

Marine Turtles in the Turks and Caicos Islands: Remnant Rookeries, Regionally Significant Foraging Stocks, and a Major Turtle Fishery

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ABSTRACT. – This study reviews the status of marine turtles in the Turks and Caicos Islands (TCI) using data gathered during a multidisciplinary study involving field surveys, questionnaire-based interviews, and molecular genetics between 2002 and 2006. Large aggregations of foraging turtles in the archipelago's waters are dominated by juvenile green (*Chelonia mydas*) and hawksbill turtles (*Eretmochelys imbricata*), with provisional mixed-stock analysis of these species suggesting that the aggregations originate predominantly from larger and relatively proximate source rookeries in the Wider Caribbean region. This study also suggests that the islands host remnant nesting populations of turtles, with hawksbill turtle nests recorded more frequently than green and loggerhead turtle (*Caretta caretta*) nests. The TCI islanders retain a culture of turtle use, with the current regulated and legitimate harvest likely to be one of the largest among the Caribbean Islands. This study suggests that historic and current harvest of turtles and their eggs in the TCI may have contributed to the apparent decline in the country's nesting populations. In order to address this conservation concern, changes to the regulation and management of the TCI's turtle fishery are necessary, but further research is needed to inform these changes.

KEY WORDS. – Reptilia; Testudines; Cheloniidae; *Eretmochelys imbricata*; *Chelonia mydas*; hawksbill turtle; green turtle; sea turtle; Caribbean; conservation; status; use; harvest

Humans in the Caribbean have used marine turtles for food for at least 4000 years (Frazier 2003) leading to a widespread reduction in Caribbean populations of several species, including green (*Chelonia mydas*) and hawksbill (*Eretmochelys imbricata*) turtles (Jackson 1997; McClenachan et al. 2006). Both species are currently listed by the International Union for the Conservation of Nature (IUCN) as endangered and critically endangered, respectively (IUCN 2007); although, these listings have been questioned (Mrosovsky 2000; Broderick et al. 2006; Godfrey and Godley 2008).

The conservation and management of marine turtles in the Caribbean is a controversial issue (Godfrey et al. 2007; Mortimer et al. 2007) that has, in recent years, been the focus of heated debate under the auspices of the Convention on International Trade in Endangered Species (CITES) of Fauna and Flora (Richardson 2000). In response to this controversy, the CITES Secretariat convened Wider Caribbean Hawksbill Turtle Range State

Dialogue meetings in 2001 and 2002 aimed at facilitating multilateral agreement over a regional hawksbill management strategy.

There are 5 UK Overseas Territories in the Caribbean, which are governed by elected governments and appointed legislatures who have responsibility for all domestic affairs including biodiversity conservation (Anonymous 1999). The United Kingdom, however, retains responsibility for security and all foreign affairs, including multilateral environmental agreements such as CITES. As a contribution to inform the Caribbean Hawksbill Turtle Range State Dialogue process, in 2001 the UK government commissioned a study to assess the status and use of marine turtle populations in its Caribbean Territories, including Anguilla, the British Virgin Islands, the Cayman Islands, Montserrat, and the Turks and Caicos Islands (TCI) (Godley et al. 2004). This paper is based largely on some of the results of that study.

Turtles in the Turks and Caicos Islands

Foraging Stocks. — Carr et al. (1982) and Fletemeyer (1984) reported that the most commonly encountered turtles in the TCI's waters were juvenile green and hawksbill turtles of all sizes, with the former occurring in unspecified abundance on the sea grass beds and tidal creeks and the latter occurring in large numbers on the islands' patch and fringing reefs. Local fishers also described a *mulatto* turtle, and while Carr et al. (1982) and Fletemeyer (1984) suggested that this might be a local name for the loggerhead turtle (*Caretta caretta*), Fletemeyer (1984) did not discount that *mulatto* turtles may in fact be ridley turtles (*Lepidochelys* spp.); although, he did not encounter them during his surveys. Leatherback turtles (*Dermochelys coriacea*) have been anecdotally recorded passing through the TCI's waters (Carr et al. 1982). Foraging aggregations of green and hawksbill turtles in the Caribbean are comprised of individuals originating from nesting populations throughout the region (Diaz-Fernandez et al. 1999; Bass and Witzell 2000; Luke et al. 2004; Bowen et al. 2007). Prior to the current study, the origin of individuals making up feeding aggregations in the TCI's waters was unknown; although, contributions of individual hawksbill turtles from neighbouring states have been documented (Bahamas: Bjorndal et al. 1985; Puerto Rico: Van Dam et al. 2008).

Nesting Populations. — Little is known of the status of the TCI's nesting turtle populations. Fletemeyer (1984) recorded hawksbill turtle nests on several islands (see Fig. 1) during 9 hours of aerial surveying and subsequent ground truthing in July 1982 but did not find green, loggerhead, or leatherback nests. From his surveys, he estimated that the hawksbill nesting population then stood at between 125 and 275 nesting females. Based on interview data, Fletemeyer (1984) also gave low confidence nesting population estimates of between 45 and 105 nesting female green turtles and between 25 and 75 nesting female loggerhead turtles. He suggested that the composite nesting season for all species was April to August. Fletemeyer's (1984) estimates of loggerhead nesting have subsequently been cited as the source suggesting that loggerhead turtles nest in the TCI in regionally significant numbers (Ehrhart 1989; Proctor and Fleming 1999; Fleming 2001).

Turtle Use In The TCI. — There is a long history of marine turtle consumption and use in the TCI. Archaeological evidence unearthed at early settlements suggests that turtles have been used in the TCI since AD 700 (Carlson 2000; Fleming 2001). Sadler (1997) documents use by Europeans from the 15th century that continued through to the early 20th century (£1,768 worth of turtle shell was exported in 1906). In acknowledgment of the need for regulated harvest, the TCI's first Turtle Protection Ordinance was passed in 1907, aimed primarily at preventing illegal turtle take by Bahamians (Sadler 1997). In 1910, a lobster and turtle meat cannery was

established on Providenciales, but trade had virtually ceased by 1930. The TCI continued to export turtle shell (often referred to as *tortoiseshell*) until the onset of the economic depression, when only £150 worth was exported in 1933 (Sadler 1997).

Fishermen in the TCI continue to harvest marine turtles for domestic consumption, but the fishery is largely incidental to the thriving export-oriented fisheries for Caribbean spiny lobster (*Panulirus argus*) and queen conch (*Strombus gigas*) (Rudd 2003). The Fisheries Protection Ordinance (1998) currently regulates turtle fishing in the TCI and has been described in detail by Richardson (2006) and Broderick, et al. (2006). In summary, while harvest of nesting female turtles and "laid" turtle eggs is prohibited, any turtle at sea weighing more than 20 pounds (9.07 kg) or measuring 20 inches (50.8 cm) from the "neck scales to the tailpiece" can be legally harvested year-round. There has been little, if any, monitoring of the turtle fishery, and data on the levels of the contemporary harvest are scarce. Carr et al. (1982) suggested that exploitation of turtles among the Caicos Islands was "minimal." In contrast, Fletemeyer (1984) estimated the national TCI harvest in 1982 to be around 850 turtles, consisting mostly of juvenile green turtles, with some adult greens and juvenile hawksbills. He reported that turtles could be found year-round at markets, although availability was sporadic, and that, because of the abundance of juvenile green turtles in the TCI's waters, the harvest did "not seem to pose a serious threat to the survival of the sea turtle population." More recently, Fleming (2001) stated that few turtles are taken, with only 3 or 4 fishers consistently taking turtles and others catching them opportunistically. Contrary to Fleming's perceptions, Rudd (2003) estimated that the turtle harvest in the TCI is "likely in the hundreds per year" but acknowledged that there are no hard data on catch levels.

There are few data on contemporary levels of consumption of turtle products in the TCI. Allan (1998) found 6 restaurants in the TCI selling turtle dishes, and Fleming (2001) also reported that turtle meat was available in several restaurants. Gaudian and Medley (2000) reported that local interest in turtle meat in the TCI was "waning" at the end of the 20th century. Bowen (2003) concurred, stating that local consumption of traditional dishes, such as turtle stew, has declined in preference for food of US origin, such as deep-fried chicken and pork ribs.

Little has been documented about trade in turtle shell from the TCI since recorded exports apparently declined in the early 20th century. Japanese customs reported the import of a total of 234 kg of turtle scutes from the TCI in 1970 and 1971 (Fleming 2001), but there has not been a significant trade in turtle shell products to tourists visiting the TCI since the 1970s (B. Riggs, Department of Environment and Coastal Resources [DECR], *pers. comm.*, 2004). Carr et al. (1982) did not note any tourist trade in turtle products but did not visit the main tourist

island of Providenciales. They did, however, record “insignificant” trade in hawksbill scutes between local fishers and Haitian buyers. Fleming (2001) reported some trade between a local fisher and Dominican traders in the early 1990s and described contemporary reports from both Dominican and TCI fishers about Dominicans fishing illegally for turtles on the TCI’s Mouchoir Banks. Both Fleming (2001) and Marte et al. (2003) reported a flourishing, albeit illegal, trade in turtle products in the Dominican Republic, which is associated largely with the tourism sector.

Fletemeyer (1984) noted that harvest of turtle eggs occurred in the TCI, estimating that between 8000 and 10,000 turtle eggs were collected per year. Fleming (2001) stated that eggs were collected “especially in South Caicos and Salt Cay, until about 15 to 20 years ago.” It is worth noting that egg harvest since 1976 would have been in direct contravention of the Fisheries Protection Regulations (1976), which prohibited possession of “laid” turtle eggs (Proctor and Fleming 1999). Indeed, Carr et al. (1982) stated that enforcement of the regulations by the authorities was “probably inadequate,” and 2 years later Fletemeyer (1984) concurred, suggesting that there was “virtually no legal enforcement” of the regulations. More recently, other authors have suggested that the recent history of drug trafficking in South Caicos and inconsistent local compliance with the TCI’s fishery regulations have made enforcement problematic for the authorities (Rudd 2003; Tewfik and Bene 2004).

