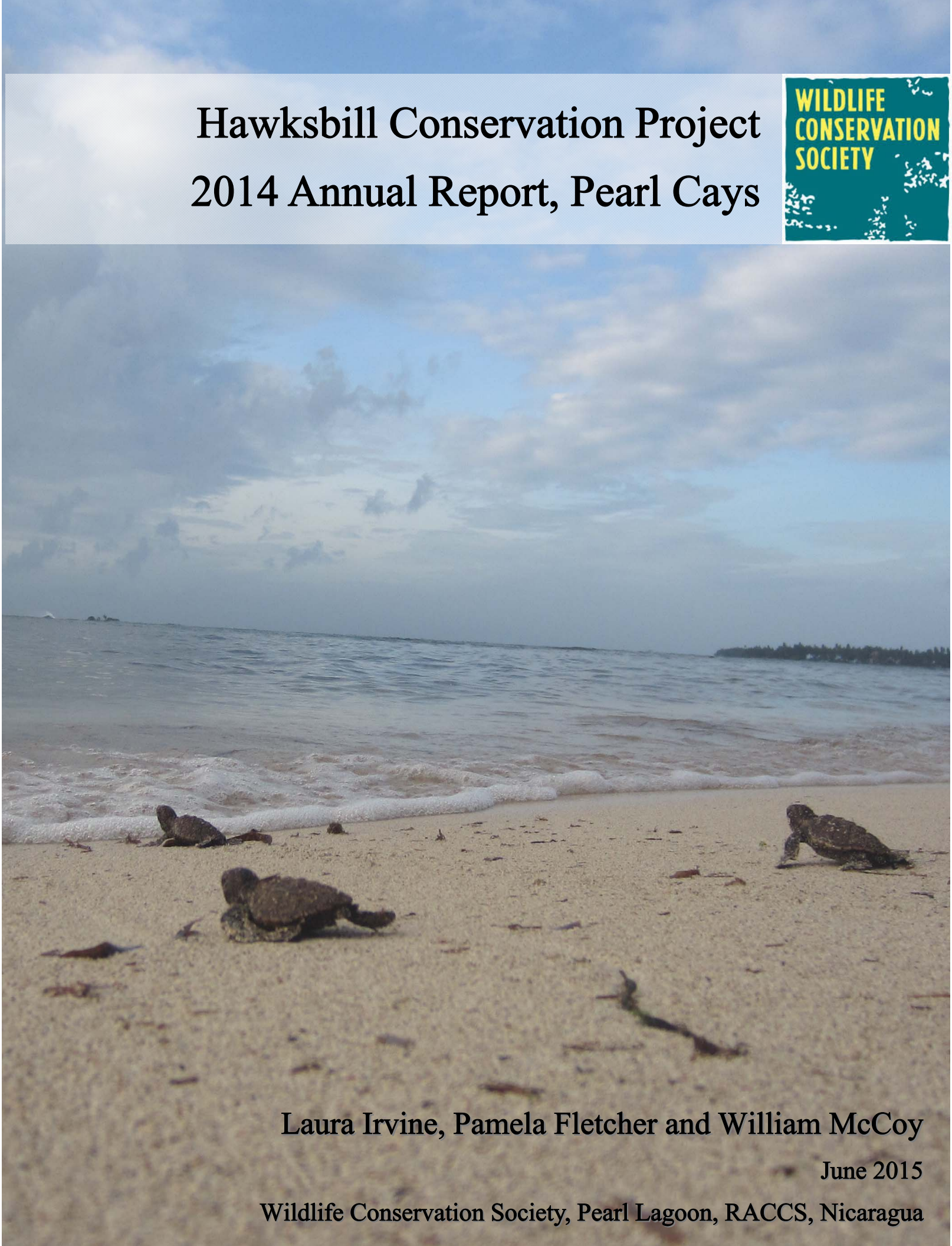
Hawksbill Conservation Project
2014 Annual Report, Pearl Cays



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EXECUTIVE SUMMARY

The Wildlife Conservation Society (WCS) conducted monitoring surveys of hawksbill sea turtles (*Eretmochelys imbricata*) in the Pearl Cays Wildlife Refuge (PCWR), Nicaragua, during the 2014 nesting season. A total of 475 clutches were recorded in 2014, the greatest number of clutches per season in the 15-year history of the project.

During the intensive monitoring period (IMP) from 17 June to 7 December 2014, WCS teams worked a total of 699.03 hours (mean=4.02 hours per day) and completed 1,153 cay surveys (defined as each time a cay was surveyed) on an average of 6.6 cay visits per day. There was a significant positive relationship between the number of clutches recorded and the number of years since initiation of the project ($r=0.8528$, $p<0.001$), starting with 154 clutches in 2000. The number of clutches laid in 2014 represented a 41.4% increase from 2013, and a 208.4% increase since 2000. The mean percentage of increase in total clutches laid per season over 15 years of the project was 9.9%. The majority of clutches (56%) laid in 2014 were located on two cays: Wild Cane with 145 (30.5% of total nest count) and Water with 121 (25.5% of total nest count).

The second lowest poaching rate in project history was recorded in 2014. There were 28 (5.9%) clutches affected by poaching during the 2014 nesting season: five partially poached clutches (at least one egg remaining to incubate) and 23 (4.8%) clutches completely poached. Ten of the 23 completely taken nests (43.5%) occurred prior to daily monitoring. The mean clutch size was 152.84 yolked eggs (SD=36.73, range=12-232) and 0.51 yolkless eggs (SD=0.98, range=0-5). Daily nest monitoring resulted in three nests reported as fully predated (0.8%), 29 nests partially predated (7.7%), three nests completely eroded (0.8%) and 16 nests flood-affected (by tides) (4.2%) during the 2014 season.

For those clutches where at least one egg hatched, hatching success (HS) and emerging success (ES) were 72.8% and 72.4%, respectively (n=282, range=1.3-100%). For clutches left *in situ* without temperature loggers, HS was 69.4% and the ES was 69.0% (n=171). For relocated clutches, HS was 65.8% and ES was 65.4% (n=125). For clutches found by signs of hatching, HS was 83.1% and ES was 81.1% (n=48). Between *in situ* and relocated nests, HS was not significant (Mann-Whitney, U=12,063.5, p=0.2115), nor was ES (Mann-Whitney, U=16,411.5, p=0.01202). Based on the number of empty egg shells >50% found in excavated nests, approximately 42,934 hatchlings were produced in 2014 – the greatest number in project history for a single season.

During the IMP, six of the 11 cays monitored were permanently inhabited (Baboon, Crawl, Grape, Lime, Water, and Bottom Tawira), three of the cays were frequently inhabited by residents or fishermen (Buttonwood, Columbilla, and Wild Cane) and two cays were not observed to be inhabited (Maroon and Vincent) during the intensive monitoring season. Bottom Tawira recorded the highest mean number of observations for people per cay-survey (11.4), with Water and Crawl second and third highest (3.3 and 3.0, respectively). A total of 69 burn events, six cutting events, one instance of taking sand, 22 instances of construction were also recorded, along with frequent clearing of vegetated areas. WCS teams continue to observe human activities harmful to hawksbill nesting habitat and conservation on a regular basis in the PCWR (i.e. harvesting of juvenile marine species, including different species of turtle and sharks).

A total of 24 encounters with turtles were recorded in 2014. Five were juveniles (one green (*Chelonia mydas*) and four hawksbills) and 19 were adults (two greens and 17 hawksbills). Of the 17 hawksbill adults, nine were new recruits (REC – not previously tagged), six were remigrants (REM – previously

tagged by the WCS or other project) and two were re-nesters (REN – recorded nesting more than once in a single season) from the 2014 season. Each turtle is tagged (if no tags present), measured, and released, including three turtles that also received satellite tags. Adult female hawksbills (REC and REM, n=10) encountered had a mean straight carapace length (notch to notch) of 79.61cm (SD=3.71, range=71.6-84.0) and a mean straight carapace width of 58.75cm (SD=4.34, range=51.0-66.6). The WCS team continued to encourage fishers, watchmen, and divers to donate live turtles for tag and release in exchange for a WCS t-shirt, or a lifejacket for every 15th donation by the same individual. To date, there have been over 1000 t-shirts and 18 life jackets rewarded for turtle donations throughout the 15-year project. In the 2014 season, there were 17 live sea turtle donations (one juvenile green turtle and 16 hawksbills - four juveniles and 12 adult nesting females).

In 2014, WCS staff continued to support Kabu Tours (www.kabutours.com), the alternative livelihoods project that promotes the transition from turtle harvesting to ecotourism. Regular efforts were made to inform local communities and authorities, tourists, and the WCS family of regular progress both during and following the 2014 season. These activities were done through a variety of mediums (radio, signage, presentations, informal talks, articles, website, etc.) and in four different languages (English, Spanish, Creole and French). The project was also featured in several international news reports celebrating the record-breaking year and long-term achievements in the Pearl Cays.

A series of recommendations were produced from project results and experience, for both the PCWR as well as the hawksbill conservation project specifically. These include but are not limited to: collaborative design and creation of a comprehensive ecosystem-based management plan for the PCWR; regulation and stricter enforcement for those human activities with negative impacts on nesting and other habitats that turtles need for survival (exploitation, tourism, construction, waste, vegetation clearing, etc.); continued and expanded engagement of local, regional and national stakeholders in education and awareness activities for conservation; continued and additional focused scientific data collection in the PCWR; and, the continuation of new methods implemented in 2014 (nest monitoring, quality control, excavation methods, survey effort, etc.).

There were many achievements to celebrate during the record-breaking 2014 hawksbill nesting season, but multiple activities still pose significant threats to this important rookery. The state of sea turtle conservation in the Pearl Cays is very fragile, sensitive to a number of different human activities, market demands, WCS presence, and volunteer compliance of regulations. Continued conservation success hinges on the consistency and expansion of current scientific and education activities, as well as dedicated efforts towards achieving progress on recommendations for the PCWR. WCS recommends continued work on these focal conservation areas for a greater positive impact on the recovery of local hawksbill population and the habitats essential for both sea turtle survival and local livelihoods.

INTRODUCTION

The hawksbill sea turtle (*Eretmochelys imbricata*) is classified as critically endangered on the International Union for the Conservation of Nature (IUCN) Red List (Mortimer & Donnelly, 2015) and also listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix I (CITES, 2014). Hawksbills have been categorized as critically endangered since 1996, after being listed as endangered as early as 1986 (Mortimer & Donnelly, 2015). On Nicaragua's Caribbean coast, hawksbill turtle nests have been recorded in the Pearl Cays Wildlife Refuge (PCWR), El Cocal, and periodically along the mainland, and all size classes have been recorded foraging in offshore coastal waters (Lagueux et al, 2003; Lagueux & Campbell, 2005; Lagueux et al, 2012). 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, this area has been identified as an important index site within the greater Caribbean region for long-term population monitoring (CITES, 2002). Estimates from 2010-2012 show a recent increasing trend in the Pearl Cays nesting population, with an estimated 60-104 females nesting per season (NOAA & FWS, 2013). More than 20 genetic haplotypes of turtles using the PCWR have been identified thus far (LeRoux et al, 2012).

Hawksbill turtles on Nicaragua's Caribbean coast are severely threatened by decades of uncontrolled harvesting 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 & Campbell, 2005; Campbell et al, 2012; Lagueux et al, 2013). In 1999, the Wildlife Conservation Society (WCS) conducted the first systematic surveys of the Pearl Cays that led to two important discoveries: (1) nearly 100% of the clutches laid were taken by local fishers for personal consumption; and, (2) 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 ('Hawksbill Conservation Project'). In addition, WCS established a 'Donate A Live Turtle Program' that provides incentives to local fishers and inhabitants on the cays to voluntarily donate live turtles to the project for tag and release (including males and juveniles, as well as green (*Chelonia mydas*) and loggerhead (*Caretta caretta*) turtles). This volunteer program is conducted throughout the year and helps save turtles while also engaging a wider audience in sea turtle conservation that might be overlooked during typical community outreach activities (i.e. fishers, cay watchmen, etc.).

Both the Donate a Live Turtle Program and the Hawksbill Conservation Project have been successful at reducing hawksbill mortality in the PCWR. For example, there has been a steady increase in the number of clutches laid annually and, although variable, a significant decrease in percentage of nests poached since initiation of the project. In addition to protecting females and eggs, we have also increased efforts to collect data on the reproductive biology of females, in order to better understand nesting ecology and habitat needs of hawksbills in the Pearl Cays. This includes the collection of genetic samples, studies on nesting habitats, and more detailed data collection on nest parameters such as thermal profiles.

The Pearl Cays hawksbill population continues to face the destruction of its nesting and feeding habitats from increasing human presence in the area. The construction of permanent houses and/or the installation of temporary structures on cays with nesting habitat negatively affects nesting behaviour, as well as indirectly affecting reproduction from the destruction and alteration of habitats (i.e. sand mining, clearing of upper beach vegetation, and construction in nesting areas) (Lagueux et al, 2013). In addition, fishing activities in the Pearl Cays such as the lobster, shark and sea cucumber fisheries contribute additional

threats to sea turtles (Lagueux et al, 2013). The lack of effective management to mitigate human impacts leads to increased human presence on the cays and in surrounding waters, which in turn increases pressure on other marine resources. A severe reduction in these populations in the PCWR could have detrimental effects on other resources and overall habitat quality, as seen in other selected marine ecosystems around the world (Jackson, 2008; Worm et al, 2009). Other factors negatively affecting hawksbill reproductive biology and survival in the Pearl Cays include the presence of domestic animals (Lagueux et al, 2013) and artificial lighting (Witherington & Martin, 2000) on nesting beaches, although these threats have recently been decreasing.

The conservation of hawksbill turtles in the PCWR is important for both the regional and global recovery of hawksbills. In this 15th year of monitoring, conservation, and research efforts, and despite the ongoing aforementioned challenges, the WCS program has made significant strides towards the recovery of this important hawksbill nesting and feeding ground. This has been achieved through stakeholder communications and a push towards better natural resource use and management practices by WCS and local communities themselves. In this report we provide results from our conservation and research efforts during the 2014 nesting season, as well as results from the 15-year effort.

PROJECT OBJECTIVES

Project objectives for the 2014 nesting season were to:

- quantify nesting activity spatially and temporally on 11 cays
- document survey effort on the cays during the nesting season
- document human activities on the cays during the nesting season
- monitor nest condition for entire incubation period
- maintain or increase survival of egg clutches and nesting females
- excavate nests after incubation period to determine hatchling success
- collect reproductive and morphometric data on nesting females
- monitor beach and nest temperatures to assess thermal parameters of nesting habitats
- promote conservation through the media, presentations and education
- build technical capacity at the local level for ecological monitoring work and resource management
- improve local collaboration and increase government involvement in conservation activities
- assist local communities to continue and expand conservation of marine turtles through sustainable turtle watching and eco-friendly tourism in the Pearl Cays
- raise awareness of fishermen and discourage the harvesting of marine turtles, particularly hawksbills
- provide incentives to local fishers and residents to donate live marine turtles of any species and age-class for tag and release

STUDY AREA

The Pearl Cays are located from 3-22 km east of the mainland, off the central Caribbean coast of Nicaragua (Figure 1), and encompass an area of approximately 700 km^2. The study area is comprised of 11 of the 22 Pearl Cays: Baboon, Bottom Tawira, Buttonwood, Columbilla, Crawl, Grape, Lime, Maroon, Vincent, Water, and Wild Cane. Cays range in size from 0.04 ha to 18.4 ha; however, the size of the cay is not necessarily related to the amount of available nesting habitat (Table 1). Total nesting area also changes throughout the season with changing tidal and wind activity. Although rare, hawksbill nesting has been reported on Crow Cam, Seal, Askill, and Little Savanna. These latter cays were not included in regular surveys because of either distance from our primary study area and/or the infrequency of nesting on each cay. No nesting activity has been reported on these cays since 2007, based on qualitative data collection acquired each year.

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 (Lagueux et al, 2011).

