon, RAAS, Nicaragua. 30 pp. (also available in Spanish).
- Heppell, S.S., L.B. Crowder, and J. Priddy. 1995. Evaluation of a fisheries model for hawksbill sea turtle (*Eretmochelys imbricata*) harvest in Cuba. NOAA Tech. Memor. NMFS-OPR-5, 48pp.
- Hillis, Z.M. and A.L. Mackay. 1989. Buck Island Reef NM Sea Turtle Program, 1989. Proceedings of the Ninth Annual Workshop on Sea Turtle Conservation and Biology. NOAA Technical Memorandum. NMFS-SEFC-232:235-237.
- Horrocks, J.A. and N. Scott. 1991. Nest site location and nest success in the hawksbill turtle *Eretmochelys imbricata* in Barbados, West Indies. *Marine Ecology Progress Series* 69:1-8.
- Kamel, S.J. and N. Mrosovsky. 2006. Inter-seasonal maintenance of individual nest site preferences in hawksbill sea turtles. *Ecology* 87(11):2947-2952.
- Lagueux, C.J. 1998. Marine turtle fishery of Caribbean Nicaragua: human use patterns and harvest trends. Ph.D. Thesis. University of Florida, Gainesville. 215 pp.
- Lagueux, C.J. and C.L. Campbell. 2005. Marine turtle nesting and conservation needs on the south-east coast of Nicaragua. *Oryx* 39(4):398-405.
- Lagueux, C.J., C.L. Campbell, A.L. Bass, and B.W. Bowen. 2001. Genetic Analysis of Nicaragua's Hawksbill Populations. Final Report (Contract #40AANF903413) submitted to the National Marine Fisheries Service. 7 pp.

- Lagueux, C.J., C.L. Campbell, and V.A. Cordi. 2006. 2005 Pearl Cays Hawksbill Conservation Project, Nicaragua. Final Report. Wildlife Conservation Society, Bronx, NY. 12 pp. (also available in Spanish).
- Lagueux, C.J., C.L. Campbell, E. Coulson, and A. Coulson. 2012. Conservation and Monitoring of Sea Turtle Nesting on the Southeast Coast of Nicaragua, 2008-2011. Final Report. Wildlife Conservation Society, Pearl Lagoon, RAAS, Nicaragua. 19 pp. (also available in Spanish).
- Lagueux, C.J., C.L. Campbell, V. Huertas and W.A. McCoy. 2011. 2010 Pearl Cays Hawksbill Conservation Project, Nicaragua. Final Report. Wildlife Conservation Society, Pearl Lagoon, RAAS, Nicaragua.. 32 pp. (also available in Spanish).
- Lagueux, C.J., C.L. Campbell, and W.A. McCoy. 2003. Nesting and conservation of the hawksbill turtle, *Eretmochelys imbricata*, in the Pearl Cays, Nicaragua. *Chelonian Conservation and Biology* 4(3):588-602.
- Lagueux, C.J., C.L. Campbell, and W.A. McCoy. 2009. 2008 Pearl Cays Hawksbill Conservation Project, Nicaragua. Final Report. Wildlife Conservation Society, Pearl Lagoon, RAAS, Nicaragua. 29 pp. (also available in Spanish).
- LeRoux, R.A., P.H. Dutton, F.A. Abreu-Grobois, C.J. Lagueux, C.L. Campbell, E. Delcroix, J. Chevalier, J.A. Horrocks, Z. Hillis-Starr, S. Troëng, E. Harrison, and S. Stapleton. 2012. Re-examination of population structure and phylogeography of hawksbill turtles in the Wider Caribbean using longer mtDNA sequences. *Journal of Heredity*. 103(6):806-820.
- Miller, J.D. 1999. Determining clutch size and hatching success. pp. 124-129. In: *Research and Management Techniques for the Conservation of Sea Turtles*. K. L. Eckert, K.A. Bjorndal, F.A. Abreu-Grobois, and M. Donnelly (Editors). IUCN/SSC Marine Turtle Specialist Group Publication No. 4. 235pp.
- Mortimer, J.A and M. Donnelly. 2008. *Eretmochelys imbricata*. In: IUCN 2011. IUCN Red List of Threatened Species. Version 2011.1. <[www.iucnredlist.org](http://www.iucnredlist.org)>. Downloaded on 21 July 2011.
- National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1998. Recovery Plan for U.S. Pacific Populations of the Hawksbill Turtle (*Eretmochelys imbricata*). National Marine Fisheries Service, Silver Springs, MD. 82 pp.
- Nietschmann, B. 1981. Following the underwater trail of a vanishing species: the hawksbill turtle. *National Geographic Society. Research Reports* 13:459-480.
- Richardson, J.I., R. Bell, and T.H. Richardson. 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.
- UNEP-WCMC. 2013. UNEP-WCMC Species Database: CITES-Listed Species. <[www.unep-wcmc-apps.org/isdb/CITES/Taxonomy/tax-species-result.cfm?displaylanguage=eng&Genus=%25Eretmochelys%25&source=animals&Species=i%20mbricata&Country=&tabname=status](http://www.unep-wcmc-apps.org/isdb/CITES/Taxonomy/tax-species-result.cfm?displaylanguage=eng&Genus=%25Eretmochelys%25&source=animals&Species=i%20mbricata&Country=&tabname=status)>
- Witherington, B.E. and R.E. Martin. 2000 (Revised Edition). *Understanding, Assessing, and Resolving Light-Pollution Problems on Sea Turtle Nesting Beaches*. Florida Marine Research Institute, Technical Report TR-2. 73 pp.