The status of marine turtles in the TCI is unclear, and it is not known whether the current culture of marine turtle use in the TCI is sustainable. Here, using an integration of data gathered during a multidisciplinary study (field surveys, questionnaire-based interviews, and molecular genetics), we present an assessment of marine turtle nesting activity and foraging stocks in the TCI, including a mixed-stock analysis, to provide the first insights into likely source rookeries of TCI’s foraging turtle aggregations. We also provide an updated estimate of the current harvest of marine turtles in the territory.

METHODS

Study Site. — The Turks and Caicos Islands (TCI) form the southeastern extremity of the Bahamas chain (lat 21°45’N, long 71°35’W). There are approximately 40 low-lying islands and cays in the territory (all < 76 m above sea level), covering a total land area of about 500 km² (Fig. 1). The TCI sit on 3 limestone platforms, the Caicos Bank, the Turks Bank, and the Mouchoir Bank, which lies to the southeast of the archipelago. The Caicos bank is the largest (6140 km²) and is fringed with extensive coral reefs and steep drop-offs extending along the northern shores of Providenciales and the Caicos Islands. The majority of the Caicos Bank leeward of these islands is shallow and sandy, with vast sea grass beds, dominated by *Thalassia testudinum*, situated close to the

main islands and some of the small cays at the southern edge of the Bank (Carr et al. 1982; Gaudian and Medley 2000; Rudd 2003). The extensive and largely pristine wetlands of North, Middle, and East Caicos are fed by a complex of tidal creeks that are commonly vegetated by sea grass and marine algae. A large area encompassing these wetlands, tidal creeks, and inshore sea grass beds was declared a Ramsar Convention Wetland of International Importance in 1990 (Fletemeyer 1984; Proctor and Fleming 1999). Grand Turk, Salt Cay and associated cays lie on the Turks Bank (324 km²), which consists mostly of a sandy bed, with extensive coral reefs and mixed coral and algae beds, while Mouchoir Bank further east is largely made up of coral and sand (Rudd 2003).

Only 6 of the main islands and a few of the small islands are currently inhabited. A national census in 2001 recorded a population of 19,886, with the majority living on Providenciales (66%), Grand Turk (20%), North Caicos (7%), and South Caicos (5%). Development in the TCI has experienced accelerated growth since the international runway was built on Providenciales in 1986 (Robinson and Fulford 1997; Gaudian and Medley 2000), and a 2006 population estimate places the TCI population at 33,202, with increases a result largely of recent influxes of immigrant workers from Haiti and the Dominican Republic (Department of Economic Planning and Statistics, www.depstc.org, 2006).

Thirty-three protected areas have been gazetted by the Government of the Turks and Caicos Islands (www.environment.tc) under the National Parks Ordinance (1998), most of which encompass islands or other marine features. Responsibility for enforcing the National Parks Ordinance and the Fisheries Protection Ordinance (1998) lies with the DECR, which is divided into 2 divisions: the Fisheries Division and the Protected Areas Division. Several of the beaches where Fletemeyer (1984) recorded turtle nesting are now protected under the National Parks Ordinance, including, for example, those located within the French, Bush, and Seal Cays Sanctuary; those on Big Sand Cay (in the Big Sand Cay Sanctuary); and beaches on Gibbs Cay and Pinzon Cay, which lie within the Grand Turk Cays Land and Sea National Park (see www.environment.tc and Fig. 1).

Nesting Beach Surveys. — Because of the remote nature of many of the cays and limited resources available for the study, surveys for nesting activity were infrequent and opportunistic. During September 2002, September 2003, October 2005, and January 2006, experienced surveyors were able to survey, at least once, accessible beaches on Grand Turk, Providenciales, Middle Caicos, Salt Cay, Big Sand Cay, Bush Cay, Fish Cay, Pinzon Cay, and Gibbs Cay looking for any signs of nesting activity, which were then recorded to species where possible based on track and nest morphology following Schroeder and Murphy (1999). In October 2005, a 3-hour aerial survey in a single-propeller aircraft was carried out also following Schroeder and Murphy (1999) to detect turtle nesting

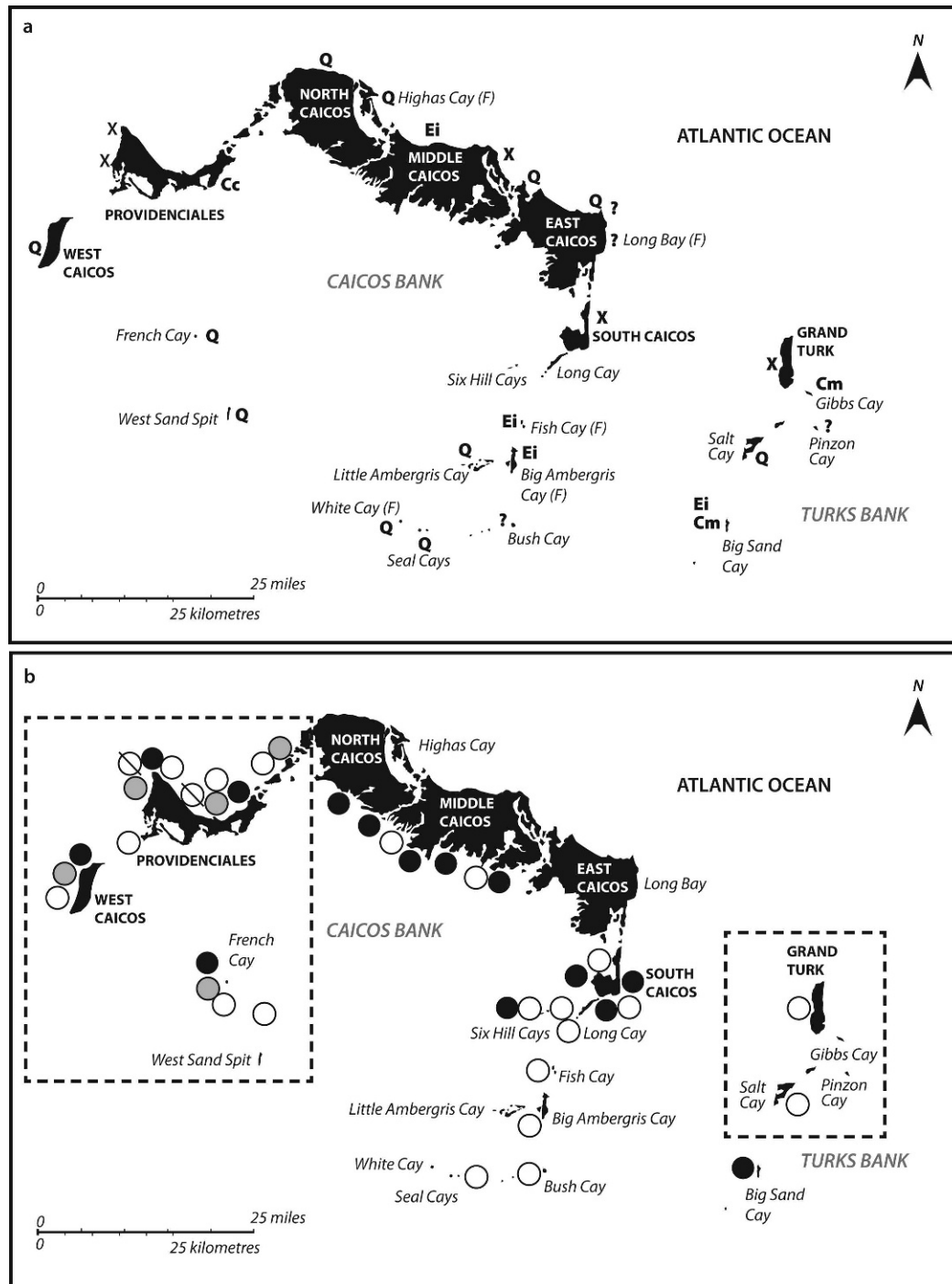


Figure 1. a) Broad-scale locations of turtle nesting activity confirmed during the surveys or suggested during the socio-economic questionnaire survey (SEQ). Ei = confirmed hawksbill turtle, Cm = confirmed green turtle, Cc = confirmed loggerhead turtle, ? = nesting activity confirmed but species unidentified, Q = current nesting activity suggested by SEQ but not confirmed during the surveys, X = no signs of nesting activity found during surveys, although SEQ suggested these sites were once used. (F) indicates locations of nesting confirmed by Fletemeyer (1984). b) Broad-scale locations of species of turtle observed by dive operators or captured during the in-water sampling. ○ = hawksbill turtle, ● = green turtle, ◐ = loggerhead turtle, ♀ = possible Kemp's ridley. Broken lines enclose the dive operator dive sites where no sampling occurred (NB = neither in-water sampling nor diver surveys were carried out along the northern coasts of North, Middle, and East Caicos).

activity on beaches on South Caicos and East Caicos and the beaches on the northern coast of Middle and North Caicos.

In-Water Capture and Mixed-Stock Analysis. — In-water capture and sampling of turtles was carried out from

2002 to 2006 to obtain tissue samples for a genetic mixed-stock analysis (Godley et al. 2004). Additional capture and tagging occurred around South Caicos in 2005 and 2006. Throughout the study, turtles were captured using a number of methods. Some were captured using a turtle

rodeo method, whereby turtles were spotted from a motorized boat during dedicated patrols at known turtle foraging habitat and then chased and captured by hand once they had tired. Other turtles were hand captured as they rested in coral heads by free divers at various sites in and around South Caicos during dedicated nocturnal sampling trips. A few turtles were tagged and sampled after being incidentally captured in nets set to catch sharks as part of another study. Some turtles were hand captured by free-diving lobster fishermen who were persuaded by the DECR to catch and land turtles they encountered while fishing for sampling and release. In addition, DECR officers were able to measure and take tissue samples from some turtles that had been captured and landed by fishermen for consumption. The curved carapace length (CCL; notch to tip) and curved carapace width of all captured and released turtles were measured using a flexible measuring tape (Bolten 1999). When an individual turtle was recaptured more than once, only the first and last CCL measurements were used in growth rate analysis. Turtles were tagged with either monel or inconel flipper tags in the trailing edge of the front flippers following Balazs (1999), and in some cases the turtles were also injected in the left shoulder with an AVID/ Destron-Fearing passive integrated transponder (PIT) tag, which was then confirmed with a PIT tag reader. Tissue samples were taken from the rear flippers following Dutton (1996).