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	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
Columbilla	3.02 / 113	Maroon	0.2 / 132		

Nesting has yet to be recorded on Top Tawira, Esperanza, Savanna, Walter, and the two unnamed cays in the northern Pearl Cays for the duration of the project due to a lack of appropriate nesting habitat (i.e. only large rocks or dense mangroves lining the coast). Black Mangrove was also added to this list in 2014, for the same reason. No nesting activity was reported on Black Mangrove in 2013 or 2014, confirmed by opportunistic surveys and qualitative data collection from temporary residents on the cay.

The study site is located within the Pearl Cays Wildlife Refuge (PCWR), established in 2010. The PCWR currently has no management plan, although recent efforts by WCS will help inform a management plan in the future.

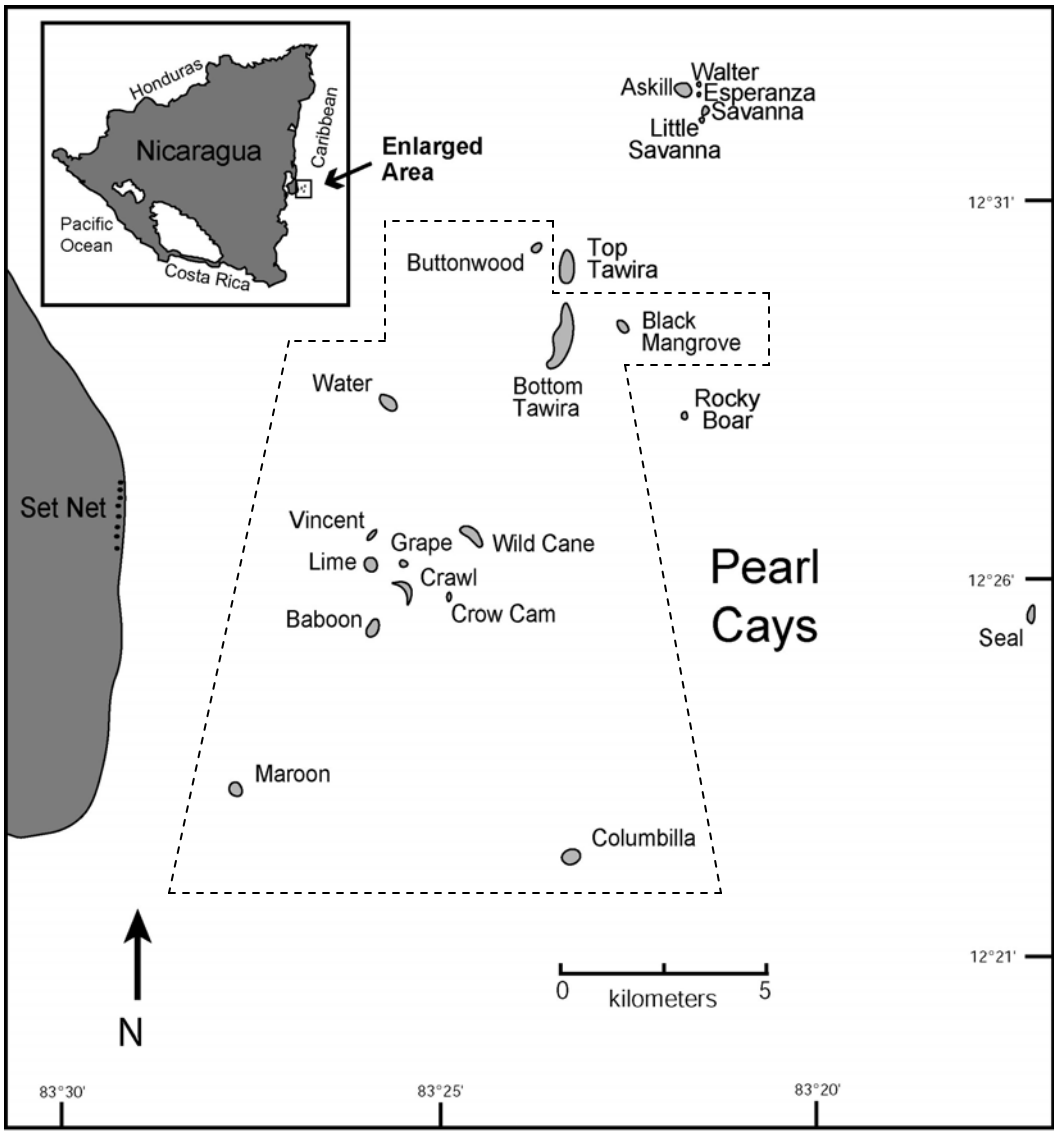

Figure 1. Map of the Pearl Cays, Nicaragua (area within dashed line indicates WCS study site).

METHODS

TRAINING AND TEAM COMPOSITION

Seasonal staff received classroom and practical training in sea turtle biology, nesting ecology, and field data collection methods by experienced WCS personnel during a one-day training workshop. Candidates were assessed by both a practical and written exam covering the materials and methods given during the

training workshop. The eight team members selected included a mixture of people from as many local communities as possible. The group of eight was split into two teams of four based on skill sets and experience, and each team would alternate for 10-day shifts. Teams were then trained during a four-day period together in the field, as well as receiving continued mentoring by the Project Coordinator and Field Supervisor throughout the season. Two Nicaragua National police also accompanied project staff on nesting beach surveys at different shifts throughout the intensive monitoring period. Police from the Bluefields station are assigned to the project, with different officers each shift. Police are given a brief orientation during each rotation.

NESTING BEACH SURVEYS

During the 2014 nesting season, monitoring surveys were conducted regularly on 11 of the Pearl Cays where hawksbill nesting occurs, and periodically on Black Mangrove Cay. A comprehensive survey protocol document was produced by the Project coordinator before starting the field season (Irvine, 2014). This document was developed from a number of different sources, including: descriptions of methods used by project over 15 years from the project field supervisors, past databases and field books, and existing literature. All methods described below are summarized from this aforementioned document.

Surveys were carried out in 10-day rotations by two different teams, each consisting of four WCS seasonal staff (team leader, panga captain, and two team members), along with the Project Coordinator (Laura Irvine) and/or Field Supervisor (William McCoy), and occasionally two National Police officers. Due to the collaborative efforts of WCS staff and the National Police, the presence of police throughout the entire nesting season was not needed. This is an exceptional achievement deserving of credit to this long-lasting partnership between WCS and the Nicaragua National Police. Therefore Police joined teams for three shifts at the start of the season, one shift in the middle of the season, and one final shift near the end of the season.

Opportunistic surveys were conducted before and after the intensive monitoring period (IMP) to record newly laid nests or any nests found by signs of hatching, and also to conduct excavations. Each cay was surveyed daily, weather permitting. Teams carried survey equipment in the Kit Bucket, which included: 50m measuring tape, field books and excavation datasheets, two compasses, two Garmin GPS units, AA rechargeable batteries and charger, pencils, pencil sharpeners, markers, flagging tape, eggshell vials filled with alcohol, white garden sticks to mark nests, excavation gloves, and drybags for GPS units and a phone with a list of emergency contacts (Figure 2).

Figure 2. Items contained in 2014 Kit Bucket except eggshell sample vials.

Teams recorded the start time into the Survey Summary Book as soon as they exited the boat onto the cay. Then teams then walked around the cay in a clockwise direction, looking for signs of nesting activity. Teams examined the beach and inland areas within 30m of the high tide line. One or two team members checked existing nests for their condition and recorded the data in the Nest Check Book. Other team members recorded nesting activity from the previous night in the Test, Track, and Nest Book. The team simultaneously observed any human activities throughout the survey on each cay and recorded them in the Human Activities Book. Before leaving the cay, the team got together and double-checked all the data books, recorded the human activities as a group, calculated the summary of nesting activities, and recorded additional comments and survey end time. Quality control of data was completed each evening.

SURVEY EFFORT

Survey effort indicated team presence on the cay and allowed us to calculate hours worked both directly on recording data and working with live turtles. Survey effort was a new addition to the data collection regime in 2014 (first collected on 8 June), and entailed the recording of a start time when the team arrived on the cay to conduct a cay-survey (defined as each time a cay was surveyed) and an end time right before they got back into the panga to leave. This data also helped estimate the times females were laying and allowed a record of more recent human activities on the cays relative to our survey hours, and estimated time for survey activities, which in turn helped improve monitoring protocols.

NEW NEST DATA

Recording each clutch allowed us to quantify spatial and temporal nesting behaviour on each surveyed cay. Teams were trained in the field to study the characteristics of the disturbance to find any new nests efficiently, looking for flipper dig marks, up and down tracks, and sand mounds. On cays where there were poachers more likely to be present (Bottom Tawira, Buttonwood, Columbilla, Maroon, and Wild Cane), teams tried to conceal the presence of a nest – as this can tip off poachers to the nest location. Teams also did not use flagging tape to mark nests on these cays, but instead wrote a more discrete number on the tree that was used as a marker for each nest.

Once the clutch was found, the nest was given a number in sequence. One fresh eggshell was collected from each recently laid clutch for a genetic study (see Population size study). Clutches were left *in situ* unless there was a significant mortality threat from poachers or environmental factors (i.e. high tides inundating the nest during the incubation period, predators in nest, etc.). Translocation of clutches is a common practice in sea turtle conservation projects all over the world, and can serve to mitigate a variety of threats that negatively affect nest success (Wyneken et al, 1988; Bolton, 1999; Kornaraki et al, 2006; Tuttle, 2007; Pfaller et al, 2008; Pike, 2008). Teams dug an artificial nest chamber with the same nest depth and shape as the natural nest. The moved nest site had similar vegetation coverage and vertical zone to the original nest site, where possible. The relocation process involved careful removal of each egg into a deep pan with sand, transport of the eggs to the new site, placement of the eggs into the artificial nest cavity, and cover of the eggs with like material. When moving the clutch, teams always maintained the eggs in their original vertical orientation so as not to cause movement-induce mortality of the embryos (Limpus et al, 1979; Bolton, 1999; Mortimer, 1999). The moved site was minimally disturbed and then camouflaged to hide the clutch from poachers. In the vast majority of cases and wherever possible, eggs were relocated less than 10 hours after being laid (or greater than 15 days), as threat of mortality is lower during these periods (Limpus et al, 1979, Miller & Limpus, 1983; Morisso & Krausse, 2004). Delayed relocations are not necessarily cause for reduced nests success (Abella et al, 2007), but they were avoided wherever possible as a best practice.

When teams found a nest, they first decided whether it needed to be relocated or left *in situ* with the supervision of the Field Supervisor and/or Project Coordinator. This involved assessing the level of significant mortality threat by tides, predators or poachers. Then, several parameters were measured for each new nest, including: distance to high tide line, length of crawl, vegetation type, vertical beach zone, distance and degree from tree marker, and GPS location (example of some in Figure 3). These data were recorded in the Nest, Test and Track Book for both *in situ* and moved locations when a nest was relocated (Annex 1). Distance and degree from tree marker were taken only for the place where the nest was left to incubate, so that teams could find the nest again for monitoring and excavations. Crawl length was measured along the centre of the turtle's track from the most recent high tide to the center of the nest cavity/egg chamber. Distance from nest to high tide was measured in a straight-line, perpendicular to the shore, from the most recent high tide line to the center of the nest cavity. Also recorded was the vertical beach zone classification (related to amount of shade received per daytime hours (Beach: 0-50% shade, Upper Beach: 51-89% shade, or Inside: 90-100% shade), GPS coordinates directly above nest cavity, navigational side of cay (north, west, etc.), and the vegetation coverage type (Vegetation: fully covered, Border: mix of vegetation and natural lack of vegetation coverage, Cleared: vegetation removed by people, or No Vegetation: natural lack of vegetation coverage).

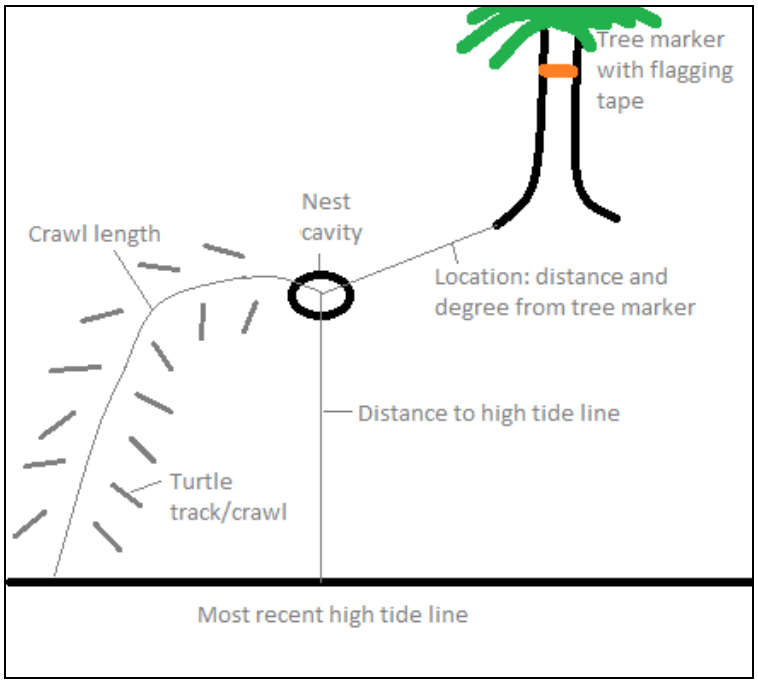

Figure 3. Some measured nest parameters for a new nest left *in situ.*

Eggs in each relocated clutch were counted when removing the eggs from the *in situ* nest and then a second time when placing the eggs into the artificial cavity. Mean clutch size was based on egg counts of relocated clutches because this number is more accurate than eggshell counts during excavations (Miller, 1999). Nest depth was measured in the original nest cavity, from the bottom of the nest to the beach surface level (using a stick across the cavity mouth at surface level). Nest depths were not measured for clutches left *in situ* until they were excavated. Finally, any notable comments about the nest were added to the field book (i.e. lay date, burst eggs found during relocation, suspicious markings around nest, etc.).

TEST AND TRACK DATA

Recording data on tests (false crawl with attempted egg chambers) and tracks (false crawl without an attempted egg chamber) allowed us to calculate the total amount of effort and site preferences of nesting turtles in the study area. These false crawls can also indicate potential disturbances to the nesting female (in the case of artificial light or human presence) or help predict the return of a nesting female to a similar area that night or in the next days (Richardson et al, 1999). During each cay-survey, teams recorded the cay, type of activity (test or track), series number for tests (first, second, etc. attempt in the series), vertical beach zone, vegetation coverage type, straight distance to high tide from middle of the test event or highest point of track, crawl length from high tide to middle of test attempt or total crawl for tracks, GPS coordinates, and any other comments for each test or track (Annex 1). Crawl lengths for first test attempts were measured along the centre of the crawl with a flexible measuring tape, from most recent high tide line to the centre of the attempted cavity. Subsequent test attempts were measured from the center of the first attempted nest cavity to the center of the second attempted nest cavity, from the center of the second attempt to the third, and so on. In the case of tracks, the measurement began at the most

recent high tide line when the turtle visibly exited the sea to the most recent high tide line when the turtle visibly re-entered the sea. If a test was connected to an eventual nest, then that nest number was indicated in the comments. All tracks and tests were camouflaged after data was collected, so not to be confused as unrecorded activity in following days. This was especially important on swap out days to avoid double counting of activities by the next team.

NEST CONDITION MONITORING

Nest checks allow us to have more accurate data when assessing final nest success, as we can account for any predated eggs, natural events, and human impacts that might have directly affected specific clutches (including the number of eggs predated and timing of human/natural events). Methods and variable definitions are based on best practices from the Sea Turtle Conservancy in Tortuguero, Costa Rica, and the Caño Palma Biological Station in Playa Grande, Costa Rica (Christen & Garcia, 2013a; Christen & Garcia, 2013b; Christen & Garcia, 2013c; Garcia, pers.com, 2013).

Each nest was assessed for its anthropogenic and environmental condition on each cay-survey (Table 2), starting from the day after they were first recorded in the Nest/Test/Track book. Teams assessed all nests on each cay-survey for any signs of predation, poaching, flooding, erosion, and any other unknown disturbances, then recorded them in the Nest Check Book. Location data in the Nest Check Book helped the teams find the exact nest location to ensure that they were checking the right location for condition. Each nest was monitored daily, weather permitting. When days were missed, 'DNC' or 'did not check' was recorded. If any abnormalities or uncertainties with conditions of nests occurred, they were discussed immediately with the Field Supervisor and/or Project Coordinator.