## PHOTOGRAPHS



Photo 1. 2012 Hawksbill Project Team. From left: Víctor Huertas (Project Coordinator), Roanie Julio, William McCoy (Field Supervisor), Kessey Johnson, Dorian McCoy, Claudia Forbes, and Harvey Antonio. Not pictured: Alex Allen, Kanrod Cayasso, Nelborth Douglas, Telia Narcisso (Logistics Assistant), Cynthia Lagueux (Program Director) and Cathi Campbell (Scientific Director).



Photo 2. Juan Enríquez (left) receiving a lifejacket from William McCoy (WCS) for his 15<sup>th</sup> sea turtle donation to the WCS Incentive Program.



Photo 3. Police A) Meyling Martínez and B) Dennis Hodgson releasing juvenile hawksbills donated to the Project in the Pearl Cays Wildlife Refuge.



Photo 4. Murals commissioned by WCS at the “Harry and Maggie Taylor” Municipal Stadium in Pearl Lagoon in preparation for the 62<sup>nd</sup> Annual Nicaragua Atlantic Coast Baseball Series (far left and far right).

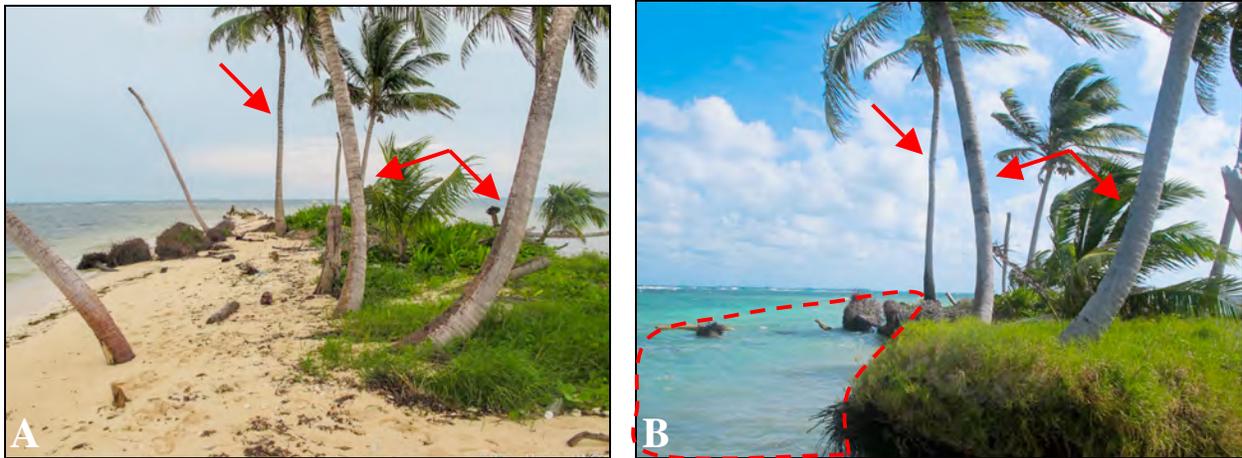


Photo 5. Severe erosion continues on Vincent Cay. A) View in August 2011 and B) same image in October 2012 (note portion of coastline lost to erosion marked with dashed red line, red arrows in both photos indicate the same reference points).



Photo 6. Degraded coral reef around Crawl Cay.