None of the animals in this study were weighed. Weights of hawksbills were estimated using the data of McGowan et al. (unpubl. data) function for mass against CCL, $\text{Mass kg} = 8.08 - 0.58\text{CCL cm} + 0.013\text{CCL}^2$, calculated from juvenile hawksbill turtles (9–76 cm CCL, $n = 223$) hand caught in the British Virgin Islands (see McGowan et al. 2008). Weights of green turtles were estimated using McGowan et al. (unpubl. data) function for mass against CCL, $\text{Mass kg} = 11.58 - 0.77\text{CCL cm} + 0.016\text{CCL}^2$, calculated from hand-caught juvenile green turtles (24–70 cm CCL, $n = 128$) during the same study. Means are followed by standard deviation unless otherwise noted.

Genetic analysis of tissue samples consisted of DNA extraction, amplification, and sequencing following methodology described in Formia et al. (2006), using primer pairs LTCM1/HCM1 for greens (Allard et al. 1994) and LTEi9/H950 for hawksbills (A. Abreu-Grobois, unpubl. data). Sequences were aligned against known haplotypes, which are centralised through the Archie Carr Center for Sea Turtle Research USA for green turtles (<http://accstr.ufl.edu/genetics.html>) and the Institute for Marine Science in Mexico for hawksbills (A. Abreu-Grobois, unpubl. data). Mixed-stock analysis was then carried out with the program Bayes (Pella and Masuda 2001; Masuda 2002), using Bayesian statistics and Monte Carlo Markov Chain iterations to calculate the probability density distribution for stock mixture proportions. Green turtle samples were analysed using summa-

rized haplotype frequencies from 14 Atlantic and Mediterranean rookeries as potentially contributing baseline populations (A. Formia, unpubl. data). The source populations of the sampled hawksbills were estimated using rookery haplotype frequencies summarized in Troëng et al. (2005) and Velez-Zuazo et al. (2008), truncating the sequence to match haplotype data from Bass (1999). In order to obtain more conservative estimates, the source rookeries were assigned equal priors, regardless of size, and contribution estimates derived from Bayes were then correlated with rookery size and distance to the TCI.

Dive Operator Recording. — During 2002 and 2003, dive operators were issued with data sheets and encouraged to record any turtles encountered during their dives. They were also provided with a Wider Caribbean Sea Turtles photographic marine turtle identification chart (WIDECAST/CEP-UNEP) and asked to record species, location, and number of turtles encountered on the data sheets as well as an estimate of straight carapace length (SCL). The 2 dive operators that participated in the survey conducted dives at fringe reef sites off West Caicos, French Cay, Pine Cay, North West Point (Providenciales), Princess Alexandra National Park (Providenciales) and South West Reef (Providenciales). For further information on this method as applied in the Cayman Islands, see Bell et al. (2009).

Socio-Economic Questionnaire Survey (SEQ). — Structured questionnaires were designed to assess the social and economic value of turtles and administered on several islands during 2003. The questionnaire was comprehensive and divided into 9 separate sections for different user groups, including fishers, turtle fishers, turtle vendors, and consumers as well as representatives of the authorities responsible for managing the turtle fishery. For example, the section of the questionnaire designed specifically for turtle fishers asked participants a suite of 44 questions regarding the economic importance of the turtles they catch; the seasonality and frequency of their turtle fishing; the capture methods they use; the size, number, and species of turtles they catch; details regarding how they use or sell their catch; and questions to gauge opinions on turtle fishery management mechanisms (for more detailed descriptions of the questionnaire, see Godley et al. [2004] and Silver and Campbell [2005]; for analysis of fisher opinions about management measures, see Campbell et al. [2009]). The questionnaire also included sections designed to record participants' local knowledge regarding marine turtles.

Sampling strategy was both opportunistic and directed; an effort was made to include known turtle fishers as well as fishers who might catch turtles opportunistically. Survey participants were typically identified by DECR officers in the project and then interviewed for 1–2 hours by trained project staff, often with a DECR officer present.

RESULTS

Nesting Beach Surveys

Figure 1a shows the results of the opportunistic nesting beach surveys, indicating not only confirmed turtle nesting activity but also where evidence of nesting activity was absent on surveyed beaches. The map also shows the potential locations of turtle nesting beaches as indicated by some of the 92 SEQ interviewees.

Surveys confirmed nesting by hawksbill turtles, with 16 fresh nesting activities recorded at 4 sites during the months of September, October, and January and a freshly emerged hawksbill nest recorded on Fish Cay also in September. Limited green turtle nesting activity (2 nests, 2 sites during September) and 1 loggerhead nesting event (in May 2005; Pardee 2005) were also recorded during the study period. A total of 10 other unidentified fresh turtle nesting activities were also recorded at Bush Cay (September 2002, $n = 3$), Long Bay, East Caicos (October 2005, $n = 3$), and Pinzon Cay (January 2006, $n = 4$). Anecdotal accounts from some SEQ interviewees suggested that in recent decades turtle nesting populations have been largely extirpated from the most densely populated islands, such as Providenciales, Grand Turk, and South Caicos.

In-Water Capture and Sighting

In total, 133 turtles were sampled during this study, including 94 hawksbill turtles, 38 green turtles and 1 hawksbill/loggerhead turtle hybrid.

Hawksbill Turtles. — Fifty-eight (61.7%) of the 94 individual hawksbills included in this study were captured on reef habitat, while 22 (23.4%) were captured on sea grass beds and sandy habitat, with habitat type not recorded for 14 captures. The animals ranged in size from 19.4 to 93.0 cm CCL, with a mean of 41.6 ± 12.4 cm. The mass of hawksbills sampled during this study was estimated and ranged from 1.7 to 66.6 kg, with a mean of 8.4 ± 8.9 kg.

Fourteen (14.9%) hawksbills were recaptured during the study, and growth rates were calculated from 11 turtles. The mean growth rate of these turtles, measuring between 24 and 49.6 cm CCL at first capture (mean = 37.1 ± 7.7 cm) and recaptured at intervals over 3 months, was 4.9 ± 2.0 cm/y (range = 1.5–8.6 cm/y, range of intervals = 3.1–49.7 months).

Figure 2a shows the length–frequency histogram for the hawksbill turtles. Where tagged turtles were recaptured, the last CCL measurement is presented. While female hawksbills in Barbados and Cuba are thought to reach maturity at carapace lengths greater than 75 cm (Moncada et al. 1999; Beggs et al. 2007), Moncada et al. (1999) suggest that a small percentage mature at CCLs as small as 51 cm, and therefore some of the 16 (17%) hawksbills in this sample with CCLs measuring between

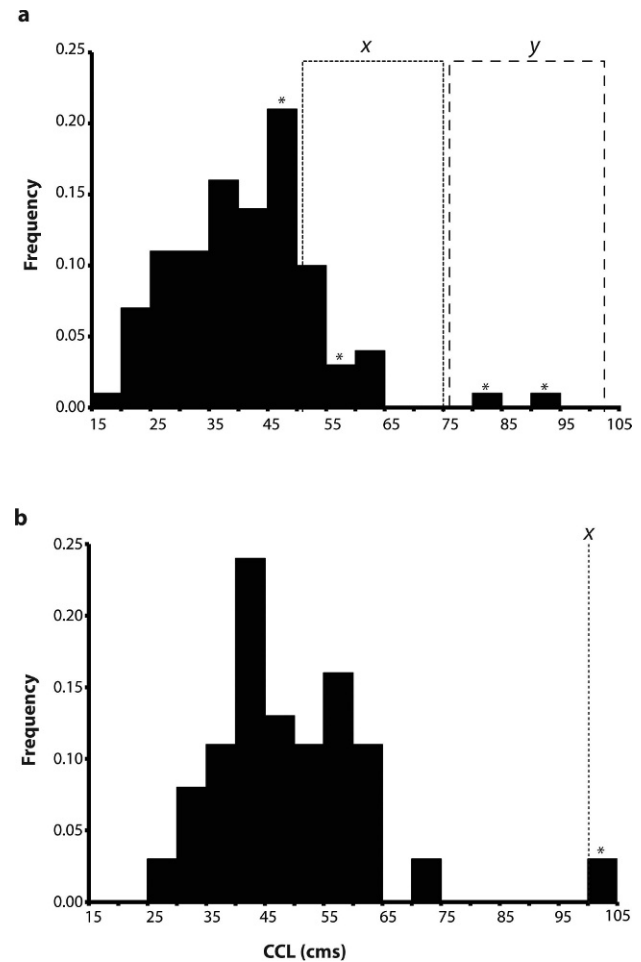


Figure 2. Length–frequency histograms for a) hawksbill and b) green turtles captured and sampled during this study. In a), broken lines marked “x” show minimal range of SCL at maturity for female hawksbills (51–75 cm) in Cuban waters from Moncada et al. (1999), and broken lines marked “y” show range of CCLs of adult nesting female hawksbills (76.2–102.4 cm) in Barbados from Beggs et al. (2007). Columns marked “*” indicate CCLs of the sampled hawksbills landed for consumption during this study. In b), line marked “x” shows the average SCL of nesting female green turtles (100.2 ± 5 cm SCL) at Tortuguero, Costa Rica (in Bjørndal et al. 2005). “*” indicates CCL of a green turtle sampled during this study that was landed for consumption at South Caicos.

50.9 and 64 cm may have been mature females. Two mature females were confirmed from the hawksbills sampled based on their external characteristics and size, with CCLs measuring 80 and 93 cm. Both these turtles were landed in South Caicos for consumption, with the larger turtle sold to Haitian traders who had it secured alive on their vessel bound for Haiti when it was sampled. Three other hawksbills in the sample were landed for consumption, with CCLs measuring 47, 48, and 58 cm.