On the 60th day of the incubation period teams checked nests for signs of hatching (depression/hatchling cave, live hatchlings exiting/around the nest, dead hatchings on top/around of nest) and record this information to determine the excavation schedule. If live hatchlings were seen exiting the nest, teams watched them go to sea. If suspected predation or if hatchlings were stuck in the nest during the final days of incubation, an impromptu excavation was performed with the consultation of the Project Coordinator.

Table 2. Nest conditions and definitions used in daily nest monitoring in 2014.

Condition (code)	Definition
Natural (NAT)	Nest was in a natural state, undisturbed by the environment, predators or people
Flooded (FLO)	Nest was inundated (water in nest)
Eroded (ERO)	Nest was eroded (saw eggs that have been washed out of the nest or clutch was fully exposed)
Taken (TAK) Partially Taken (P.TAK)	Nest was fully (TAK) or partially taken by poachers (P.TAK), as indicated by an empty egg chamber with digging marks, footprints, stick holes, sometimes a few egg shells, difference in depth of nest since the nights before, etc.
Predated (PRE) Partially Predated (P.PRE)	Nest was fully (PRE) or partially predated (P.PRE), known by evidence such as hole dug up near the nest, animal prints, egg shells scattered around the nest, sand spray, lack of footprints or stick holes, crab holes leading to nest, presence of predator itself, etc.
Unknown (UNK)	Nest was in an unknown condition
Hatchlings (HAT)	Signs of hatching were observed at nest (hatchling tracks or hatchling cave)

Definitions guided primarily by Christen & Garcia, 2013c.

POPULATION SIZE STUDY

Genetic analysis of hawksbill eggshell albumen fluid increases understanding of the status of the hawksbill rookery and its nesting ecology by providing a more accurate estimate of population size, average re-nesting and remigration intervals, and nest site fidelity during subsequent nesting events. A better understanding of demographic parameters helps managers to address the needs of this critically endangered species, which in turn can inform effective protection measures. This study began in 2013, with permission from the Ministerio del Ambiente y los Recursos Naturales (MARENA, Autorizacion No. 003-062013) and cooperation with the University of Georgia. The team collected one fresh eggshell from each clutch encountered, emptied the contents far from the nest site, and placed the shell into a plastic vial with 95% alcohol solution buffer. Samples were stored in the WCS office in Pearl Lagoon.

HUMAN ACTIVITY SURVEY

Human activities were recorded on each cay to identify any negative anthropogenic impacts on nesting beach habitats that might affect turtle nesting or nesting habitat quality/availability. Teams made daily observations of any human activities that were new since the last survey on that cay. Data collected included: number of people and location, the number and type of any animals and location, the number of incidents of burning, cutting or clearing – along with location, the number of incidences of taking sand and construction, and the location of each, and any comments on those activities or other events which did not fit into the predesigned form (i.e. three boats of turtle fishermen on cay, ongoing house construction, tourists visiting cay, etc.) (Annex 1).

TEMPERATURE LOGGERS

Temperature loggers were used to understand and predict long-term trends in thermal profiles in our study site. These thermal parameters can be used to predict hatchling sex ratios, define pivotal temperatures, and diagnose thermal-induced mortality of embryos (Merchant Larios, 1999; Godfrey & Mrosovsky, 1999; Wibbels, 2003). As a part of an ongoing study, temperature loggers (TL) were placed in two different fashions: (1) paired TLs were placed in 10 randomly selected nests and then adjacent to these nests, on each of the surveyed cays, and (2) 30 TLs were also placed in random locations at the start of the nesting season along different areas of nesting beach habitat for baseline thermal data collection. Each TL had a distinct serial number written on the protective plastic casing.

The 30 baseline TLs were placed at a depth of 35cm and covered in sand 10cm from the surface. A standard white golf ball was placed in the hole and covered up to surface level so that metal detectors could find the TLs again if they were not found using the locations data. The location (distance to marker tree and compass degree), GPS coordinates, date and number of the TL were recorded for each installation, and a flagging tape was placed on the marker tree labelled with “TL” and the serial number

of the TL. The average percentage of shade the location would receive during the day was estimated by the team and type of vegetation cover was also recorded.

Paired TLs were placed in and adjacent to 10 randomly chosen *in situ* nests throughout the season. The instructed goal was to place one roughly every two weeks over a 10-week period. Fifty percent of the clutch was removed temporarily from the nest, taking care not to rotate the eggs. TL serial numbers were recorded before one was placed in the center of the clutch and the temporarily displaced eggs were put back into the nest and covered. The paired TL was buried 35cm deep, 1m from the nest in parallel to the high tide line. Then the golf ball was placed at a depth of 10cm in the hole and covered up to surface level. Location, date, GPS coordinates and TL serial numbers were recorded in the nest book and the Field Coordinator's project field book. The average percentage of shade at the location throughout the day and type of vegetation cover were also recorded, the latter estimated by the Field Coordinator. TLs were donated by Dr. Thane Wibbels of the University of Alabama at Birmingham.

NEST EXCAVATIONS

Nest excavations determined the hatching success (% of neonates to exit their eggshells) and emerging success (% of neonates exit the nest) for each clutch (Miller, 1999). Nest contents were used to determine causes of mortality, as well as potential number of neonates newly added into the local population.

The mean incubation period for hawksbill turtles is estimated at 60 days (US Fish and Wildlife Service, 2014; IUCN MTSG, 2014). However, we were advised that mean incubation period in the Pearl Cays was closer to 70 days (Lagueux, pers.com, 2014). Nests were checked for signs of hatching at 60 days, and excavated after 75 days or sooner if evidence of hatching was observed during monitoring surveys. Using location data, teams measured nest locations and carefully dug into the nest. If live hatchlings were present, the team checked a few hatchlings for physical development and activity levels. Unhatched and live (or suspected live) eggs were covered with sand and recorded in the Nest Check Book. If no live hatchlings or live unhatched eggs were in the nest, the nest contents were dug up, separated into categories, and counted. Nest depth was then measured from the bottom of the nest to the surface level (using a stick across the cavity mouth at surface level).

Once all eggs were categorised, the excavation lead put on disposable gloves and counted the total unhatched yolked eggs to record on the Excavation Data Form (Annex 1). Each unhatched egg was examined externally (searching egg for holes or pips) and internally (opening eggs with no punctures and searching all content for development stage, predation, and deformities). Twenty excavation variables were defined in 2014 (Figure 2). A laminated excavation guide was used as a reference to identify development stages, predation signs, deformities and other important information (Annex 1). Developmental stages were not based on biological stages but used as guides to help investigate timing of any disturbances to the clutch that might have significantly affected hatching or emerging success. All excavations were either performed or supervised by the Project Coordinator, or supervised by the Field Supervisor. After the data collection was completed and the excavation data was double-checked, all contents were put back into the nest and buried.

Excavation Variables

Empty eggshells: empty egg shells found in nest, over 50% of complete empty eggshell found
Live hatchlings: hatchlings found alive in nest
Dead-in-nest hatchlings: hatchlings that are out of egg and found dead in nest

Yolkless categories:
Hydrated: unfertilized with albumen inside
Dehydrated: unfertilized without albumen inside
Predated: unfertilized with evidence of predation

Unhatched egg categories:
No embryo: no evidence of any sign of embryo or blood
Pipped eggs: triangle shaped hole right near face of dead hatchling in stage 4, inside undisturbed egg

Embryo development stages:
Stage 1: 0-25% of egg content is embryo, remaining content is yolk
Stage 2: 26-50% of egg content is embryo, remaining content is yolk
Stage 3: 52-75% of egg content is embryo, remaining content is yolk
Stage 4: 76%-100 of egg content is embryo, remaining content is yolk

Predated* egg categories:
Microbe: evidence of suspected fungi or bacteria (use visual and olfactory cues to assess) in the case that eggshell is not penetrated by other predators (i.e. crab hole)
Crab: small circular holes found, not many contents or no contents in egg
Ants: smaller multiple holes (size of ant head) with ants present
Other: evidence of predation by multiple predators without clear first cause or unable to determine type of predation
** when an egg is labeled as predated, it is not also recorded in the development stage category*

Deformities:
Albino: hatching is devoid of colour pigment, usually with blue eyes
No eyes: hatchling has skin covering eye socket or no eyes at all
Twins: hatchling has two embryos (including two conjoined embryos)
Other: any other 'natural' deformity or injury to hatchling not caused by external factors

Figure 4. Excavation variable definitions in 2014 (adapted from Wyneken et al, 1988; Eckert et al, 1999; Miller 1999; Christen & Garcia, 2013c., Garcia, pers.com., 2013)

TAG AND RELEASE PROGRAM

The tag and release program began in 1999 to collect reproductive and morphometric data on individual turtles. Two methods were used to obtain subjects: night surveys and the "Donate A Turtle" incentive program. Night surveys consisted of patrolling beaches on selected cays with high density nesting (i.e. Wild Cane, Water, Crawl) every 1.5 hours from approximately 19h00 until sunrise in search of nesting females. Field staff was trained to locate, observe, and capture nesting females on land. During encounters with these individuals, care was taken not to disturb the nesting process. Once the nesting attempt was completed, WCS field staff approached the turtle to restrain it for data collection.

When the Field Supervisor and/or Project Coordinator were in the field, a 'Tagging Kit' and two straight callipers were brought on daily surveys or stored in the covered temporary base camp where the teams

reside during the season. The 'Tagging Kit' included: data forms for processing turtles, pencils, pencil sharpener, two sets of Inconel pliers and at least 10 Inconel #681 metal tags (National Band & Tag Co., Newport, Kentucky, U.S.A.), 10 Passive Integrated Transponder (PIT) tags (12mm, 125kHz or 134kHz from Biomark, Inc) and Biomark PIT tag applicator, Biomark hand-held PIT tag scanner, cotton swabs, alcohol swabs for taggers hands and to sterilize equipment if needed, 1.5m flexible measuring tape, two straight callipers of 120cm and 80cm lengths, disposable gloves, 95% alcohol solution, vial of new skin, tweezers, scissors, vials filled with saturated salt solution for tissue samples, 150kg hanging scale, and a clip board (Figures 5a&b).

Figures 5a & 5b. Items contained in 2014 Tagging Kit except scale and callipers.

Individual adult or sub-adult turtles not bearing tags were tagged with Inconel metal tags on the trailing edge of each front flipper, proximal to the first scale. Tags were placed with 2/3 of the tag length overlapping the flipper and 1/3 overhang from the flipper, to minimize friction on the skin if swelling occurs while still avoiding likelihood of the tag snagging on anything. In addition, PIT tags were inserted into the left front flipper tricep of each turtle not previously tagged to minimize loss of data on individuals from metal flipper tag loss.

Straight and curved measurements and weight data were collected, and a tissue sample was obtained for genetic analysis from a rear flipper of females not previously sampled. Tissue samples ~2-3mm in size were taken from skin on the rear flipper using tweezers and scissors, after the area on the turtle and equipment was sterilized with 95% alcohol solution. In 2014, standard sea turtle morphometric measurement methods were employed, as guided by Bolton (1999) and Wyneken (2001). Tissue samples were stored in a sealed vial with a saturated salt buffer solution, consistent with the methods used in LeRoux et al (2012).

SATELLITE TAGGING

Wildlife Computers SPLASH10 309A, SPLASH10-BF 297B and SPOT5 model satellite tags were used to track the spatial movements of individual turtles (i.e. depth, temperature, distance, location, etc.). Extensive satellite tagging of green sea turtles has been conducted by the Sea Turtle Conservancy and other organizations in the Tortuguero region of Costa Rica, just south of the Nicaraguan border (STC, 2015). These tagging efforts have revealed a great deal about the movements of the region's population. SPLASH10 309A tags generate low-resolution location data through the ARGOS satellite system and collect data on temperature and depth. SPLASH10-BF 297B tags can collect higher resolution location data using their Fastloc system that uses GPS technology for determining location. They are also able to collect data on temperature but not depth. SPOT5 tags collect low-resolution location data and no depth data but tend to have longer battery lives than SPLASH tags (Holmes, unpublished data, 2015).

The satellite tags were attached using Devcon© 5 minute Epoxy with fiberglass and Loctite Fixmaster Metal Magic Steel ™, following a protocol developed by the New England Aquarium Rescue Department and the Northeast Region Stranding Network for Rehabilitated Hard-shelled Turtles (Wildlife Computers, 2012). First, satellite tags were programmed using software from Wildlife Computers. The Project Coordinator also received technical aid and guidance from Katherine Holmes (WCS, New York) when setting up and learning how to deploy the tags. An instructional guide was developed for future tagging efforts by the Project Coordinator, that contribute to a more comprehensive satellite tag process document developed by WCS (Holmes, unpublished data, 2015).

INCENTIVE PROGRAM - DONATION OF LIVE TURTLES

The "Donate A Turtle" incentive program began in 2009 and was used to encourages fishers and residents to donate live marine turtles to the project for tag and release. A WCS t-shirt was given for each turtle donated to the project and a life jacket for every 15th 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". The program was also promoted in monthly radio announcements and through regular interpersonal communications with fishers and residents.

QUALITY CONTROL OF DATA

Data in 2014 went through several quality control checks to ensure accuracy. When in the field, the data recorder and one other team member checked all data for completeness and legibility. Then, the team leader, with the help of another team member, checked the data again that night when transferring nest data to the Nest Check Book. The Project Coordinator checked data opportunistically when in the field

and then systematically for each variable when entering the data into the Excel database, often with another team member when in the field, resolving any issues with team as soon as possible. Finally, a team member and the Project Coordinator reviewed all electronic databases, cross-referencing them with field books as a final proofing measure at the end of the season. Data for the report was analysed using the Microsoft Office Suite Excel Program (Microsoft, 2003) and R Statistical Software Package (R, 2015).

RESULTS

NESTING BEACH SURVEYS

SURVEY EFFORT

Eight candidates (five men and three women) were selected to work for the project from the 15 candidates who attended the training workshop in 2014. The teams included: Rick Hansack, Keffrey McCoy, Claudia Forbes, Mikle Allen, Byron "Coco" Blandon, Isolett Garth, Antony Sambola, Roy Julio and Darson Humphries (left halfway through the season), representing three local communities in the Pearl Lagoon basin: Haulover, Lafé and Pearl Lagoon. Surveys conducted in the 2014 season were classified as either daily surveys during the intensive monitoring period (IMP) (17 June – 7 December) or opportunistic surveys outside the IMP (10 & 21 May, 3 & 8 June, and 20 December 2014; 2 & 25 February 2015). The IMP was 174 days long, during which time teams worked a total of 699.03 hours (mean=4.02 hours per day, range=2.56-5.07) (Figure 6).

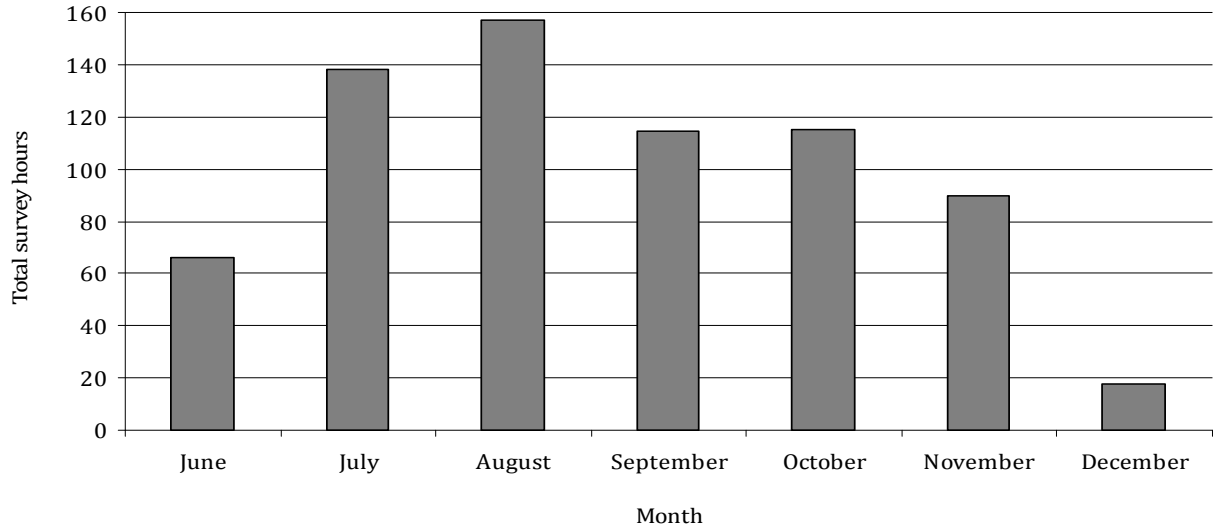

Figure 6. Total survey hours per month during the Intensive Monitoring Period (IMP) for 2014.