Mixed-stock analysis of 38 juvenile hawksbills indicates likely rookeries of origin in Mexico, US Virgin Islands (USVI), Antigua, Puerto Rico, and Cuba (Fig. 3a). Although percentage contributions exhibit wide confidence intervals, it is worth noting that the lower confidence limit for the Mexican contribution is above

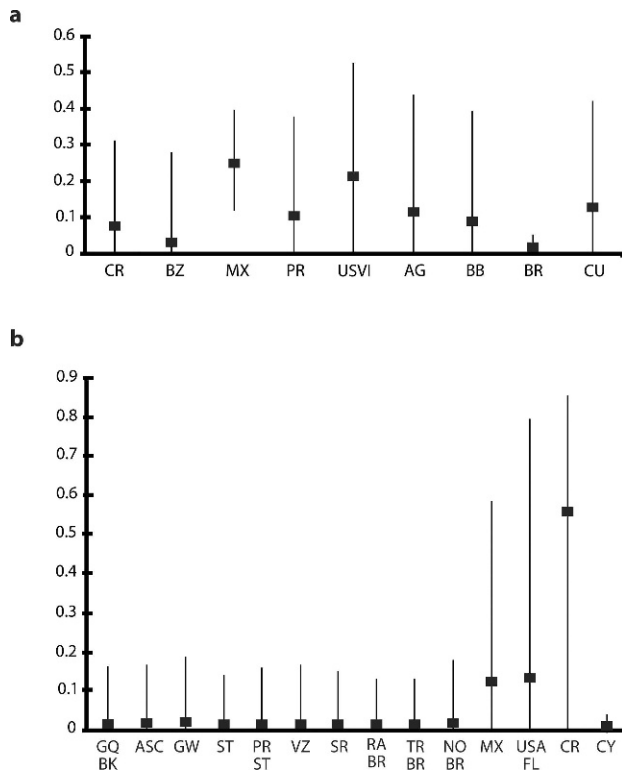


Figure 3. Frequency contributions to the hawksbill (a) and green turtle (b) mixed stocks from all known potential rookeries based on mitochondrial DNA haplotype frequency distributions. Mean contribution (black squares) and upper and lower percentiles were calculated using 10,000 Monte Carlo Markov chain iterations assuming equal priors, using the software Bayes (Pella and Masuda 2001). AG = Antigua, ASC = Ascension Island, BB = Barbados, BR = Brazil, BZ = Belize, CR = Costa Rica, CU = Cuba, CY = Cyprus, GQ BK = Bioko Equatorial Guinea, GW = Poilao Guinea Bissau, MX = Mexico, NO BR = Fernando de Noronha Brazil, PR = Puerto Rico, PR ST = Principe Sao Tome & Principe, RA BR = Rocas Atoll Brazil, SR = Suriname, ST = Sao Tome & Principe, TR BR = Trinidad Brazil, USA FL = Florida, USVI = US Virgin Islands, VZ = Venezuela.

zero (Fig. 3a). Population connectivity can also be assessed based on haplotype presence in populations (Table 2). Haplotypes A, F, and Q are the most common in the sampled hawksbills and can also be considered common in nesting females in Barbados and Cuba (haplotype A), Puerto Rico, USVI, Belize and Costa Rica (haplotype F), and Mexico (haplotype Q). There was a significant negative correlation between log-transformed rookery contribution and distance (Pearson's correlation coefficient $r = -0.782$, $p = 0.013$) but not between log-transformed rookery contribution and source population size (Pearson's correlation coefficient $r = 0.117$, $p = 0.765$).

Figure 4 shows the juvenile hawksbill/loggerhead hybrid turtle. The animal measured 43.3 cm CCL, and while its carapace and head morphology resembled that of a juvenile hawksbill, its short, thick neck and general colouration were more indicative of a juvenile loggerhead. Indeed, genetic analysis revealed this specimen's mitochondrial DNA was that of a loggerhead turtle.



Figure 4. The hawksbill/loggerhead hybrid juvenile turtle sampled and released during this study (photo credit Peter Richardson/MCS).

Green Turtles. — Of 38 individual green turtles sampled, 20 were caught during dedicated sampling with South Caicos turtle fishermen on the sea grass beds along the southern shores of North, Middle, and East Caicos. Green turtles are abundant at these sites, and sampling trips encountered many more green turtles than were caught. One of these sampling trips (on 10 September 2003) employed 2 South Caicos turtle fishermen (1 pilot, 1 catcher) who hand captured 11 juvenile green turtles and 2 juvenile hawksbill turtles in under 1 hour. In total, 24 (63%) green turtles were captured on sea grass beds and sand flat habitat, while 12 (32%) were hand caught on patch reefs. Capture habitat was not recorded for the 2 other green turtles in this sample.

Animals ranged in size from 26 to 103.5 cm CCL, with a mean of 49.2 ± 13.7 cm. The mass of green turtles sampled during this study was estimated to range from 2.4 to 103.3 kg, with a mean of 15.4 ± 16.9 kg.

Figure 2b shows the length–frequency histogram for the green turtles and indicates that 94% ($n = 36$) of the turtles sampled in this study were juveniles. Only 4 green turtles were recaptured during the study, and 2 were recaptured at intervals longer than 3 months, with 1 turtle growing 1.1 cm in 94 days and the other growing 1.5 cm in 137 days. One sampled green turtle was a mature female (CCL = 103.5 cm) landed for consumption at South Caicos in September 2002. Butchery of this turtle revealed well-developed oviductal eggs. It is worth noting that 7 (18%) juvenile green turtles, measuring 46 to 64.6 cm CCL, exhibited lesions (Fig. 5) suggestive of early-stage fibropapillomatosis (Jacobsen et al. 1989; Herbst 1994). Local turtle fishers interviewed during the SEQ knew of the disease, referring to it as “old turtle disease,” and 1 fisher also reported having caught a hawksbill with the disease.

Mixed-stock analysis of tissue samples from 17 green turtles sampled during this study indicates that the probable nesting rookeries of origin. Mexico, Florida,



Figure 5. A juvenile green turtle sampled during this study exhibiting fibropapilloma-like growths (photo credit Peter Richardson/MCS).

and Costa Rica (Tortuguero) likely make important contributions to the juvenile green turtle aggregations in TCI's waters (Fig. 1b). The most common haplotype in the TCI is CM-A3, one relatively widespread in Caribbean rookeries, including Costa Rica, Florida and Mexico. As with the hawksbills, rookery contribution and rookery distance (both log transformed) showed a significant negative correlation (Pearson's correlation coefficient $r = -0.650$, $p = 0.009$), while log-transformed rookery size was not correlated with log-transformed rookery contribution to the mixed stock (Pearson's correlation coefficient $r = 0.398$, $p = 0.142$).

Foraging Aggregations. — Figure 1b shows the broad scale distribution of sites where turtles were either sighted or in-water sampled during this study. No diver surveys or sampling trips associated with this study were carried out along the north coasts of North, Middle, and East Caicos.

Dive Operator Recording. — Five dive operators collaborated with this study, recording a total of 432 turtle sightings. Two Providenciales-based operators regularly completed the forms, recording 301 and 121 turtle sightings, respectively, while a dive operator in Grand Turk recorded 7 sightings (from 8 dives), and 2 operators on Salt Cay recorded 3 sightings (from 3 dives). Figure 1b

shows a broad scale distribution of the different species of turtles encountered.

Hawksbill turtles were the most commonly encountered species recorded by the dive operators, with the next being the *mulatto* (Table 1). When asked to identify this species on the WIDECAST photographic turtle ID chart, all the participating dive operators indicated that they were seeing Kemp's ridley turtles. Dive operators also recorded 12 loggerhead sightings and 12 green turtle sightings, while 23 sightings were unidentified to species. Individual turtles may have been sighted multiple times on different dives during this study, so these data do not necessarily indicate abundance.

Marine Turtle Harvest

Of the 92 SEQ interviewees, 13 were former fishers, and 46 were current fishers. The majority of these 59 fishers fish or fished primarily for conch ($n = 52$), lobster ($n = 54$), or finfish ($n = 54$), while 50 (84.5%) catch or have caught turtles in the past. Thirty-three (66%) of the 50 former and current turtle fishers caught turtles opportunistically, while 9 caught turtles both opportunistically and intentionally, and only 8 caught turtles intentionally (16%).

Table 1. Summary of turtle sightings recorded by dive operators.

Species	Percentage and no. of records (<i>n</i> = 432)	Estimated CCL range (cm)
Hawksbill turtle	83.8% (<i>n</i> = 362)	22.9–121.9
Green turtle	2.8% (<i>n</i> = 12)	40.6–91.4
Loggerhead turtle	2.8% (<i>n</i> = 12)	61.0–121.9
<i>Mulatto</i> (suspected Kemp's ridley)	4.2% (<i>n</i> = 18)	30.5–91.4
Unidentified	6.5% (<i>n</i> = 28)	30.5–91.4

Turtles were not identified as the most economically important target species by any of the 46 current fishers, although 35 (75.6%) of them claimed to be currently engaged in turtle harvest (including 34 licensed fishers and 1 unlicensed fisher). Twenty-two of these fishers (62.9%) reported catching turtles for sale, while 13 (37.1%) did not sell the turtles they caught. Those who did sell turtle meat sold it to restaurants and private customers in the TCI.

Twenty-four (68.6%) of the 35 active turtle fishers reported catching green turtles either solely by hand or by using a handheld lobster hook, while 20 (57.1%) reported using these methods to catch hawksbills. Other methods mentioned included use of nets (*n* = 2), Hawaiian sling (*n* = 2), and spear gun (*n* = 1), while some fishers did not provide this information.

Hawksbill Turtle Harvest. — Twenty-three (65.7%) of the 35 current turtle fishers gave estimates of their average annual hawksbill turtle harvest, with estimates ranging from 1 to 30 turtles per year and a mean of 5.3 per year (median: IQ range = 3:1.5–5). The estimated average annual harvest of hawksbill turtles taken by these 35 active turtle fishers is approximately 186 turtles.