A total of 1,153 cay-surveys (defined as each time a cay was surveyed) were conducted in the IMP. A mean of 6.6 cays were visited per day every month during the IMP, averaging six or more cays visited per day each month except for December, when poor weather limited access to multiple cays. An additional seven surveys were conducted opportunistically before and after the IMP, totalling 50 cay-surveys (mean= 7.14 cays). Mean survey effort during the four outings was 5.11 hours. In December and February, opportunistic surveys were conducted to perform excavations, which required longer cay visits.

NESTING ACTIVITY

In 2014, the greatest number of clutches in project history was recorded with 475 clutches. The first clutch captured in the study was laid on 5 May and the last on 12 December, both on Water cay. The temporal distribution of clutches conformed to past project seasons, with peaks in July (n=136) and August (n=121), based on estimated and confirmed lay months (Figure 7). Lay dates for 51 nests found by signs of hatching (FBD=Found By Depression), were estimated using the mean incubation period in 2014, which was 66 days (SD=5, range=55-82, n=209).

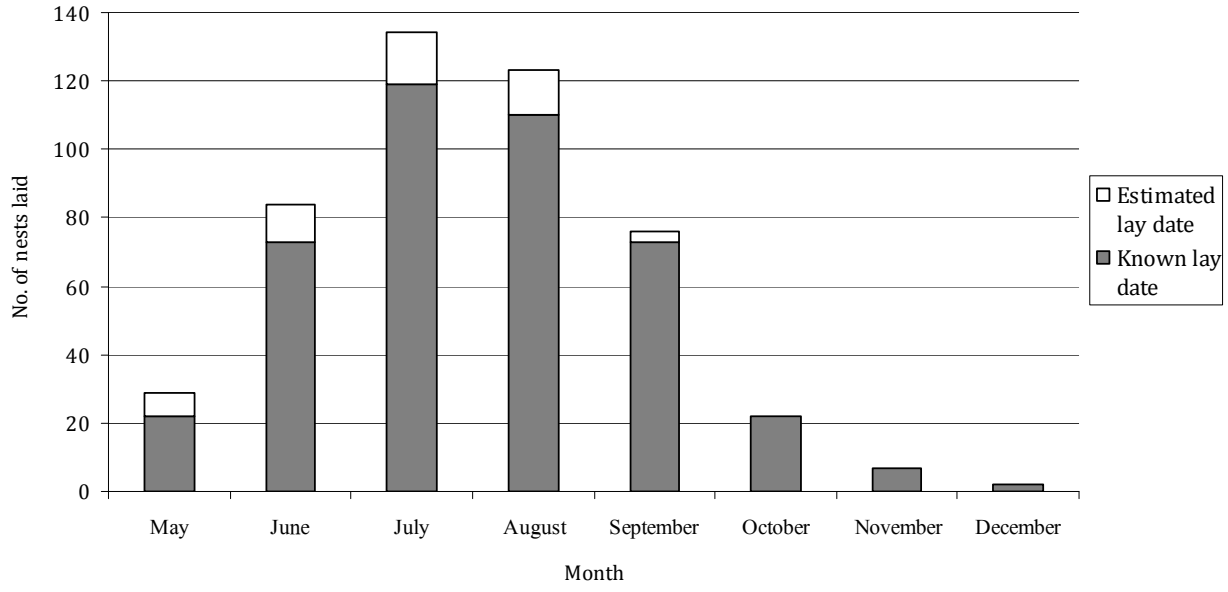

Figure 7. Number of hawksbill clutches laid per month in 2014.

Teams confirmed exact lay dates for 358 clutches (75.4% of all nests) to accurately calculate incubation periods and excavation dates. There was a significant positive relationship between the number of clutches recorded and the number of years since initiation of the project ($r=0.8528$, $p<0.001$, Figure 8). The number of clutches laid in 2014 represented a 41.4% increase from 2013, and a 208.4% increase from the first year of the project (2000). The mean percentage of increase in total clutches laid per season over 15 years of the project was 9.9%. The majority of clutches (56%) laid in 2014 were located on two cays

(Table 3). Wild Cane cay had the greatest number of clutches with 145 (30.5%), followed by Water cay with 121 (25.5%).

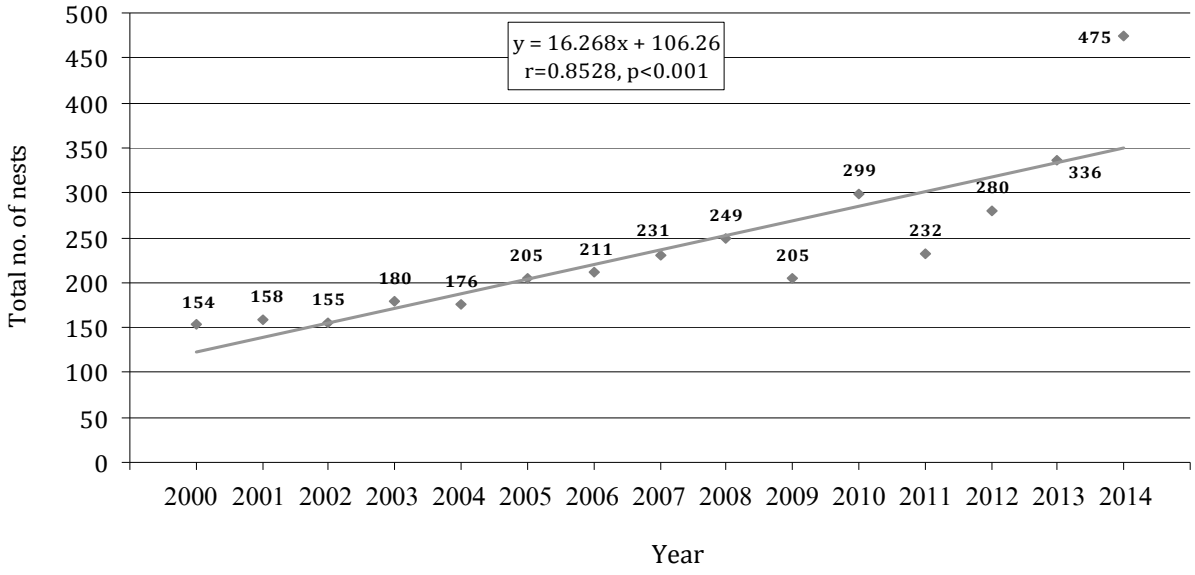

Figure 8. Trend in hawksbill nesting on the Pearl Cays from 2000 - 2014

Table 3 – Spatial distribution of total, FBD and moved clutches for the 2014 season.

Cay	No. of clutches	Percentage of total clutches (%)	No. clutches FBD	No. of clutches moved
Baboon	40	8.4	5	20
Bottom Tawira	11	2.3	4	1
Buttonwood	4	0.8	1	0
Columbilla	25	5.3	0	20
Crawl	46	9.7	5	9
Grape	39	8.2	2	19
Lime	37	7.8	3	4
Maroon	2	0.4	1	1
Vincent	5	1.1	0	2
Water	121	25.5	10	74
Wild Cane	145	30.5	20	36
TOTAL	475	100.0	51	186

No clutches were recorded on Black Mangrove cay. Of the 475 clutches, 289 (60.8%) were left *in situ* (10 with Temperature Loggers and 279 without) and 186 were relocated. Clutches were relocated when significant mortality threats were posed by inundation (n=118), poaching (n=44) or predation (n=10). The second lowest poaching rate in project history was recorded in 2014 (Figure 9). There were 28 (5.9%) clutches affected by poaching during the 2014 nesting season: five partially poached clutches with some eggs remaining to incubate and 23 (4.8%) clutches completely poached (Figure 10). Ten of the 23

completely taken nests (43.5%) occurred prior to daily monitoring. For the five partially poached nests, between four and 190 eggs remained in clutches for incubation, and a total of 333 hatchlings were estimated to have emerged from these nests.

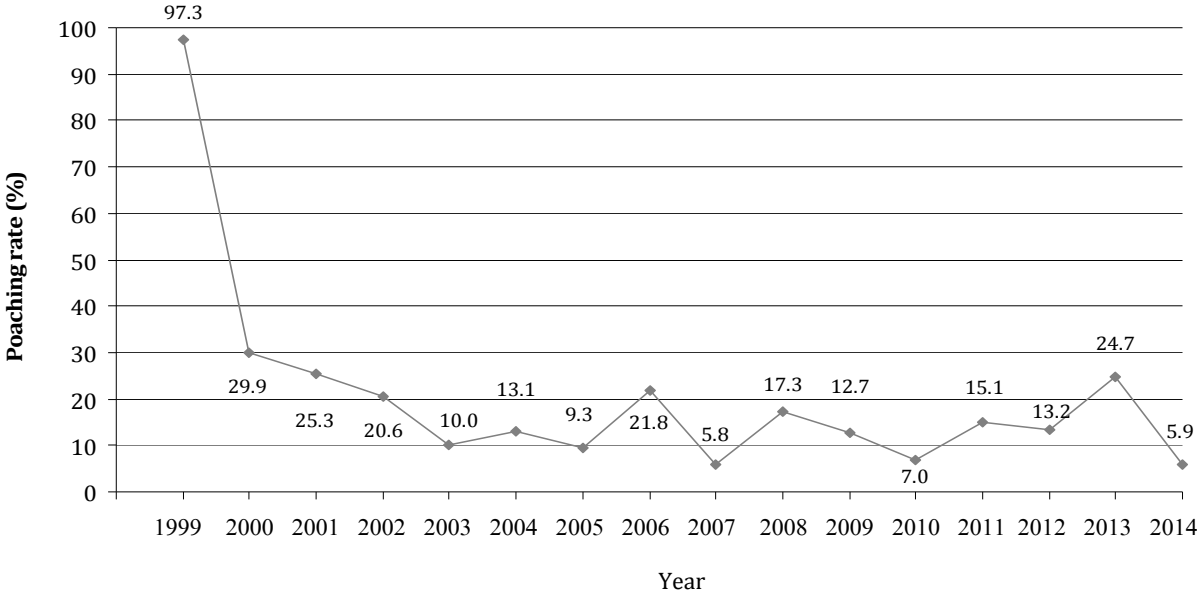

Figure 9. Poaching rate from preliminary study in 1999 to project duration 2000-2014.

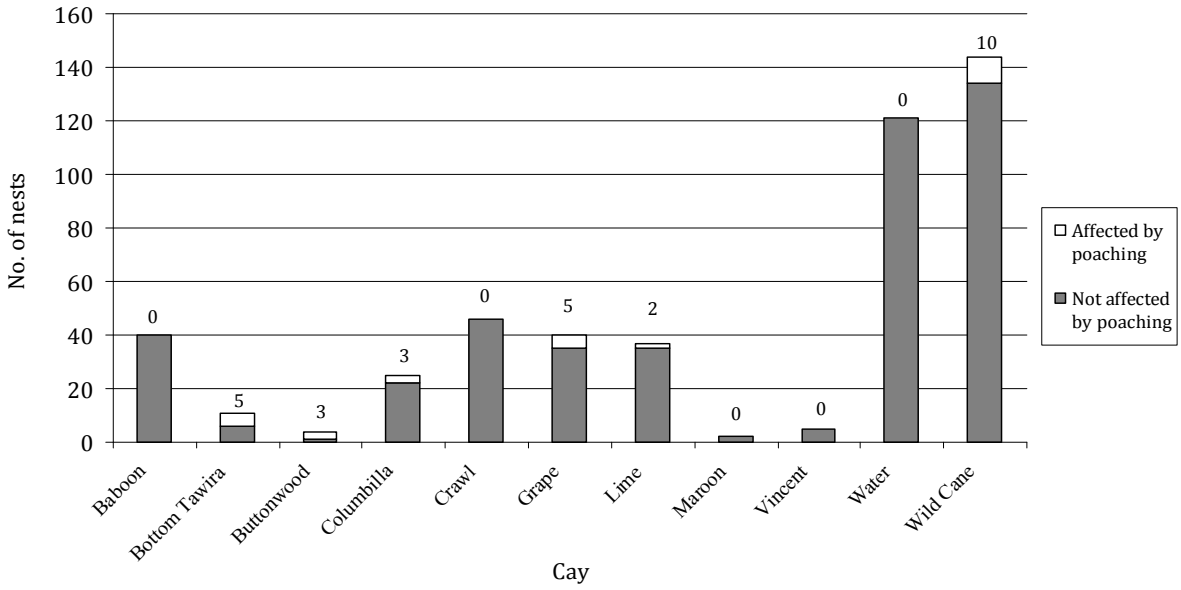

Figure 10. Number of nests affected by poaching in total nest count per cay in 2014.

Clutch sizes were determined by using data from relocated clutch counts for those not suspected or observed to have evidence of poaching or predation before teams arrived to relocate the nest (n=181). The mean clutch size was 152.84 yolked eggs (SD=36.73, range=12-232) and less than one yolkless egg (mean=0.51, SD=0.98, range=0-5). Relocated clutches had a mean *in situ* nest depth of 43.0cm (SD=5.0, range=31-56, n=184). All *in situ* locations for nests (including those left *in situ*, later relocated or taken) had a mean straight distance from the center of the nest cavity to the most recent high tide line of 5.15m (SD=3.12, range=0.45-22.10, n=475). The mean crawl length from the high tide to the centre of each clutch was 8.96m (SD=8.36, range=1.12-77.92, n=180). An accurate crawl length could not be measured unless the entire up-track was visible to teams. In some cases, the track was difficult to locate due to heavy rains, tides, vegetation, or human activity on the cay.

The vast majority (78.5%) of females laid their nests in the upper beach vertical zone, with 12.9% laying in the open beach zone and 8.6% laying in the inside zone. Although there were a large number of nests laid in beach or upper beach zones with no vegetative cover (n=147), the majority of nesting females chose to lay in areas with some or full vegetative cover (n=306, 64.4%). The most preferred nesting sites in 2014 were in the upper beach zone with full vegetative coverage (n=164, 34.5%). Nests meeting criteria to be relocated (n=186) were most often in the upper beach (n=123, 66.1%) or beach (n=54, 29.0%) zones. These nests were moved to other upper beach (n=121) or Inside zone (n=65) locations with reduced threat of inundation, predation, or poaching.

A total of 73 tracks and 401 tests were recorded in 2014. Mean crawl length for all tracks was 6.42m (SD=6.92, n=73). Within the 401 total tests, there were 196 separate test events that included between one and 11 attempted egg chambers per event. There were 27 clutches laid that were linked to at least one test. Mean crawl length from the most recent high tide line to all first tests was 8.10m (SD=5.16, n=101).

NEST CONDITION MONITORING

Nest condition (environmental and anthropogenic) was checked for each nest during each cay-survey. Clutches incubating on Baboon, Crawl, Grape, Lime, Vincent, and Wild Cane cays (n=300) were checked almost daily during the IMP, while clutches on Water cay (n=121) were checked less regularly, and clutches on Bottom Tawira, Buttonwood, Columbilla, and Maroon cays (n=31) were checked even less frequently. Consistency in monitoring was based on access to cays, with the latter five cays being more difficult to access in windy/rough weather conditions.

Clutches that were monitored during the majority or entire duration of their incubation period (n=377) were used in the following analysis. Clutches laid outside the IMP (May, mid to end-October, November and December, n=62), FBD clutches within the allowed period (n=34), and clutches where confusion by team resulting in an absence of adequate monitoring (n=2) were excluded from the analysis. All poached (n=23) and partially poached (n=5) nests were included in the analysis, regardless of date found. For those nests monitored, the vast majority (n=299, 79.3%) were visibly undisturbed by any environmental or human impacts during the incubation period. Three nests were fully predated (0.8%), 29 nests were partially predated (7.7%), three nests were completely eroded (0.8%) and 16 nests were flood-affected (by tides) (4.2%) during the 2014 season (Figure 11).

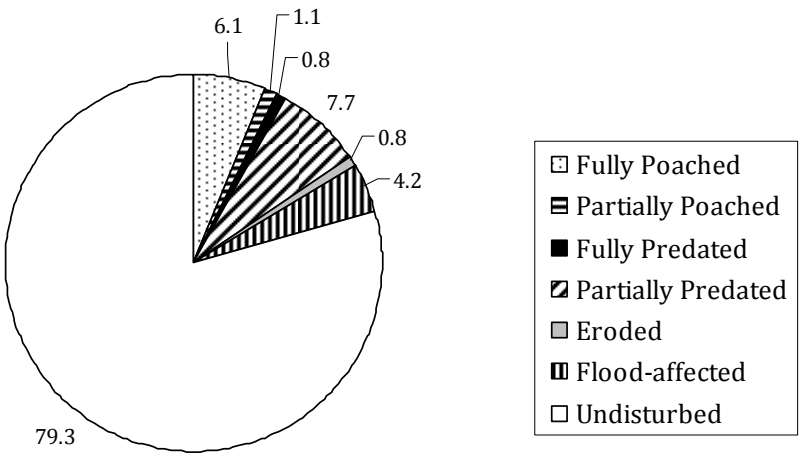

Figure 11. Percentage of fully monitored nests (n=377) with observed environmental or human impacts in 2014.

NEST SUCCESS

A total of 446 excavations were conducted for the 2014 season. The 23 taken, three eroded, and three nests that could not be located post-emergence were not excavated (the latter are labelled as 'lost'). Along with total nest success results, clutches were analysed using four status categories: *in situ*, *in situ* nests with temperature loggers, relocated and FBD (Figure 12). Relocated clutches with a difference in total yolked egg count between relocation and excavation that was greater than 15 were left out of the analyses, as well as any clutches suspected of unrecorded animal predation or those not able to be monitored for the majority of their incubation period (aside from those relocated nests with 15 or less difference between relocated and excavation total yolked egg count) (n=124).

For those clutches where at least one egg hatched, hatching success (HS) and emerging success (ES) were respectively 72.8% and 72.4% (not including FBD nests, n=282, range=1.3-100%). For clutches left *in situ* without temperature loggers, HS was 69.4% and the ES was 69.0% (n=171). For relocated clutches, HS was 65.8% and ES was 65.4% (n=125). Clutches left *in situ* with temperature loggers inserted in nests had a HS of 63.6% and an ES of 63.5% (n=7), however one clutch with a temperature logger was completely predated. For FBD clutches, HS was 83.1% and ES was 81.1% (n=48). These nests were not monitored throughout the incubation period, thus hatching success and emerging success calculated in this report could be misrepresentative (more positive).

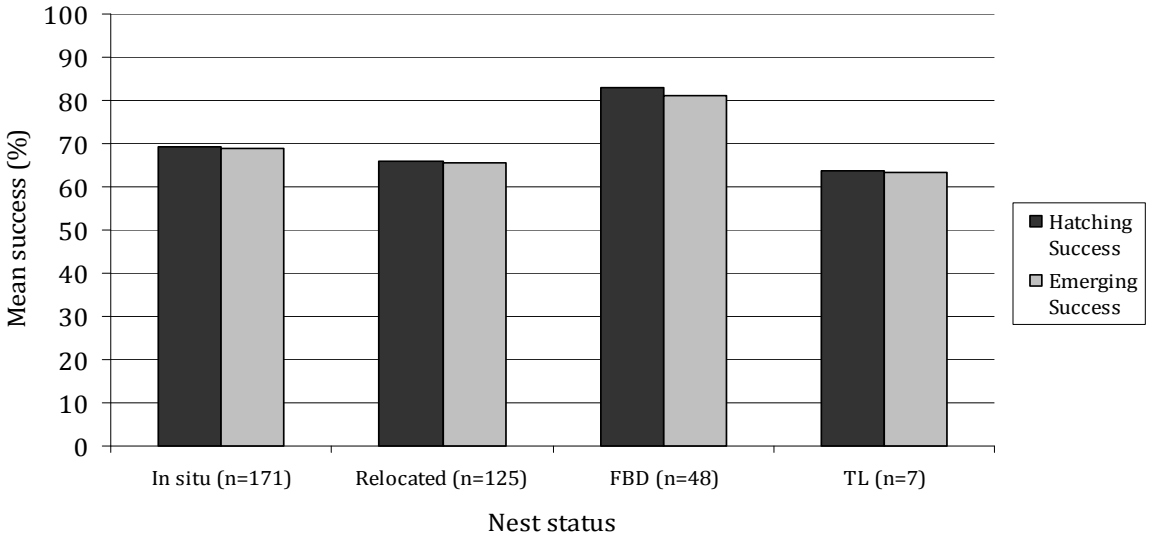

Figure 12. Mean hatching and emerging success per clutch status in the 2014 season

Between *in situ* and relocated nests, HS was not significant (Mann-Whitney, U=12,063.5, p=0.2115), nor was ES (Mann-Whitney, U=16,411.5, p=0.01202). When analysing correlations between spatial and temporal variables and both HS and ES, there were low levels of correlation only for navigational side of cay and the lay-month (VIF=0.24 for side and VIF=0.23 for lay-month). Those clutches laid in October and November had lower mean success rates than other months, albeit lower absolute number of clutches as well (Figure 13).

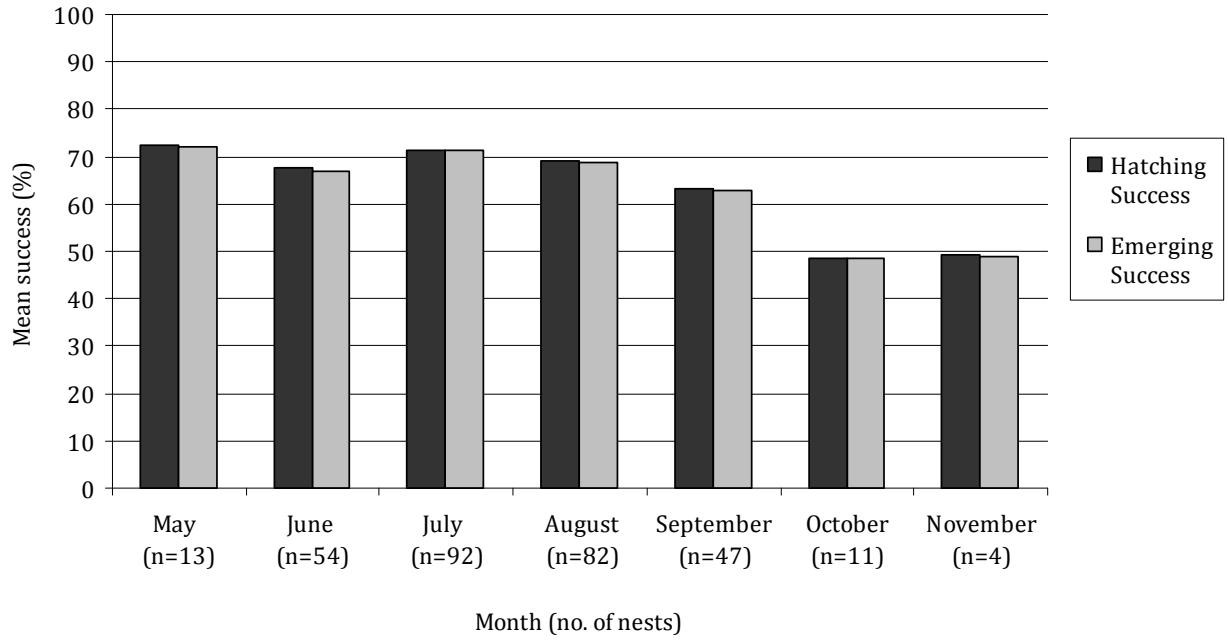

Figure 13. Mean hatching and emerging success by lay month for the 2014 season.

Results of HS and ES for relocated and *in situ* nests by cay are described in Figure 14. The greatest success results were found for *in situ* clutches on Grape cay (HS=82.4%, ES=82.2%) and for relocated nests on Lime cay (HS and ES=79.3%). Lowest success results were found for *in situ* clutches on Crawl cay (HS=61.7%, ES=61.6%) and for relocated clutches on Baboon cay (HS=57.4%, ES=57.1%). *In situ* clutches on Baboon, Grape and Water cay (n=13, 12, 29 respectively) had higher success than relocated nests (n=14, 8, 56 respectively), while *in situ* clutches on Crawl, Lime and Wild Cane cays (n=30, 20, 71 respectively) had lower success than relocated clutches (n=5, 2, 24 respectively). Mean ES for *in situ* and relocated clutches was as follows: Lime=73.7%, Water=73.4%, Grape=72.1%, Wild Cane=69.6%, Baboon=66.7% and Crawl=62.9%.

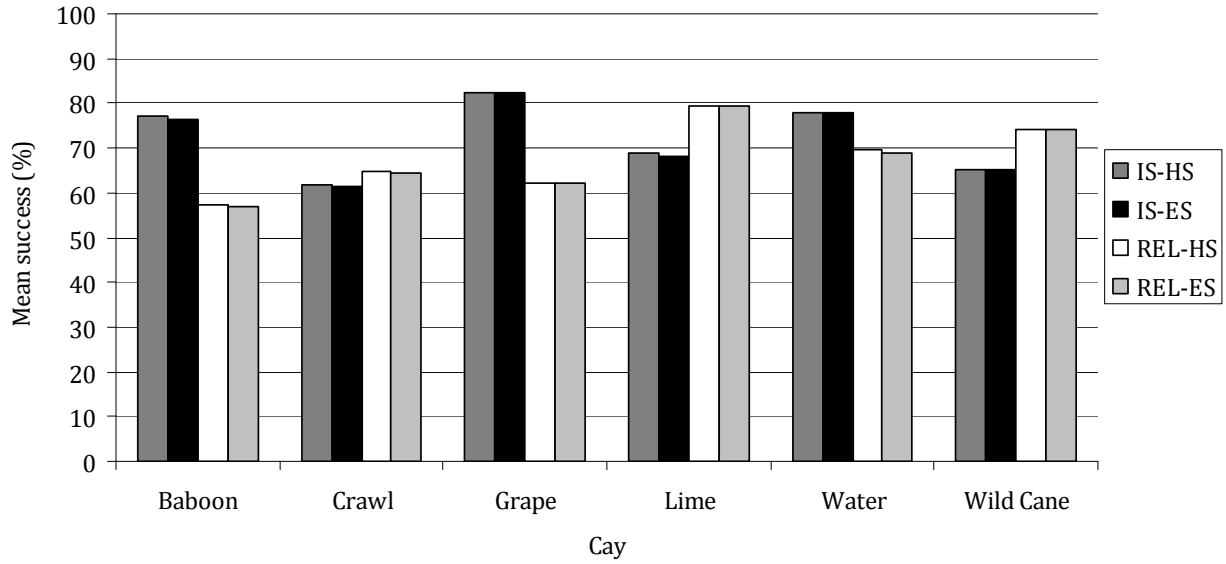

Figure 14. 2014 hatching success (HS) and emerging success (ES) for *in situ* (IS) and relocated (REL) nests by cay.

Based on the number of empty egg shells >50% found during excavations, a minimum of approximately 42,934 hatchlings were produced in 2014. It is difficult to give an exact number due to some nests being eroded or lost. Also, eggshell fragments <50% present in the majority of nests could not be counted as whole empty egg shells since they could be from an additional unknown number of hatched-out eggs. In the 15 year monitoring program, the 2014 season recorded the greatest number of hatchlings estimated to have been produced in a single season (Figure 15).

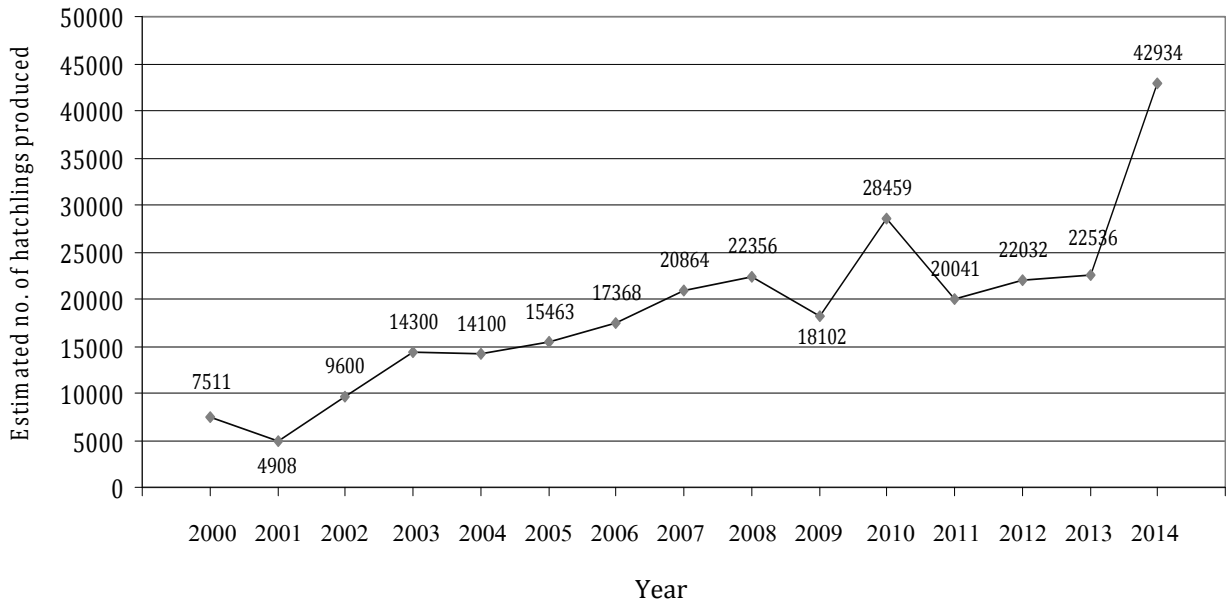

Figure 15. Estimated minimum number of hatchlings produced per year from 2000-2014.

POPULATION SIZE STUDY

WCS staff collected 403 fresh eggshells during surveys in 2014, representing a sample of ~85% of the total clutches recorded for the season. Twelve tissue samples were also collected from individual turtles tagged and measured in 2014. Eggshell and tissue samples were picked up in late February 2015 by the CITES permit holder to be processed and analyzed out of country.

HUMAN ACTIVITIES SURVEYS

Data on human activities were collected on every cay-survey. Six of the 11 cays monitored were permanently inhabited (Baboon, Crawl, Grape, Lime, Water, and Bottom Tawira), three of the cays were frequently inhabited by residents or fishermen (Buttonwood, Columbilla, and Wild Cane) and two cays were not observed to be inhabited (Maroon and Vincent) during the IMP, leading to uniform observations of each cay-survey for Baboon, Crawl, Grape, Lime, and Water cays. In addition, the WCS survey team (four to eight people) inhabited Crawl from 15 June to 7 December. WCS staff were excluded from the number of people observed per cay-survey, however construction of the base camp and any burning events were included.

Bottom Tawira recorded the highest mean number of observations for people per cay-survey (11.4), with Water and Crawl second and third highest (3.3 and 3.0, respectively; Figure 16). The highest mean

number of dog observations was also on Bottom Tawira (5.9), followed by Water (2.0). Mean observations of chickens were highest on Baboon and Crawl (7.2 for both), followed by Lime (5.8). Maroon and Vincent had no observations of any human activity during the IMP. A total of 69 burn events, six cutting events, one instance of taking sand and 22 instances of construction were observed during the IMP. Large areas of Baboon, Crawl, Grape, Lime, and Water continue to be raked/"cleared" regularly, impeding the new growth and regeneration of native vegetation that could help secure/stabilize the substrate in nesting areas.