Hawksbill turtles of various sizes are currently caught with the smallest reported at 4.5 kg (below the legal limit of 9 kg) and the largest reported as 158.7 kg. Twenty of the 35 current turtle fishers offered estimates of the average sized hawksbill turtle they catch. These ranged from 13.6 to 90.7 kg, with a mean of 36.7 ± 21.4 kg, again much larger than the estimated mean weight of the hawksbills hand caught and sampled during this survey. Beggs et al. (2007) reported that female hawksbill turtles nesting in Barbados weighed between 44–92 kg with a mean weight of 68.2 ± 8.8 kg, while Moncada et al. (1999) reported that female hawksbills in Cuban waters were reaching sexual maturity at much smaller sizes than reported in Barbados. While small juvenile hawksbills are taken in the TCI harvest, the SEQ results suggest that the fishery tends to target larger size classes, including subadult and adult turtles.

Green Turtle Harvest. — Thirty-one (88.6%) of the 35 current fishers gave estimates of their average annual green turtle harvest, with estimates ranging from 1 to 50 turtles per year and a mean of 6.7 per year (median: IQ range = 5:2–9.5). The estimated average annual harvest

Table 2. Foraging green and hawksbill turtle haplotype distributions (hawksbill sequences are truncated as in Velez-Zuazo et al. 2008).

Haplotype	No.
Hawksbills	
A (Ei-A01)	12
Alpha (Ei-A02)	1
B (Ei-A03/Ei-A57)	1
F (Ei-A09/11/45/ 46/Ei-A63)	12
N (Ei-A20)	1
Q (Ei-A23/24)	9
B (Ei-A28)	1
Ei-A53 ¹	1
No. of samples	38
No. of haplotypes	8
Green turtles	
CM-A1	1
CM-A3	11
CM-A5	2
CM-A8	2
CM-A16	1
No. of samples	17
No. of haplotypes	5

¹ This haplotype was not previously identified by other genetic surveys in the region.

of green turtles taken by these 35 active turtle fishers is approximately 235 turtles.

Fishers reported catching green turtles of various sizes (reports were converted from pounds to kilograms), with smallest reported at 2.3 kg, thus below the legal limit of 9 kg, and the largest reported as 226.8 kg. Twenty-five of the 35 current turtle fishers offered their own estimates of the average sizes of the green turtles they catch. These ranged from 11.3 to 90.7 kg, with a mean of 32.4 ± 19.7 kg, much larger than the estimated mean weight of the green turtles hand caught and sampled during this survey. The SEQ results therefore suggest that the TCI fishery tends to target the larger size classes present, including large juveniles, subadult, and adult turtles.

Harvest of Nesting Females. — None of the former or current turtle fishers interviewed said that they catch female turtles on the nesting beaches; although, some interviewees suggested that this was apparently common practice in the past. Today, nesting turtles are rarely encountered by the TCI islanders, as nesting appears to be limited to remote cays that are rarely visited at night when the turtles nest (see Fig. 1). Illegal take of nesting turtles is therefore likely to occur only very occasionally, if at all.

Turtle Egg Harvest. — The SEQ identified 7 (7.6%) respondents who still collect turtle eggs and 17 who used to collect eggs. One of the 7 current egg collectors claimed that he collected eggs on a monthly basis, 5 said that they collected them occasionally (between 2 and 4 times per year), and one said that he collects them opportunistically. Indeed, of all current and former egg collectors, 50% (*n* = 12) said that they collected eggs opportunistically. Only 1 interviewee said that he had

formerly collected eggs for sale, usually between June and September, but had stopped visiting the beaches and collecting in 1990. Prior to that, he sold turtle eggs for US\$3 for a dozen. Eggs are still occasionally offered for consumption in South Caicos (P. Richardson and J. Silver, *pers. obs.*).

Turtle Consumption in the TCI

Of the 92 TCOT SEQ interviewees, 83.7% ($n = 77$) eat or have eaten turtle meat, with 52 (56.5%) reporting that they currently eat turtle meat. However, it is worth noting that this sample is not representative, as there is a very strong sampling bias toward fishers, a social group that is likely to use turtle products more than other groups. Eight of 15 restaurant owners interviewed during the SEQ were selling turtle meat dishes, while 1 fish market owner in Grand Turk was selling raw turtle meat. While the fish market owner purchased turtle meat to sell on a daily basis, 2 of the restaurants reported buying turtle meat on a weekly basis, 2 restaurants bought it on a monthly basis, 3 bought it on a yearly basis, and 1 reported buying it less frequently than yearly. All 8 restaurants purchased green turtles, 6 purchased hawksbill turtles, and 1 did not distinguish between the species.

DISCUSSION

The Turks and Caicos Islands appear to provide good developmental foraging habitat for regionally important abundances of juvenile green and hawksbill turtles. The legal harvest of turtles in the TCI, which targets larger size classes of green and hawksbill turtles, including adults, consists of hundreds of animals and is possibly one of the largest among the Caribbean Islands and is certainly comparable to other significant and legal turtle harvests in the region (Carrillo et al. 1999; Grazette et al. 2007; Mortimer et al. 2007). The TCI also host nesting populations of hawksbill, green, and loggerhead turtles, with hawksbill turtles appearing to nest most frequently, mostly on remote and uninhabited cays. Without genetic data on TCI's native turtle populations and with only limited information on past and present nesting turtle numbers, the effect of the TCI turtle fishery on native turtle populations remains unclear. However, this study recorded continued turtle egg harvest and indicates that the fishery likely includes some adult females from native TCI turtle populations. Based on firsthand, anecdotal accounts of turtle harvest and trends in turtle nesting in recent decades and in light of similar scenarios involving other small nesting turtle populations in the Caribbean (Bell et al. 2006, 2007; McClenachan et al. 2006), the TCI harvest may well be compromising the future of the TCI's native turtle populations.

This study confirmed that hawksbill turtles still regularly nest on several remote beaches and cays on the TCI but probably in low densities; although, nesting

density may be greater earlier in the season before the months when this study's opportunistic beach surveys occurred. For the first time in recent decades, the study confirmed limited green and loggerhead turtle nesting activity. Some of the nesting sites reported by Fletemeyer (1984) were confirmed to still host nesting. Contrary to Fletemeyer (1984), we suggest that the TCI green turtle nesting season lasts through to September and therefore may at least overlap with the nearby Bahamas' green turtle nesting season, lasting from June to September as described by Carr et al. (1982).

Fresh nesting activities found during this survey confirm that hawksbill nesting occurs in the months of September, October, and January. In addition, by estimating an incubation period of approximately 60 days (Bjorndal et al. 1985; Mrosovsky et al. 1992) from the freshly emerged hawksbill nest recorded in September, we can confirm that hawksbill nesting also occurs in July. This study therefore suggests that the hawksbill nesting season in the TCI extends from at least July to January, considerably longer than Fletemeyer's (1984) estimate. This is consistent with reports from former egg harvesters interviewed during this study and comparable to the hawksbill nesting season on relatively proximate beaches of Cuba as described by Moncada et al. (1999). No evidence was found to support the claim that loggerhead turtles nest in the TCI in regionally significant numbers, and we suggest that this is not likely to be the case. Comprehensive monitoring of the TCI's nesting beaches is required to fully illuminate the composition, distribution, and seasonality of the TCI's nesting turtle populations. However, this study suggests that the turtle nesting populations in the TCI are small compared to those found in many other Caribbean states. While some larger, protected nesting populations of green and hawksbill turtles in the Caribbean appear to be showing signs of recovery in response to conservation (Garduño-Andrade 1999; Seminoff 2004; Troëng and Rankin 2005; Richardson, Hall, et al. 2006; Beggs et al. 2007; Diez and Van Dam 2007), many smaller nesting populations in the region have declined or have been extirpated because of unsustainable harvest (McClenachan et al. 2006). If the TCI harvest continues to target larger size classes including adults, TCI's apparently depleted native turtle populations may also be threatened with extirpation.

Green, hawksbill, and loggerhead turtles still occur in TCI's waters, with juvenile green and hawksbill turtles apparently the most widespread and abundant species. Adult green and hawksbill turtles are also present, apparently in fewer numbers; although, the biases inherent in the sampling methods (e.g., smaller turtles are probably easier to catch) mean that the population structures of the species present require further investigation, ideally with a broader suite of sampling methods. Adult loggerheads are present too, but it is unclear whether loggerhead turtles are resident or transient in TCI's waters. The presence of *mulatto* turtles as described

by Fletemeyer (1984) was also reported but not confirmed and requires further investigation. Fibropapilloma has been known to be widespread throughout the Caribbean green turtle populations for some time (Williams et al. 1994). This study confirmed, for the first time, the presence of Fibropapilloma symptoms in the TCI green turtle foraging aggregations and recorded anecdotal evidence that the disease may also affect local hawksbill turtle aggregations; although, the extent of this disease in these stocks is unknown.

Patch reefs, fringing reefs, and sea grass beds in the TCI appear to provide important developmental foraging habitat for hawksbill turtles. Indeed, mean growth rate ($4.9 \pm 2.0 \text{ cm y}^{-1}$) of juvenile hawksbills in this study is higher than that of similarly sized hawksbills in the Cayman Islands (Blumenthal et al. 2009a) and the US Virgin Islands (Boulon 1994) and at the higher range of growth rates exhibited by juvenile hawksbills in Puerto Rico (Diez and Van Dam 2002), suggesting that the TCI's coral reefs provide good quality developmental foraging habitat. Length frequency analysis of juvenile hawksbills included in this study is comparable to similar analyses for juvenile hawksbills sampled using similar methods elsewhere in the northern Caribbean region (e.g., British Virgin Islands—McGowan et al. 2008; Cayman Islands—Blumenthal et al. 2009a, 2009b) but most notably in the US Virgin Islands (Boulon 1994). Similar analyses of hawksbills hand caught in Puerto Rico (Leon and Diez 1999; Diez and Van Dam 2003) include a higher percentage of small postrecruitment turtles than were sampled in this study ($< 25 \text{ cm SCL}$). While this could be an artifact of this study's sampling biases, it may be suggestive that the TCI's reefs do not provide primary recruitment habitat as important as that provided by the reefs in Puerto Rican waters. While Bowen et al. (2007) found size and proximity of hawksbill nesting populations positively influence their contribution to feeding aggregations, Velez-Zuazo et al. (2008) did not find an effect of size or location on rookery contributions. Analysis of sampled TCI hawksbills indicated a significant negative correlation between rookery contribution and distance from the TCI, with substantial contributions from the regionally significant and relatively proximate nesting populations in Cuba, the US Virgin Islands, Puerto Rico, and Antigua, all located in the northeastern Caribbean, as well as Mexico, the conspecific largest nesting population in the wider Caribbean (Meylan 1999; IUCN 2002; McClenachan et al. 2006).

Sea grass beds and tidal creeks on the Caicos banks appear to support an abundance of juvenile green turtles, providing a regionally important developmental habitat for this species. The length–frequency analysis of juvenile green turtles included in this study is comparable to similar analyses for juvenile green turtles sampled in similar habitat in the Bahamas (Bjorndal et al. 2005) and in the British Virgin Islands (McGowan et al. 2008). As with the hawksbills, the mixed-stock analysis from the

small number of green turtle samples showed a significant negative correlation between rookery contribution and distance from the TCI, with regionally significant nesting populations in Costa Rica, Florida, and Mexico making important contributions to the TCI's foraging juvenile green turtle aggregation. These nesting populations are showing significant signs of recovery (Seminoff 2004; Troëng and Rankin 2005).

While the TCI's turtle fishery is considered less economically important than other fisheries in the Islands, there is an ongoing culture of marine turtle use in the TCI, where green and hawksbill turtles are regularly caught and legally landed to meet consumer demand. While illegal practices of occasional egg collection and the landing of undersized turtles are associated with the legal turtle harvest, this study found no evidence of other significant sources of turtle mortality in the TCI (e.g., bycatch). This study estimates that at least around 420 turtles are legally harvested in the TCI's waters each year. While the SEQ sample was subject to a significant confounding sampling bias created by DECR officers purposefully leading interviewers to known turtle fishers, these extrapolations likely provide conservative estimates for the actual annual harvest of turtles in TCI's waters.

In 2003, there were 491 commercial fishers licensed to fish in the TCI, while an unknown number of unlicensed fishers fished for personal consumption (J. Campbell, DECR, *pers comm.*, 2004). While the actual number of active licensed fishers and other fishers who catch turtles in the TCI is not known, the fishers interviewed during the SEQ represent approximately 9.2% of fishers licensed in 2003. The fishers interviewed in this study therefore most likely represent a fraction of the number of individuals currently engaged in turtle harvest in the TCI, and therefore the annual harvest of turtles in the TCI is probably much higher than these minimum estimates. In addition, most SEQ interviews were carried out in Providenciales and South Caicos, where the largest fishing communities are based, and may not reflect levels of harvest by fishers based on Grand Turk or Salt Cay, North Caicos, and Middle Caicos. Furthermore, several fishers interviewed during this study corroborated Fleming's (2001) assertion that migrant fishers from the Dominican Republic also catch turtles in the TCI's waters, but no migrant fishers participated in the SEQ.

While this study's sampling biases mean that the harvest estimates should be treated with caution, even these minimum estimates corroborate Rudd's (2003) assessment that the annual turtle harvest involves hundreds of animals. Indeed, the current level of take is probably much higher and could be comparable to other legal turtle harvests among the Caribbean islands, including Cuba's contentious former turtle harvest that harvested an annual quota of 500 hawksbills (Carrillo et al. 1999; Mortimer et al. 2007) and the annual turtle

harvest in Grenada, thought to be around 780 green and hawksbills (Grazette et al. 2007).

The harvest of juvenile and adult turtles is considered to be a primary threat to depleted green and hawksbill populations around the world (Meylan and Donnelly 1999; Seminoff 2004), and a reduction in mortality of large juvenile, subadult, and adult size classes is considered key to the recovery of depleted marine turtle populations (Crouse et al. 1987; Crouse 1999). The Fisheries Protection Ordinance (1998) currently allows the TCI turtle fishers' preferred targeting of larger size classes, including adults, which, presumably, they take because of a higher meat yield and therefore higher sale value. One harvested adult female green turtle sampled during this study was probably breeding locally, but the harvested adult hawksbills sampled in this study may have been either visiting breeders or resident foragers. Given the geographic range of these animals, it has been suggested that nations operating or promoting harvest of foraging turtle aggregations could be undermining conservation efforts elsewhere (Mortimer et al. 2007). It is unclear whether the TCI harvest significantly impacts nesting hawksbill populations in proximate states, such as Puerto Rico, that are likely contributing breeding adults to the TCI foraging aggregation (Van Dam et al. 2008). However, in Puerto Rico, where considerable resources are invested in the conservation and monitoring of its nesting turtle populations, hawksbill nesting activity has significantly increased since the 1980s despite the TCI harvest (Diez and Van Dam 2007). In any case, the harvest of adult turtles in the TCI's waters is likely to impact the TCI's depleted native populations and, as in other UK Overseas Territories (e.g., Montserrat: Martin et al. 2005), is a conservation concern. Indeed, decimation of turtle nesting populations due to local harvest is not without precedent in UK Overseas Territories, with the Cayman Islands' turtle nesting populations having been drastically depleted by the country's historical harvest (Bell et al. 2006, 2007).

From their Caribbean-wide mixed-stock analysis of hawksbill turtles, Bowen et al. (2007) conclude that turtle harvests at feeding habitats will impact nesting populations throughout the region, with greatest detriment to those nearby; although, this has been contended by Godfrey et al. (2007). It is not clear how the TCI annual harvest of hundreds of large juvenile and subadult foraging green and hawksbill turtles is affecting TCI foraging aggregations and their contributing nesting populations. Trends in hawksbill nesting populations in the US Virgin Islands are thought to be stable (Eckert 1995, in Meylan 1999) and are unknown in Cuba (Moncada et al. 1999). However, other contributing green and hawksbill nesting populations have recently experienced significant signs of recovery (e.g., green turtles—Costa Rica, Mexico; hawksbill turtles—Mexico, Antigua, Puerto Rico—Garduño-Andrade 1999; Seminoff 2004; Troëng and Rankin 2005; Richardson, Hall, et al. 2006;

Diez and Van Dam 2007), again despite the harvest in the TCI.

Prohibition of use of marine turtles has traditionally been widely advocated by marine turtle experts, and has been incorporated into relevant multilateral environmental agreements (see Campbell 2002; Campbell et al. 2002; Richardson, Broderick, et al. 2006). More recently, some authors have called for constructive dialogue regarding the role of marine turtle use in conservation (Mrosovsky 2000; Godfrey et al. 2007), and population modeling of recovering green turtle populations in Hawaii strongly indicates that limited harvest could now be sustainable (Chaloupka and Balazs 2007). As there is no hard turtle harvest data originating from the TCI, it is currently not possible to assess whether the harvest is sustainable with respect to the contributing nesting populations. However, encouraging signs of recovery within some of these contributing populations, despite decades of the TCI turtle harvest, suggest that with improved management, the TCI's harvest could achieve sustainability, at least with respect to these recovering contributing populations.

Clearly, more outreach and enforcement are necessary to implement the existing legislation that protects turtle eggs and undersized turtles. Indeed, other analysis of the SEQ data suggests that the majority of fishers interviewed in the TCI agreed that their government should actively protect turtles and better enforce existing laws (Campbell et al. 2009). This study, however, indicates a need to protect the TCI's dwindling native adult turtles when they return to TCI's waters to reproduce. To address this concern, Godley et al. (2004) provided recommendations for change to legislation and fishery management, including the introduction of a closed season during the composite turtle reproductive season, maximum size limits to prevent capture of adults, species restrictions, and the introduction of fisher licences and quotas. These measures are not without precedent and feature in the legislation regulating turtle harvests in other UK Overseas Territories in the Caribbean (see Bell et al. 2006; Richardson, Broderick, et al. 2006).

However, the SEQ process indicated varied acceptance of such measures by interviewed fishers, with the majority agreeing with size restrictions but showing mixed acceptance of closed seasons, quotas, and species restrictions (Campbell et al. 2009). These mixed reactions within the community may be problematic for future efforts to improve fishery management. For example, the introduction of a closed season of at least 7 months to cover the known hawksbill nesting season in the TCI (comparable to the current 8-month closed season for the British Virgin Islands' turtle fishery; see Richardson, Broderick, et al. 2006) may well meet with resistance from some within the sector, which has a documented history of noncompliance (Rudd 2003; Tewfik and Bene 2004). There was also uncertainty among the fisher community regarding their ownership of and future role in the management of the turtle fishery. Less than half

identified themselves as likely participants in future fishery regulation, with some suspicious that this study may inevitably lead to prohibition of the fishery (Silver and Campbell 2005; Campbell et al. 2009).

In order to inform future policy and management changes, it is clear that further stakeholder consultation is required. Similarly, improved biological data regarding the extent of harvest, status of nesting populations and in-water stock, and further mixed-stock analysis are required to better understand future fishery management. Further research is also required to establish the significance of foreign turtle fishing effort in and turtle product export from TCI's waters. So long as CITES does not extend to the TCI, the alleged and observed export of turtle products to the Dominican Republic and Haiti does not contravene current legislation in the TCI. However, the TCI government has drafted national legislation in preparation for accession to CITES, which may well eventually outlaw current export and which will require further appropriate amendments to the current fisheries legislation to regulate movement of turtle products from the TCI (Richardson, Broderick, et al. 2006). Amendments to the Fisheries Protection Ordinance (1998) should also take into account the TCI's obligations under the Convention of Migratory Species, as it is questionable whether the TCI's turtle harvest currently satisfies this convention (Richardson, Broderick, et al. 2006).

The Turks and Caicos Islanders have been harvesting marine turtles for centuries, but this regionally significant harvest may now threaten the territory's native green and hawksbill turtle populations and may have the potential to impede recovery of nesting populations in nearby states. Turtle fishery management in the TCI is in need of review to prevent the loss of the TCI's nesting turtles, but legislative amendments alone will not be sufficient to achieve this aim. While the turtle fishery appears to be of little economic significance to most TCI fishers, this traditional harvest benefits a local collective of fishers, vendors, and consumers. Future efforts to inform and effect major changes to the management of this long-standing fishery should therefore make every effort to generate participation, understanding, and consent among this collective in order to facilitate compliance that is by no means guaranteed.