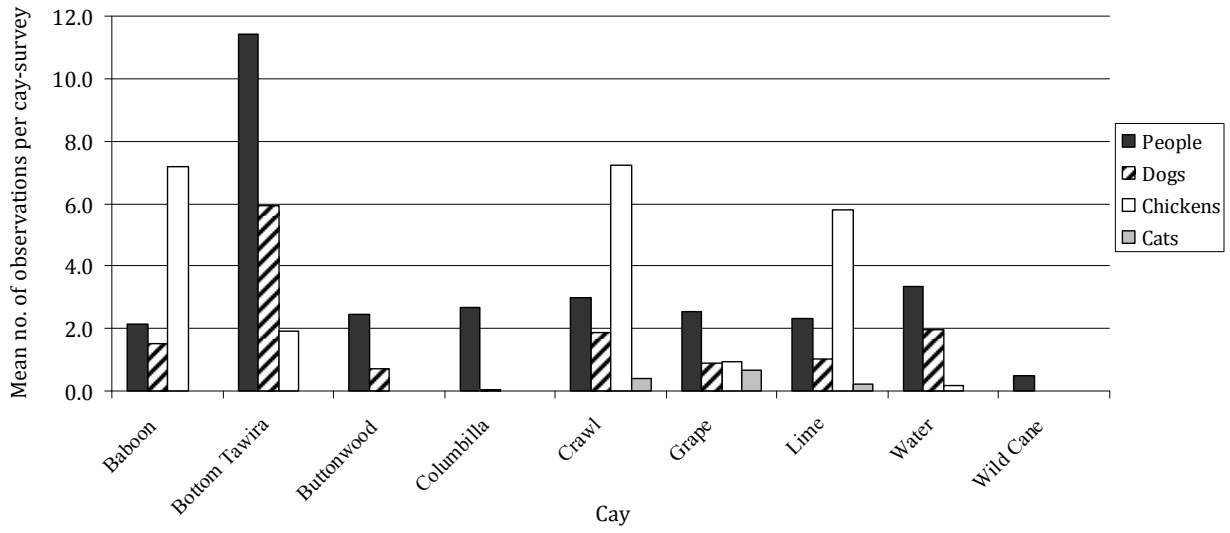

Figure 16. Mean number of human and animal observations per cay-survey in 2014.

Although not observed on every cay-survey in 2014, an anecdotal summary of consistent human and animal presence on the most frequently surveyed cays was as follows:

- **Baboon**: one watchman (occasionally with family) with two dogs and multiple chickens, occasional tourists
- **Columbilla**: frequent groups of turtle fishermen camped out for a number of days
- **Crawl**: one watchman or the watchman's son and wife with two dogs, one cat and multiple chickens, frequent tourists
- **Grape**: one watchman with his wife and child, with one dog, two cats and a few chickens, occasional foreign residents
- **Lime:** one watchman, occasionally with family, with one dog, two cats and multiple chickens, occasional tourists and rarely residents
- **Water**: two watchmen with two dogs, occasional local residents
- **Wild Cane**: rarely groups of fishermen camped out

Police joined WCS teams for three shifts at the start of the season, one shift in the middle of the season, and one shift near the end of the season. During this time they issued warnings to individuals suspected of poaching on Bottom Tawira and Grape cays.

TEMPERATURE LOGGERS

At least two baseline temperature loggers (TLs) were placed on each cay on 17-19 June, 2014, with a total of 30 baseline TLs put in. Ten paired nest TLs were placed from 19 June until 8 October. The in-nest temperature logger of the paired nest loggers were all removed during excavations for the 10 sampled nests. The remaining other 10 paired and the 30 baseline temperature loggers were removed on 18 February 2015. Data will be analysed by Dr. Thane Wibbels' lab at the University of Alabama at Birmingham.

TAG AND RELEASE PROGRAM

FLIPPER TAGGING

A total of 24 encounters with turtles were recorded in 2014. Five were juveniles (one green (*Chelonia mydas*) and four hawksbills (*Eretmochelys imbricata*)) and 19 were adults (two greens and 17 hawksbills, Figures 17-18). Of the 17 hawksbill adults, nine were new recruits (REC – not previously tagged), six were remigrants (REM – previously tagged by the WCS or other project) and two were re-nesters (REN – recorded nesting more than once in a single season) from the 2014 season. Unfortunately, one juvenile hawksbill was found dead in an abandoned fishing net off the coast of Baboon, one donated juvenile green died before release (suspected injury from fishing lines it was caught in) and four individuals (two REM and two REC) were not recorded in detail for inclusion in this report due to absence of core WCS staff upon their encounter. Adult female hawksbills (REC and REM, n=10) encountered had a mean straight carapace length (notch to notch) of 79.61cm (SD=3.71, range=71.6-84.0) and a mean straight carapace width of 58.75cm (SD=4.34, range=51.0-66.6).

Figures 17-18 – Project Coordinator implants a Passive Integrated Transponder (PIT) tag (left), team members and police officer watch a turtle finish covering her nest on Baboon (right).

Available data from 1999 to 2011 and 2014 were used to track and present some of the nesting activity for four of the REM hawksbills encountered in the 2014 season (Table 5).

Table 5. Historical encounter activity of four hawksbill re-migrants encountered in 2014.

Turtle ID	Age class/Sex	First tagging date	Location	Subsequent encounters	Location
H5613	Adult/Female	2004: 10 August	Crawl Cay	2007: 27 August	Crawl Cay
				25 September	Crawl Cay
				2011: 28 July	Crawl Cay
				22 August	Crawl Cay
				3 September	Crawl Cay
				16 September	Crawl Cay
				17 September	Crawl Cay
				2014: 9 September	Crawl Cay
H6227	Adult/Female	2006: 11 September	Water Cay	2009: 11 July	Water Cay
				28 July	Water Cay
				29 July	Water Cay
				27 August	Grape Cay
				10 September	Grape Cay
				2011: 8 July	Water Cay
				23 July	Water Cay
				6 August	Water Cay
				2014: 24 September	Water Cay
H6677	Adult/Female	2008: 6 July	Wild Cane Cay	2008: 5 August	Baboon Cay
				9 August	Columbilla Cay
				2014: 9 July	In water
H8497	Adult/Female	2010: 17 August	Water Cay	2014: 29 July	Grape Cay

SATELLITE TAGGING

Three satellite tags (Wildlife Computer SPLASH10 309A, SPLASH10-BF 297B, and SPOT5 models) were deployed on individual nesting hawksbill turtles in the Pearl Cays in 2014 (Figures 19-22). Night patrols were conducted opportunistically on five separate occasions on multiple cays to locate candidates for satellite tags. The standard process for tagging and morphometric data collection was followed (Irvine, 2014), along with the satellite tagging. Data collection is ongoing and results may be shared when available.

Figures 19-22. Team 2 with the first recipient of a satellite tag: 'Sally' (top left), Project Coordinator demonstrates how to attach satellite tag (top right) 'Stephi' going to sea with her satellite tag (bottom left), Team 1 with satellite tagged 'Shaan' (bottom right)

INCENTIVES PROGRAM

DONATION OF LIVE TURTLES

The WCS team continued to encourage fishers, watchmen, and divers to donate live turtles in exchange for a WCS t-shirt, or a lifejacket for every 15th donation by the same individual. Donated turtles were then tagged and released. To date, there have been over 1000 t-shirts and 18 life jackets rewarded for turtle donations throughout the project's 15-years. In the 2014 season, there were 17 live sea turtle donations, 1 of which one was a juvenile green turtle and 16 were hawksbills (four juveniles and 12 adult nesting females). The five juvenile turtles were caught at sea, and the 12 adults were caught as they were returning to the sea after nesting. The greatest number of turtles donated by a single participant in 2014 between July and September was eight (one of which – 'Stephi' – was a recipient of a satellite tag).

ALTERNATIVE LIVELIHOODS PROGRAM

In 2014, WCS staff continued to support Kabu Tours (www.kabutours.com), the alternative livelihoods project that promotes the transition from turtle harvesting to ecotourism. The Project Coordinator gave talks to visiting tourists, demonstrated field activities with ecotourism staff and tourists (Figure 23), and answered numerous questions about sea turtle biology, project work, and local conservation efforts. In addition, the Project Coordinator helped to provide educational and outreach scripts for the Kabu Tours 'Island Walk' activity (where tour guides take guests around Crawl to share information about the local environment and conservation), provided regular feedback on company promotional materials, and offered logistical support throughout the year.

Figure 23. WCS team demonstrates how to conduct nest relocations for Kabu Tours staff.

AWARENESS AND OUTREACH

WCS staff regularly shared information with local communities, authorities, and tourists. These activities were done through a variety of mediums and in four different languages (English, Spanish, Creole and French), in order to reach a large and diverse audience.

RADIO ANNOUNCEMENTS

Monthly radio announcements were aired to share progress about the project, thank staff members and collaborators, re-emphasize the importance of participatory conservation efforts in the Pearl Cays Wildlife Refuge, and to remind residents of the law prohibiting the harvest of hawksbill turtle eggs, meat and scutes. These announcements were made by the Project Coordinator and one of the team leaders, or

by the Field Supervisor. Where possible, announcements were made in Creole, English and Spanish. We aimed to go on the air at the busiest listening times of the day to increase the likelihood of reaching more people at once. The project was also mentioned on the Coast Hour, one of the most popular radio shows on the Caribbean coast of Nicaragua, when teams called in to radio shows to share information about the project and acknowledge team members in the field. Radio announcements were aired before the 2014 season began to encourage people to apply for WCS seasonal staff positions.

NEST TALLY SIGN

After the first month of the intensive monitoring period, the Project Coordinator designed a sign to hang out front of the WCS office in Pearl Lagoon to update people passing by about the 2014 season's running nest tally (Figure 24). Throughout the season, local community members and visiting tourists were regularly seen reading or commenting on the sign. The running count allowed people to track nesting in real time. Team members updated the sign when in from the field, which boosted staff moral and made teams feel proud to have worked an increasing amount of nests each rotation. When the project broke the all-time record for number of nests in a season, both teams came to the WCS office to celebrate and change the sign together. The sign often sparked discussion and comments from people passing by and even motivated some people to come into the office and learn more about the project. It was a simple yet effective tool for disseminating information.

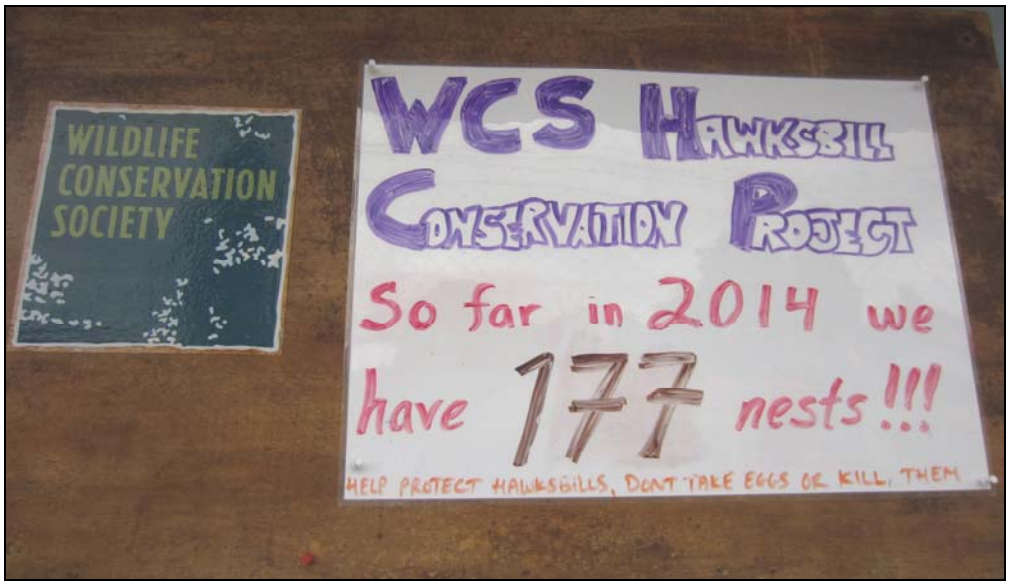

Figure 24. Nest tally sign in front of the WCS office in Pearl Lagoon in July 2014.

TOURIST OUTREACH ACTIVITIES

Throughout the 2014 nesting season, national and international tourists visited Pearl Lagoon and the Pearl Cays. Formal presentations or informal discussions about the hawksbill conservation project were held with 165 tourists between June 2014 and March 2015 (Figure 25). Excursions booked through Kabu Tours included a stop at the WCS office, where WCS staff would explain the hawksbill conservation project and WCS conservation efforts to visitors. Since the vast majority of tourists going to the cays visited Crawl cay where the project base camp is located, WCS staff had opportunities to share information about the project. Staff gave tourists a summary of the project history, outlined the project activities and objectives, shared statistics about the season (current number of nests, how many nests have hatched, nests on any particular cay, etc.), listed local and international threats to sea turtles, and talked about the importance of local and global sea turtle conservation efforts. This was done either formally with a PowerPoint presentation in the WCS office, or informally through discussions in various environments. Communications were provided in English, Creole, Spanish and French.

Based on qualitative data collected during these interactions, many tourists came to the Pearl Cays specifically to see turtles. Wherever possible, tourists would be invited to join staff on surveys of Crawl for live demonstrations of project activities. Many tourists and local watchmen also observed nest excavations, nest hatch-outs, recording of new nests, and even the satellite tagging process. The numbers in Figure 25 are slightly underestimated due to insufficient reporting of all interactions in the field when Project Coordinator not present.

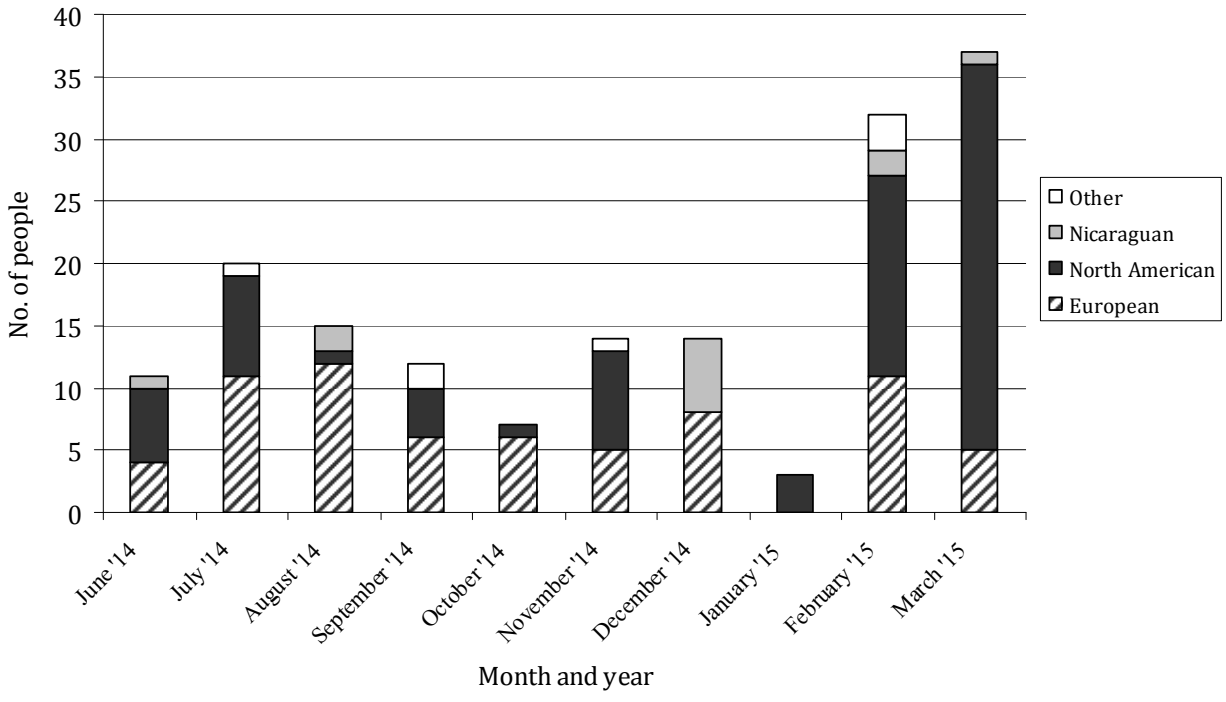

Figure 25. Number of tourists by nationality that received outreach about the WCS hawksbill project each month.

LOCAL OUTREACH ACTIVITIES

A variety of different initiatives were undertaken by WCS staff to participate in information sharing or education within the local communities. WCS staff was able to respond to a call from a local fisher in Kahkabilla who had a juvenile green turtle caught as bycatch in the lagoon. When brining the turtle back to Pearl Lagoon, it caught the attention of ~25 local children in Kahkabilla and Pearl Lagoon (Figure 26). For each group of interested youngsters, the Project Coordinator explained what had happened, efforts for conservation for sea turtles in the area, and encouraged children to protect and care for sea turtles.

WCS Marine Coordinator, Pamela Fletcher, took part in the Pearl Lagoon Youth Environment Club in the summer of 2014, run by local PeaceCorps volunteer Geri Mezzoni. She provided materials for environment-related educational activities and participated in meetings where environmental education was the main topic for the day. Plans to interact with children on sea turtle conservation education activities in schools in the off-season are in place, including an Earth Day presentation as well as formal workshops ('charlas') in classrooms in Pearl Lagoon and Haulover.

Figure 26. Talking turtles with children in Kahkabilla

At the end of the intensive monitoring season (December), WCS seasonal staff members were given a short presentation on summarized seasonal data that they helped collect. This included general data summaries of the main variables of the surveys (number of nests, poaching rate, breakdown of nests by cay, number of days worked, number of excavations led, number of nests moved, etc.), as well as a team by team breakdown for these variables to determine the 'winners' for the season. The WCS seasonal staff members were given an anonymous evaluation form to fill in so the Project Coordinator and Field Supervisor could obtain feedback and improve efforts in 2015. Presentations were prepared on the results of the season, hawksbill biology, and hawksbill conservation issues for local communities, local and regional authorities (specifically MARENA and SERENA), and members of the Nicaragua National Police for May 2015. The proposed dissemination plan in communities is supported by WCS seasonal

staff as project ambassadors. The Project Coordinator also designed a project brochure as an additional outreach material.

In another attempt to spread the word about the project and conservation, WCS sponsored two large billboard spaces on the back wall of the local Pearl Lagoon baseball stadium. There is a lot of visibility in the stadium from local people, as well as many Nicaraguan and international visitors, throughout the regular season. WCS renewed the rental of these spaces, as well as cleaned and touched up our two paintings before the playoffs, as they were held in Pearl Lagoon this year.

OTHER INFORMATION-SHARING ACTIVITIES

The Project Coordinator submitted monthly reports throughout the season, which included data and activity summaries for all project work. Reports had the same structure throughout, for easier reading. They began with a summary of highlights, followed by more detailed outlines of data for nesting activity, human activities, nest success/excavations, survey effort, outreach activities and any other activities completed by the Project Coordinator that month. These documents were further summarized for reports to WCS headquarters in New York by the Marine Program Coordinator.

Information about the hawksbill project achievements and progress were also shared with an international audience in 2014 and 2015. A project photo of a hatchling going to sea on Water was featured on the WCS website homepage, with a link to a December Facebook post that had over 2,100 likes and ~350 shares (including being shared by the Ocean Conservancy, United Nations Environment Programme – Caribbean Environment Programme, USAID, Eco Central America, Nature Caribé, and many other turtle and conservation enthusiasts around the world). In addition to this incredible opportunity to share project information, the WCS President and CEO Dr. Chistián Samper, referenced the Nicaragua hawksbill project as a success story in his 2015 article in The Huffington Post (Samper, 2015). In this article, a photo and description of the project success were shared to an international audience. The project photo of a nesting female hawksbill going back to sea on Baboon cay was chosen as the thumbnail photo to represent the article when shared on Facebook. On the David Suzuki Foundation website alone, the article reached over 1,200 likes and received almost 500 shares. The Sea Turtle Conservancy, with 161,240 people following their Facebook page, shared another similar article about the project posted by Mongabay on 28 January 2015. The project was mentioned in at least 12 international articles between December 2014 and January 2015. Using this same information, WCS NY created a video posted on YouTube in January 2015 that described the project history and success. This video was narrated by Caleb McClennen, Director of Marine Programs at WCS (https://www.youtube.com/watch?v=FGefBU_03f0), and titled "Hawksbill Sea Turtle Numbers in Nicaragua Explode". Photos of the project are also in contention for the WCS Gala invitation and will be displayed during the slide show at the event, which will be held in June 2015.

During a visit to WCS Canada in December 2014, the Project Coordinator shared information about the hawksbill project and other efforts in Nicaragua, also hearing a summary of WCS Canada work. She was also asked to contribute an editorial for the WCS Canada blog "Muddy Boots", which was published on their website on 12 March 2015 (http://muddybootswcs.blogspot.ca/2015/03/wcs-in-nicaragua-canadian-scientist.html), along with an announcement on Twitter and Facebook. The blog entry details the hawksbill conservation project, sea turtle conservation, and insights from a Canadian working for sea

turtle conservation abroad in Nicaragua. The entry was also circulated on the WCS Marine Program list serve by Kaitlyn Septon (WCS NY).

Finally, the Project Coordinator and other WCS support staff have started creating and populating a WCS Nicaragua website prototype, based on WCS templates used for other programs around the world. This website has detailed information on Nicaragua's wild places and species in focus, as well as project history, publications, reports, links for fundraising, partnerships, games and other pertinent information that to increase awareness and education about WCS conservation work in Nicaragua.

DISCUSSION AND RECOMMENDATIONS

The 2014 season was record-breaking in terms of number of clutches and number of estimated hatchlings produced. It was also the season with the second lowest poaching rate in project history. This is the tenth consecutive year to record over 200 clutches, the second consecutive year to record over 300 clutches and the first year to record well over 400 clutches in a season in the Pearl Cays. Change in nesting levels between years is not uncommon, especially considering the reproductive biology of sea turtles, and can often be attributed to changes in environmental factors (Lagueux et al, 2014). As hawksbills have a reproductive age of ~25 years (Mortimer & Donnelly, 2015), higher survival rates rather than an increase in nesting population is likely the cause of increased nesting activity (Campbell et al, 2009). Although some fishers continue killing hawksbills and loggerheads, we believe the Incentives Program has resulted in an overall decrease in the mortality of both species, as well as juvenile or sub-adult green turtles in the Pearl Cays. Stricter regional and international regulations for commercial fisheries targeting areas that overlap with sea turtle distribution, such as the requirement for Turtle Excluder Devices on shrimp trawlers that prove to decrease sea turtle mortality (Crowder et al, 1994; Lewison et al, 2002; Epperly, 2003), and increased protection on a regional and global level, could also be contributing positively to increased survival of regional sea turtle populations (Bjorndal et al, 1999). Increasing trends for number of clutches per season have also been reported for regional hawksbill populations in other long-term monitoring projects of nesting beaches in Antigua (Richardson et al, 2006), Barbados (Beggs et al, 2007), Brazil (Marcovaldi et al, 2007) and Mexico (Garduño-Andrade et al, 1999), which reflects positively on regional conservation efforts for this critically endangered species.

When interpreting poaching rates, fluctuations have been directly correlated with intensity and type of human activity in the Pearl Cays Wildlife Refuge (PCWR). For example, a higher poaching rate (24.7%) relative to trends since the initiation of the project was reported in 2013 due to the presence of sea cucumber fishers on Wild Cane cay (Lagueux et al, 2014, unpublished data). This cay typically has the highest or second highest number of nests per season, and was without the presence of watchman or permanent residents for many years. Acopios (lobster buying stations) are present on cays with historical problems of poaching (Bottom Tawira and Buttonwood). Another example is 2006, where monitoring activities by WCS had to be suspended, and a poaching rate of 21.8% was recorded. The lowest poaching rate was observed in 2007 (5.8%), although it did not include the poached nests for one of the cays (Seal cay) in the study area so this calculation could be underrepresented. Nonetheless, this rate occurred when WCS activities returned to regular intensity after the period of suspension. In 2014, there were no sea

cucumber fishers present on Wild Cane cay or any other nesting cay, and qualitative information collected from Field Supervisor indicated that the lobster fishery was not perceived as successful or intense as in years past by lobster divers in the Pearl Cays. These factors could contribute to the lower poaching rates, but also emphasize the fragility of the conservation success from year to year. If these human activities and associated poaching violations are not regulated appropriately, and if WCS monitoring activities are decreased in any way, it is likely that poaching rates could increase as seen in the past. Continued efforts towards education and outreach within stakeholder groups and local communities are thus an essential activity to both uphold and further intensify.

Additionally, daily monitoring of nest condition has led to a more accurate assessment for those nests previously classified as partially poached even though no suspicious evidence was present (for example, in 2013 this occurred for 19 nests). However, there were still considerable nests where the difference between yolked egg count at relocation and excavation was greater than 15 (n=55). A stricter threshold was used in 2014, only including nests with 15 or less difference, whereas it was previously 20. If we used the previous threshold of 20 eggs difference, only 46 nests would fall under this category. Further investigation, particularly with regards to counting errors during relocation and accounting for all eggshells affected by predation during daily monitoring, should be completed. As well, 10 of the 23 completely poached nests (43.5%) occurred prior to the intensive monitoring period (IMP). There were also 51 clutches found by signs of hatching (FBD) in 2014, 18 of which (35.3%) were estimated to have laid before the IMP began. Although seasonal changes in both temporal distribution of clutches laid as well as intensity of human activity on the cays are expected, these data could indicate a need for an earlier start of the Intensive Monitoring Period in the future.

As beaches in the Pearl Cays tend to be relatively narrow in length, the open beach vertical zone does not make up a large portion of available nesting habitat. Furthermore, many nests laid in this zone (n=were relocated to upper beach or inside zones due to threat of inundation or exposure to poaching or predation). This means that clutches typically incubate in areas with more shade and thus cooler temperatures, which has implications on site selection, nest success, sex-ratio of hatchlings and differing threats (i.e. roots in nest a greater risk but more vegetation coverage shelters from poaching and predation). As sex is determined by temperature during a critical phase of development for sea turtles, lower temperatures result in more male-producing opportunities (Godfrey & Mrosovsky, 1999; Merchant Larios, 1999; Wibbels, 2003). Beaches in the Caribbean, as well as many other regions around the world, are observed to be warmer than pivotal temperatures and thus have widely been reported as female-producing (sometimes as much as over 90% females) (Godfrey et al, 1999; Wibbels et al, 1999; Mrosovsky & Godfrey, 2010). As data continues to be collected on thermal parameters of nesting habitat and within nests, longer-term patterns and predictions can be made. The results can be vital to management and conservation strategies, according to experts (Mrosovsky & Godfrey, 2010). If the Pearl Cays nesting site is confirmed as a male-producing beach due to these lower temperatures, this site can be an important focal point for conservation measures of this critically endangered species in the face a changing climate.

Maintaining nesting habitat in a natural thermal state, as well as in any condition ideal for nesting, will also depend on the regulation of human activities in the cays that directly affect the quality of this habitat. Observations of clearing, cutting and burning events in or around nesting habitat, although less in 2014 than in previous years, continue to damage the quality and size of areas available for nesting and ideal incubation. Vegetated upper beach vertical zones are a preferred nesting area for hawksbills (Horrocks & Scott, 1991; National Marine Fisheries Service & U.S. Fish and Wildlife Service, 1998; Kamel & Mrosovsky, 2006). This season, 306 nests (64.4% of total nests) were laid in areas with partial or full

vegetative cover. Alteration of these habitats can negatively affect hawksbill nesting behaviour and embryonic mortality in the following ways: reducing ideal nesting habitat, increase temperatures for incubating clutches in areas with no vegetative cover, increase predation rates with greater exposure of nests, reducing diversity and abundance of cay vegetation, and further increase the already rapid speed of erosion of coastal habitats. Evidence of clearing was observed in 2014, although these observations are decreasing with time and education compared to previous years. However, more outreach to watchmen and residents on the cays of the impact of these behaviours could help reduce or halt these activities that are contributing to habitat degradation and potential changes in thermal profiles of beaches.

Nest relocation of doomed eggs continues to be a regular practice in the project. Hatching and emerging success between relocated and *in situ* clutches was not significant. This justifies the continued practice of translocation of endangered nests to safer locations when threatened by tides, predators or poachers. Examining why some cays have greater or lower success differences between relocated and *in situ* clutches is worth further investigation. This is especially important in terms of finding more idea sites for relocated nests for those cays with lower success for relocated nests (Baboon, Grape and Water cays). Nests relocated in 2014 on Baboon cay were concentrated in one area. This strategy should be reassessed in the future to consider more diversity in relocated sites, where possible, so that not all nests are subject to the same degree of potentially negative consequences (i.e. predation, organic matter, etc.). More comprehensive and higher resolution spatial analyses of nest location on cays should be done to better assess areas that yield the highest emerging success, and consistency of these areas in producing such success figures over the duration of the project when considering other human and environmental factors.

In 2014, teams were not able to survey Bottom Tawira, Buttonwood and Maroon cays as frequently as the other cays in the study site due to access limitation in rougher weather conditions. This is a concern especially for Bottom Tawira and Buttonwood, as there is constant human presence on these cays by some people that are not supportive of conservation measures, based on qualitative data collection and past project experience. Thus, nests on these cays potentially face a higher threat of poaching, which has also been confirmed when looking at past season data. It also means that the number of unsuccessful nests (either unhatched so no signs of depression, or poached) could be underrepresented. This could have also applied to Columbilla, particularly during periods of rougher weather in July and late-October that limited safe access to the cay. In 2014, a partnership with one resident on Bottom Tawira is believed to have led to a small number of nests at the end of the season being unaffected by poaching. Similar partnerships on Buttonwood and Columbilla are unlikely, so alternative solutions to reduce poaching should be explored.

WCS fully supports economic and development opportunities for local communities and governments, through both the exploration of new ventures and expansion of existing activities. WCS staff offer support in terms of training and knowledge-sharing to tour operators that visit our office in Pearl Lagoon or encounter our teams in the cays during the monitoring season. WCS continues to support the alternative livelihoods project Kabu Tours, by providing guidance and training to fishermen transitioning from turtle harvesting to ecotourism. Staff also spoke to tourists that visit the office or cays in order to increase awareness and educational opportunities about sea turtle and conservation of natural resources. It is clear that activity within the PCWR is and will continue to increase. Considering this trend, both tourism and exploitation-based activities need to be properly regulated to reduce the amount of stress on natural resources and ecosystem functioning. This is essential for the sustainable use and continued health of the PCWR. A recent proposal to build a resort property on one of the higher-density nesting cays (Crawl cay) raises concerns about environmental impacts and sustainability of natural resources for communal use in the future. Crawl historically records one of the higher number of clutches of all cays

per season, accounting for ~10% of nests this past season (n=46). The intense amount of construction, increased boat and human activity on nesting beaches and other important local habitats that turtles use during their life-cycles, artificial light usage and a number of other activities involved in the building and maintenance of such a resort, will undoubtedly have a negative impact on this critically endangered species and its habitat.

Further discussion about historical activity in the Caribbean coast of Nicaragua being correlated to nesting spikes in 2014 should be examined. Considering the reproductive age of hawksbills, it would be interesting to assess activities in Nicaragua 25 years ago that might have allowed for higher nest success, lower rates of mortality or reduced activity in general in the Pearl Cays. Evidence from other parts of the world indicate that times of war often act as recovery periods for typically exploited marine resources, as ships are sometimes repurposed for wartime activities and people are refocused on wartime responsibilities rather than marine resources use and extraction such as fishing (Roberts, 2007). Also in times of war there are large scale migrations and land use changes that also affect resource use. Civil war in Nicaragua was coming to an end in the late 1980s, meaning that soldiers were returning home to traditional activities, and war-affected areas were more accessible than the previous decade. An example of this has already been proven in the Caribbean spiny lobster (*Panulirus argus*) fishery in Nicaragua, where a dramatic decrease in fishing effort and landings was seen in the 1980s (INPESCA, 2010; Figure 27). Further research into nesting populations along the Caribbean coast in comparison with the Pearl Cays might provide insights into the contribution of historical activities towards the increases in clutches laid in 2014.