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LITERATURE CITED

- ALLAN, C.J. 1998. Conched Out: A Review of the Trade in CITES Listed Species in the United Kingdom Overseas Territories in the Caribbean. Godalming: WWF-UK, 80 pp.
- ALLARD, M.W., MIYAMOTO, M.M., BJORNDAAL, K.A., BOLTEN, A.B., AND BOWEN, B.W. 1994. Support for natal homing in green turtles from mitochondrial DNA sequences. *Copeia* 1994:34–41.
- ANONYMOUS. 1999. Partnership for Progress and Prosperity: Britain and the Overseas Territories. UK Government White Paper Presented to Parliament by the Secretary of State for Foreign and Commonwealth Affairs.
- BALAZS, G.H. 1999. Factors to consider in the tagging of sea turtles. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). *Research and Management Techniques for the Conservation of Sea Turtles*. IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 101–109.
- BASS, A.L. 1999. Genetic analysis to elucidate the natural history and behaviour of hawksbill turtles (*Eretmochelys imbricata*) in the wider Caribbean: a review and reanalysis. *Chelonian Conservation Biology* 3:195–199.
- BASS, A.L. AND WITZELL, W.N. 2000. Demographic composition of immature green turtles (*Chelonia mydas*) from the east central Florida coast: evidence from mtDNA markers. *Herpetologica* 56:357–367.
- BEGGS, J.A., HORROCKS, J.A., AND KRUEGER, B.H. 2007. Increase in hawksbill sea turtle *Eretmochelys imbricata* nesting in Barbados, West Indies. *Endangered Species Research* 3:159–168.
- BELL, C.D., BLUMENTHAL, J.M., AUSTIN, T.J., EBANKS-PETRIE, G., BRODERICK, A.C., AND GODLEY, B.J. 2009. Harnessing recreational divers for the collection of sea turtle data around the Cayman Islands. *Tourism in Marine Environments* 5(4): 245–257.

- BELL, C.D., BLUMENTHAL, J.M., AUSTIN, T.J., SOLOMON, J.L., EBANKS-PETRIE, G., BRODERICK, A.C., AND GODLEY, B.J. 2006. Traditional Caymanian fishery may impede local marine turtle population recovery. *Endangered Species Research* 2: 63–69.
- BELL, C., SOLOMON, J.L., BLUMENTHAL, J.M., AUSTIN, T.J., EBANKS-PETRIE, G., BRODERICK, A.C., AND GODLEY, B.J. 2007. Monitoring and conservation of critically reduced marine turtle nesting populations: lessons from the Cayman Islands. *Animal Conservation* 10:39–47.
- BJORNDAL, K.A., BOLTON, A.B., AND CHALOUKKA, M.Y. 2005. Evaluating trends in abundance of immature green turtles, *Chelonia mydas*, in the Greater Caribbean. *Ecological Applications* 15:304–314.
- BJORNDAL, K.A., CARR, A., MEYLAN, A.B., AND MORTIMER, J.A. 1985. Reproductive biology of the hawksbill *Eretmochelys imbricata* at Tortuguero, Costa Rica, with notes on the ecology of the species in the Caribbean. *Biological Conservation* 34:353–368.
- BLUMENTHAL, J.M., AUSTIN, T.J., BELL, C.D., BOTHWELL, J.B., BRODERICK, A.C., EBANKS-PETRIE, G., GIBB, J.A., LUKE, K.E., OLYNIK, J.R., ORR, M.F., SOLOMON, J.L., AND GODLEY, B.J. 2009a. Ecology of hawksbill turtles *Eretmochelys imbricata* in a western Caribbean foraging area. *Chelonian Conservation and Biology* 8:1–10.
- BLUMENTHAL, J.M., AUSTIN, T.J., BOTHWELL, J.B., BRODERICK, A.C., EBANKS-PETRIE, G., OLYNIK, J.R., ORR, M.F., SOLOMON, J.L., WITT, M.J., AND GODLEY, B.J. 2009b. Diving behaviour and movements of juvenile hawksbill turtles *Eretmochelys imbricata* on a Caribbean coral reef. *Coral Reefs* 28:55–65.
- BOLTON, A. 1999. Techniques for measuring sea turtles. In: Eckert, K.L., Bjorndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). *Research and Management Techniques for the Conservation of Sea Turtles*, IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 110–114.
- BOULON, R.H. 1994. Growth rates of wild juvenile hawksbill turtles, *Eretmochelys imbricata*, in St. Thomas, United States Virgin Islands. *Copeia* 1994:811–814.
- BOWEN, B.W., GRANT, S.W., HILLIS-STARR, Z., SHAVER, D.J., BJORNDAL, K.A., BOLTON, A., AND BASS, A.L. 2007. Mixed-stock analysis reveals the migrations of juvenile hawksbill turtles (*Eretmochelys imbricata*) in the Caribbean Sea. *Molecular Ecology* 16:49–60.
- BOWEN, D. 2003. Peas ‘n’ Grits & ‘Penn On’: True Turks and Caicos Cuisine. *The Times of the Islands* Fall 2003:27–32.
- BRODERICK, A.C., FRAUENSTEIN, R., GEORGE, T., GLEN, F., HAYS, G.C., JACKSON, A.D., RUXTON, G.R., AND GODLEY, B.J. 2006. Are green turtles globally endangered? *Global Ecology and Biogeography* 15:21–26.
- CAMPBELL, L.M. 2002. Science and sustainable use: views of marine turtle conservation experts. *Ecological Applications* 12:1229–1246.
- CAMPBELL, L.M., GODFREY, M.H., AND DRIF, O. 2002. Community-based conservation via global legislation? Limitations of the Inter-American Convention for the Conservation of Sea Turtles. *Journal of International Wildlife Law and Policy* 5: 121–143.
- CAMPBELL, L.M., SILVER, J.J., GRAY, N.J., RANGER, S., BRODERICK, A.C., FISHER, T., GODFREY, M.H., GORE, S., HODGE, K.V.D., JEFFERS, J., MARTIN, C.S., MCGOWAN, A., RICHARDSON, P.B., SASSO, C., SLADE, L., AND GODLEY, B.J. 2009. Co-management of sea turtle fisheries: biogeography versus geopolitics. *Marine Policy* 33:137–145.
- CARRILLO, E., WEBB, G.J.W., AND MANOLIS, S.C. 1999. Hawksbill turtles (*Eretmochelys imbricata*) in Cuba: an assessment of the historical harvest and its impacts. *Chelonian Conservation and Biology* 3:264–280.
- CARLSON, B. 2000. Grand Turk: Its bones are the key to an unexpected past. *The Times of the Islands* 4:54–57.
- CARR, A., MEYLAN, A.B., MORTIMER, J., BJORNDAL, K.A., AND CARR, T. 1982. Survey of sea turtle populations and habitats in the Western Atlantic. NOAA Technical Memorandum NMFS-SEFC 91.
- CHALOUKKA, M. AND BALAZS, G.H. 2007. Using Bayesian state-space modelling to assess the recovery and harvest potential of the Hawaiian green sea turtle stock. *Ecological Modelling* 205:93–109.
- CROUSE, D.T. 1999. Population modelling and implications for Caribbean hawksbill sea turtle management. *Chelonian Conservation and Biology* 3:185–188.
- CROUSE, D.T., CROWDER, L.B., AND CASWELL, H. 1987. A stage-based population model for loggerhead sea turtles and implications for conservation. *Ecology* 68:1412–1423.
- DIEZ, C.E. AND VAN DAM, R.P. 2003. Sex ratio of immature hawksbill sea turtle aggregation at Mona Island, Puerto Rico. *Journal of Herpetology* 37:533–537.
- DIEZ, C.E. AND VAN DAM, R.P. 2007. Mona and Monito Island-Puerto Rico hawksbill turtle research project: Research Report for 2006. Unpublished technical report prepared by the Mona Island Hawksbill Research Group in collaboration with Departamento de Recursos Naturales y Ambientales de Puerto Rico, Chelonia, Inc., and Universidad de Puerto Rico-recinto de Rio Piedras.
- DIAZ-FERNANDEZ, R., OKAYAMA, T., UCHIYAMA, T., CARRILLO, E., ESPINOSA, G., MARQUEZ, R., DIEZ, C., AND KOIKE, H. 1999. Genetic sourcing for the hawksbill turtle, *Eretmochelys imbricata*, in the northern Caribbean region. *Chelonian Conservation and Biology* 3:296–300.
- DUTTON, P.H. 1996. Methods for the collection and preservation of samples for sea turtle genetic studies. In: Bowen, B.W. and Witzell, W.N. (Eds.). *Proceedings of the International Symposium on Sea Turtle Conservation Genetics*. NOAA Technical Memorandum NMFS-SEFSC-396, p. 173.
- EHRHART, L.M. 1989. Status report of the loggerhead turtle. In: Ogren, L., Berry, F., Bjorndal, K., Kumpf, H., Mast, R., Medina, G., Reichart, H., and Witham, R. (Eds.). *Proceedings of the Second Western Atlantic Turtle Symposium*. NOAA Technical Memorandum NMFS-SEFC-226, pp. 122–139.
- FLEMING, E.H. 2001. Swimming against the tide. Report for TRAFFIC, North America, pp. 133–138.
- FLETMEYER, J.R. 1984. The national report for the country of Turks and Caicos Islands. In: Bacon, P., Berry, F., Bjorndal, K., Hirth, H., Ogren, L., and Weber, M. (Eds.). *Proceedings of the Western Atlantic Turtle Symposium*. Miami, FL: University of Miami Press, pp. 409–422.
- FORMIA, A., GODLEY, B.J., AND BRUFORD, M.W. 2006. Mitochondrial DNA diversity and phylogeography of endangered green turtle (*Chelonia mydas*) population in Africa. *Conservation Genetics* 7:353–369.
- FRAZIER, J. 2003. Prehistoric and ancient historic interactions between humans and marine turtles. In: Lutz, P., Musick, J.A., and Wyneken, J. (Eds.). *The Biology of Sea Turtles*, Volume 2. Boca Raton, FL: CRC Press, pp. 1–38.
- GARDUÑO-ANDRADE, M., GUZMAN, V., MIRANDA, E., BRISENO-DUENAS, R., AND ABREU-GROBOIS, F.A. 1999. Increases in hawksbill turtle (*Eretmochelys imbricata*) nesting in the Yucatan Peninsula, Mexico, 1977–1996: data in support of successful conservation? *Chelonian Conservation and Biology* 3:286–295.