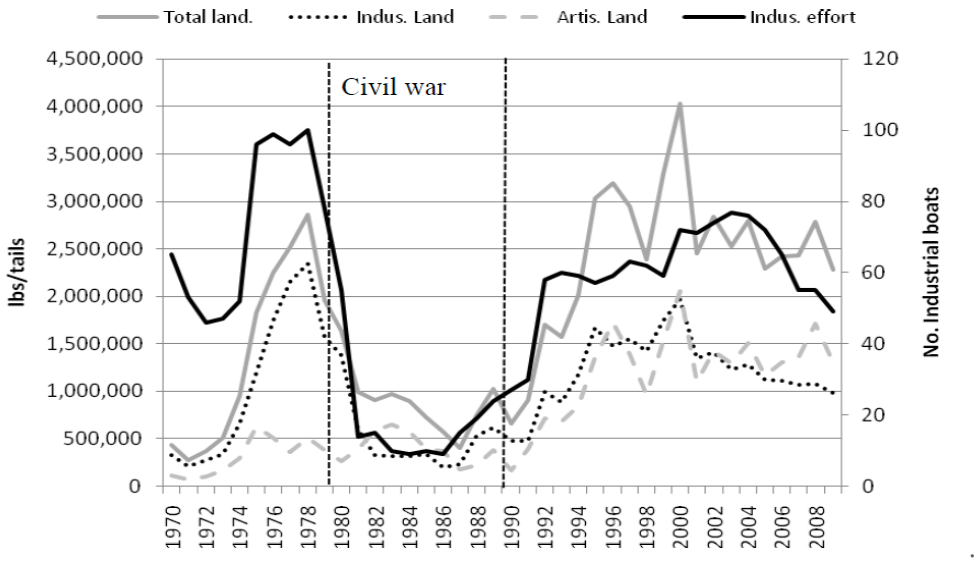

Figure 27. Historical trend of Nicaragua's lobster landings (artisanal and industrial) and corresponding number of industrial boats (dive and traps) operating in the fishery. Dashed vertical lines represent the beginning and end of the civil war when the lobster fishery was interrupted (data from INPESCA, 2010; graph by Chang Bennett, 2010).

It has long been known that a plethora of human activities contribute to damage or loss of nesting and other important habitat used by sea turtles during their life-cycles, significantly affecting their chances of

survival (Lutcavage et al, 1997; Mortimer & Donnelly, 2015). The Pearl Cays and their available nesting habitat continue to decrease in overall area due to harmful human and environmental impacts. The condition of the cays as well as surrounding marine habitats continues to suffer due to human activity, regardless of the establishment of the Pearl Cays Wildlife Refuge in 2010. WCS feels strongly that this degradation will continue at an increasing rate without a comprehensive management plan for this protected area, adequate enforcement of existing and developing regulations, and a continued education and awareness program. Immediate steps are needed to ensure the sustainable use of these natural resources that are essential to local communities' health and socio-economic survival. WCS has started the process of literature reviews and plans to conduct primary research on the socio-economic dependencies and patterns of use in the PCWR in local communities, in partnership with local university BICU. Further cooperation with local to regional authorities and community stakeholder groups will be a part of this process. Not only do strict regulations need to be put into place, but vigilant institutional oversight of these regulations must be conducted to enforce regulations efficiently for the benefit of all resource users. This will require strong support from all levels, including national to communal governments, Ministerio del Ambiente y los Recursos Naturales (MARENA), Secretaría de los Recursos Naturales (SERENA), stakeholder groups, local businesses, community members and conservation organisations active in the region.

Regulations should particularly include the halt of negative human activities such as vegetation clearing, burning events and construction on or near hawksbill nesting areas. Vegetated upper beach vertical zones are a preferred nesting area for hawksbills in the Pearl Cays, and any alteration of these habitats can negatively affect hawksbill nesting behaviour and alter the conditions for embryonic development. WCS also highly recommend strict regulations and enforcement for tourism activities in the PCWR that have conservation and sustainable use of these resources as a top priority. Efforts to recruit resources and support to be focused towards enforcement should be a focal point in the strategy currently in place to grow the tourism sector. To decrease waste and control specific human impacts to turtle nesting, we also reiterate past project recommendations to: install proper sewage systems and waste disposal on cays where humans are permanently residing, control presence of domestic animals on the cays, and control human interaction with nesting turtles and hatchlings by offering supervision of this passive interaction by WCS-trained staff and guides only.

Further recommendations for the WCS Hawksbill Project include:

1. More detailed studies on beach profile, nesting beach area, vegetation abundance and diversity, and continued data collection on thermal parameters both in baseline and nest locations.
2. Increased intensity of training for teams to build greater local capacity – teaching teams how to measure live turtles and record data, teaching team leaders how to tag turtles and enter/check data, providing more skill and knowledge building opportunities while in field or in office on a variety of environment and conservation topics/areas.
3. Increase WCS involvement in communities during the season by assigning radio announcements to teams and organising periodic activities in local schools with teachers, Peace Corps volunteers and government officials (especially Alcaldia Environment Department and Communal Board).
4. Recommencing visits to the Upper Cays during the monitoring season to both reduce mortality of turtles in that area and increase the number of individuals in the tag and release program and the number of collaborators in the incentives program. Informal conversations with fishermen on the

Upper Cays in 2014 confirm intention to cooperate with turtle donations when WCS teams visits the area, as has been done in past years.

5. Exploratory surveys on new nesting habitat of Upper Tawira, but exclusion of Black Mangrove in the study area unless changes in viable nesting habitat are observed or qualitative information from resident fishers provides proof of nesting.

In addition to the above list, we also recommend the continuation of the following project improvements implemented in 2014 based on: quality and scope of data collected, positive feedback from staff and efficiency of project activities to meet desired objectives:

a. Nest condition monitoring to collect more accurate data on factors affecting nest success: daily monitoring should be supported by on-going training in the field to ensure proper methods are respected. Increased reporting of exact number of eggs affected by predation incidents and any crab holes or signs of predation in the larger vicinity around nests should be a priority.

b. Intensive data quality control checks: continue stricter quality control and assurance process developed in 2014. This five to seven layered process increased the confidence in the quality and accuracy of data collected and should be continued in the future.

c. Excavation methods: continue to train and monitor team leaders or other motivated team members to conduct excavations. Keeping more specific categories for predation, development stages and deformities, while using the laminated guide as a reference, should also continue. Increased emphasis on how to determine an empty eggshell >50% and identification of predation types should be a main focus, and the Project Coordinator should be observing excavations throughout the season to ensure quality of methods and data collected are to standard.

d. Survey effort: continue recording start and end times on each cay-survey throughout the intensive monitoring period to better define presence on cays and survey hours.

e. Staff presence in field: maintain staff presence in the field by either the Field Supervisor or Project Coordinator. Having both in the field for the first rotation of each team ensured proper training, supervision, and evaluation of each team. This was especially important at the start of the season, when confusion or difficulties can arise, and when new method are implemented (i.e. when excavation season starts). Daily communication between Field Supervisor or team leader and Project Coordinator was essential to reduce confusion or repeated minor mistakes, and ensure proper scheduling of field activities. Project Coordinator should make an effort to be in the field at least once a month where possible. The involvement of WCS staff as a part of the field team adds overall positive moral and motivation, as well as ensuring quality data and compliance with methods.

CONCLUSION

There were many achievements to celebrate during the 2014 season, including 475 clutches laid and a reduction of 91.4% in the poaching rate since the project began in 2000. Almost double the number of hatchlings was produced in 2014 than any single season before, and the nest success rates were slightly higher than in some past years. WCS staff was able to continue outreach and incentive programs in order to educate stakeholders and tourists about the project and reduce the mortality of juvenile and adult turtles. Continued conservation success hinges on the consistency and expansion of these activities, as well as dedicated efforts towards achieving progress on the listed recommendations above.

Although the 2014 season was successful on many accounts, multiple threats continue to jeopardize the recovery of this important hawksbill rookery in the Pearl Cays. The state of sea turtle conservation in the Pearl Cays remains fragile, sensitive to a number of human activities, market demands, WCS presence, and regulatory enforcement. More effort into youth programs and amongst different stakeholder groups in local communities needs to be organised. Increasing communication and cooperation with communal to regional governments, and government bodies such as MARENA and SERENA, should also continue to be a main focus of the project. Although there is evidence of a reduction in overall mortality of hawksbills that has potentially led to increased nesting populations, human activities on the cays threaten to undermine conservation efforts by reducing viable nesting habitat for future generations of nesting females. These impacts on land undoubtedly transfer to marine ecosystems, further degrading sensitive habitats that sea turtles need for foraging, breeding, migration, and resting. The lack of management planning and enforcement in the Pearl Cays Wildlife Refuge further impedes conservation efforts and threatens the delicate balance of resources that local communities depend on for their survival and livelihoods.

Hawksbills, like other species of sea turtles, face numerous threats throughout their life-cycles that need mitigation both within and outside national borders. If focused action is taken to control activity within the national jurisdiction, it could positively contribute to international efforts for these species. Evidence of this trans-boundary effect already exists in the region, with many nesting beaches in the wider Caribbean recording increasing clutch and population trends. Continued and expanded scientific data collection to understand the local population and their habitat needs are also essential for informing effective resource management. Including local communities and stakeholders in the process of conservation decision-making, planning, management, and education programs can help focus on local behaviour changes that can have greater impacts on extraction activities, perceptions, and even market drivers. With continued and growing local cooperation and investment, WCS conservation efforts are increasingly developed into sustainable and long-term community initiatives.

WCS feels confident that stronger efforts on regulation and enforcement in the PCWR, coupled with increasing WCS hawksbill conservation project scientific data collection and educational activities in local communities, will lead to a greater positive impact on both the recovery of local hawksbill population and the habitats essential for both sea turtle survival and local livelihoods.

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ANNEX 1 – 2014 DATA FORMS

Survey Summary Data Form

Date		Team			
Cay*	**# TST**	**# TRK**	**NST# TAK**	**NST# MOV**	**NST# DNM**
WC					
GR					
LI					
VI					
BA					
CR					
WA					
CO					
BT					
BW					
MA					
BM					

START AND END TIMES	
WC	CO
GR	BT
LI	BW
VI	MA
BA	BM
CR	**Comments**
WA	

*Cay codes: WC=Wild Cane, GR=Grape, LI=Lime, VI=Vincent, BA=Baboon, CR=Crawl, WA=Water, CO=Columbilla, BT=Bottom Tawira, BW=Buttonwood, MA=Maroon, BM=Black Mangrove

Other codes: DNM=did not move, TST=Test, TRK=Track, MOV=moved/relocated, TAK=taken by poachers

New Nest Data Form

Nest #	Date		Cay
Crawlorg	DNM/Moved	--------->	Reason
Zoneorg	Vegorg		HTLorg
GPSorg		Ac	Side
Eggs	Yolkless		NDorg
Zonemov	Vegmov		HTLmov
GPSmov		Ac	Comments
Location			
Stick / Cinta	Eggshell	Y / N	

Data codes: Crawlorg=length of crawl to in situ nest cavity, DNM=did not move, org=in situ location, mov=relocated location, Veg=vegtetation type, Zone=vertical beach zone, HTL=distance to high tide line, Eggs=total yolked eggs in clutch, Yolkless=total yolkless eggs in clutch, NDorg=nest depth of in situ nest, Ac=accuracy of GPS reading, Side= navigational side of cay where nest is located, Stick=if a stick was put in the nest, Cinta=if flagging tape was used to mark a tree for location, Eggshell= if eggshell sample was taken

Test or Track Data Form

Date			Team					
Cay	Tst/Trk	Zone	Veg	HTL	Crawl	GPS	Ac	Comments

Data codes: Tst= test, Trk=track, Zone=vertical beach zone, Veg=vegetation type, HTL=distance to high tide line from center of attempted nest cavity or highest point of track from high tide line, Crawl = track length, Acc=accuracy of GPS reading

Human Activities Data Form

Date		Team										
Cay	# people	side	#/type animals	side	burn/clear/cut	zone	side	taking sand	side	construction	side	comments

Excavation Data Form

Date **Team**

Cay **Laying date**

Nest #

TOTAL YOLKED EGG COUNT: **Nest Depth**

Empty Eggshells >50% Pipped eggs Yolkless hydrated dehydrated predated

Unhatched eggs

No embryo Stage 1 Stage 2 Stage 3 Stage 4

Predated eggs

Microbe Crabs Ants Other/Unknown

Deformities Albino No eyes Twins Other

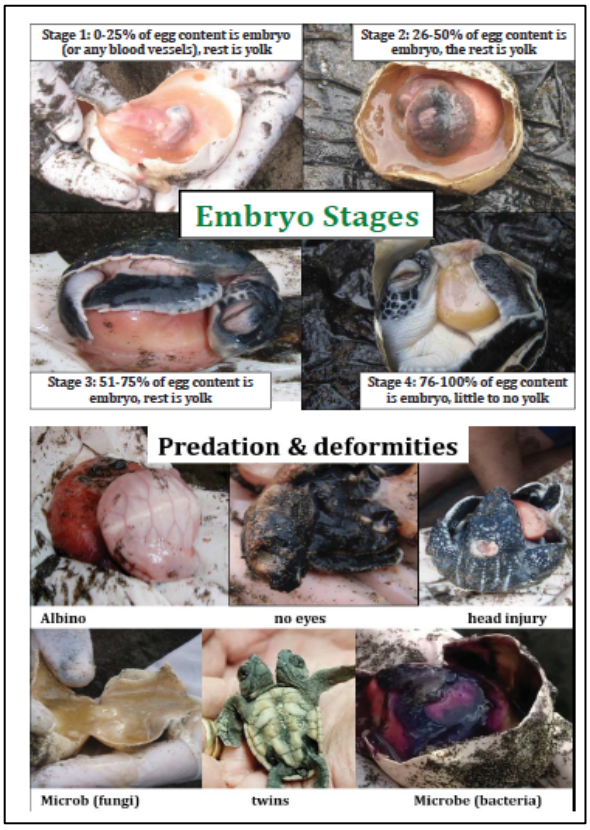
Hatchlings Live Dead in nest

Nest destroyed by other turtle Y / N **Stick found:** Y / N

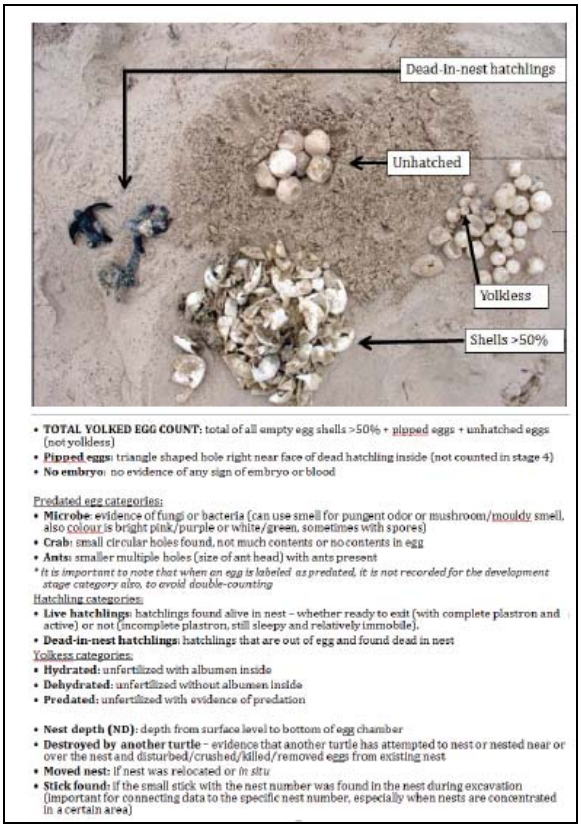
Comments

Data codes can be found in the main report text in Figure 4.

Excavation Data Guide



Front (p.1)



Back (p.2)