- GAUDIAN, G. AND MEDLEY, P. 2000. The Turks and Caicos Islands. In: Sheppard, C. (Ed.). Seas at the Millennium: An Environmental Evaluation, Volume 1, Regional Chapters: Europe, the Americas & West Africa. New York: Pergamon, pp. 587–594.
- GODFREY, M.H. AND GODLEY, B.J. 2008. As we see it: Seeing past the red: flawed IUCN global listings for sea turtles. *Endangered Species Research* 6:155–159.
- GODFREY, M.H., WEBB, G.J.W., MANOLIS, C., AND MROSOVSKY, N. 2007. Hawksbill sea turtles: can phylogenetics inform harvesting? *Molecular Ecology* 16:3511–3513.
- GODLEY, B.J., BRODERICK, A.C., CAMPBELL, L.M., RANGER, S., AND RICHARDSON, P.B. 2004. An assessment of the status and exploitation of marine turtles in the UK Overseas Territories in the Wider Caribbean. Final Project Report to the Department of Environment, Food and Rural Affairs and the Foreign and Commonwealth Office, 253 pp.
- GRAZETTE, S., HORROCKS, J.A., PHILLIP, P.E., AND CRAFTON, J.I. 2007. An assessment of the marine turtle fishery in Grenada, West Indies. *Oryx* 41:330–336.
- HERBST, L.H. 1994. Fibropapillomatosis of marine turtles. *Annual Review of Fish Diseases* 4:389–425.
- INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE. 2002. Hawksbill turtles in the Caribbean region: basic biological characteristics and population status. Consolidated paper presented to the CITES Secretariat as part of the Hawksbill Range States Dialogue Process, 52 pp.
- INTERNATIONAL UNION FOR THE CONSERVATION OF NATURE. 2007. 2006 IUCN Red List of threatened species. www.iucnredlist.org (10 October 2007).
- JACKSON, J.B.C. 1997. Reefs since Columbus. *Coral Reefs* 16(Suppl):S23–S32.
- JACOBSON, E.R., MANSELL, R.B., SUNDBERG, J.P., HAJAR, L., REICHMANN, M.E., EHRHART, L.M., WALSH, M., AND MURRU, F. 1989. Cutaneous fibropapillomas of green turtles (*Chelonia mydas*). *Journal of Comparative Pathology* 101:39–52.
- LEON, Y.M. AND DIEZ, C.E. 1999. Population structure of hawksbill turtles on a foraging ground in the Dominican Republic. *Chelonian Conservation and Biology* 3:230–236.
- LUKE, K., HORROCKS, J.A., LEROUX, R.A., AND DUTTON, P.H. 2004. Origins of green turtle (*Chelonia mydas*) feeding aggregations around Barbados, West Indies. *Marine Biology* 144:799–805.
- MARTE, A.C., FERREIRAS, E., AND VANDERHORST, P. 2003. Preliminary study of the tortoiseshell trade in the Dominican Republic. In: Seminoff, J.A. (Comp.). Proceedings of the Twenty Second Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-503, 308 pp.
- MARTIN, C.S., JEFFERS, J., AND GODLEY, B.J. 2005. The status of marine turtles in Montserrat (eastern Caribbean). *Animal Biodiversity and Conservation* 28:159–168.
- MASUDA, M. 2002. User's Manual for Bayes: Bayesian Stock Mixture Analysis Program. Juneau: National Marine Fisheries Service, Alaska Fisheries Science Center, Auke Bay Laboratory.
- MCCLENACHAN, L., JACKSON, J.B.C., AND NEWMAN, M.J.H. 2006. Conservation implications of historic sea turtle nesting beach loss. *Frontiers in Ecology and the Environment* 4: 290–296.
- MCGOWAN, A., BRODERICK, A.C., FRETT, G., GORE, S., HASTINGS, M., PICKERING, A., WHEATLEY, D., WHITE, J., WITT, M.J., AND GODLEY, B.J. 2008. Down but not out: marine turtles of the British Virgin Islands. *Animal Conservation* 11:92–103.
- MEYLAN, A.B. 1999. Status of the hawksbill turtle (*Eretmochelys imbricata*) in the Caribbean region. *Chelonian Conservation and Biology* 3:177–184.
- MEYLAN, A.B., AND DONNELLY, M. 1999. Status justification for listing the hawksbill turtle (*Eretmochelys imbricata*) as Critically Endangered on the 1996 IUCN Red List of Threatened Animals. *Chelonian Conservation and Biology* 3(2):200–224.
- MONCADA, F., CARRILLO, E., SAENZ, A., AND NODARSE, G. 1999. Reproduction and nesting of the hawksbill turtle, *Eretmochelys imbricata*, in the Cuban Archipelago. *Chelonian Conservation and Biology* 3:257–263.
- MORTIMER, J.A., MEYLAN, P.A., AND DONNELLY, M. 2007. Whose turtles are they anyway? *Molecular Ecology* 16:17–18.
- MROSOVSKY, N. 2000. Sustainable Use of Hawksbill Turtles: Contemporary Issues in Conservation. Issues in Wildlife Management No. 1. Darwin: Key Centre for Tropical Wildlife Management, 107 pp.
- MROSOVSKY, N., BASS, A., CORLISS, L.A., RICHARDSON, J.I., AND RICHARDSON, T.H. 1992. Pivotal and beach temperatures for hawksbill turtles nesting in Antigua. *Canadian Journal of Zoology* 70:1920–1925.
- PARDEE, M. 2005. DECR announces the birth of 101 baby loggerhead turtles. *The Times of the Islands* Fall 2007:47.
- PELLA, J. AND MASUDA, M. 2001. Bayesian methods for analysis of stock mixtures from genetic characters. *Fishery Bulletin* 99:151–167.
- PROCTOR, D. AND FLEMING, L.V. (Eds.). 1999. Biodiversity: The UK Overseas Territories. Peterborough, Joint Nature Conservation Committee. 131 pp.
- RICHARDSON, J.I., HALL, D.B., MASON, P.A., ANDREWS, K.M., BJORKLAND, R., CAI, Y., AND BELL, R. 2006. Eighteen years of saturation tagging data reveal a significant increase in nesting hawksbill sea turtles (*Eretmochelys imbricata*) on Long Island, Antigua. *Animal Conservation* 9:302–307.
- RICHARDSON, P. 2000. Obstacles to objectivity: first impressions of a CITES CoP. *Marine Turtle Newsletter* 89:1–4.
- RICHARDSON, P.B., BRODERICK, A.C., CAMPBELL, L.M., GODLEY, B.J., AND RANGER, S. 2006. Marine turtle fisheries in the UK Overseas Territories of the Caribbean: domestic legislation and the requirements of multilateral agreements. *Journal of International Wildlife Law and Policy* 9:223–246.
- ROBINSON, C.B. AND FULFORD, M. 1997. Grace Bay revisited, Providenciales. In: Cambers, G. (Ed.). Managing beach resources in the smaller Caribbean Islands. Papers presented at a UNESCO–University of Puerto Rico Workshop, 21–25 October 1996, Mayaguez, Puerto Rico. Coastal region and Small Island papers, No. 1, UPR/SGCP-UNESCO, Mayaguez, 262 pp.
- RUDD, M.A. 2003. Fisheries landings and trade in the Turks and Caicos Islands. *Fisheries Centre Research Reports* 11:149–161.
- SADLER, H.E. 1997. Turks Islands Landfall. Grand Turk: Marjorie E Sadler, 151 pp.
- SCHROEDER, B. AND MURPHY, S. 1999. Population surveys (ground and aerial) on nesting beaches. In: Eckert, K.L., Bjørndal, K.A., Abreu-Grobois, F.A., and Donnelly, M. (Eds.). Research and Management Techniques for the Conservation of Sea Turtles, IUCN/SSC Marine Turtle Specialist Group Publication No. 4, pp. 45–55.
- SEMINOFF, J. 2004. Green turtle Red List assessment. www.iucn-mtsg.org. (01 May 2009).
- SILVER, J.J. AND CAMPBELL, L.M. 2005. Fisher participation in research: dilemmas with the use of fisher knowledge. *Ocean & Coastal Management* 48:721–741.

- TEWFIK, A. AND BENE, C. 2004. ‘‘The Big Grab’’: non-compliance with regulations, skewed fishing effort allocation and implications for a spiny lobster fishery. *Fisheries Research* 69:21–33.
- TROÈNG, S., DUTTON, P.H., AND EVANS, D. 2005. Migration of hawksbill turtles *Eretmochelys imbricata* from Tortuguero, Costa Rica. *Ecography* 28:394–402.
- TROÈNG, S. AND RANKIN, E. 2005. Long-term conservation efforts contribute to positive green turtle *Chelonia mydas* nesting trend at Tortuguero, Costa Rica. *Biological Conservation* 121:111–116.
- VAN DAM, R.P., DIEZ, C.E., BALAZS, G.H., COLÓN COLÓN, L.A., MCMILLAN, W.O., AND SCHROEDER, B. 2008. Sex-specific migration patterns of hawksbill turtles breeding at Mona Island, Puerto Rico. *Endangered Species Research* 4:85–94.
- VELEZ-ZUAZO, X., RAMOS, W.D., VAN DAM, R.P., DIEZ, C.E., ABREU-GROBOIS, A., AND MCMILLAN, W.O. 2008. Dispersal, recruitment and migratory behaviour in a hawksbill sea turtle aggregation. *Molecular Ecology* 17:839–853.
- WILLIAMS, E.H., BUNKLEY-WILLIAMS, L., PETERS, E.C., PINTO-RODRIGUEZ, B., MATOS-MORALES, R., MIGNUCCI-GIANNONI, A.A., HALL, K.V., RUEDA-ALMONACID, J.V., SYBESMA, J., DE CALVENTI, I.B., AND BOULON, R.H. 1994. An epizootic of cutaneous fibropapillomas in green turtles *Chelonia mydas* of the Caribbean: part of a panzootic? *Journal of Aquatic Animal Health* 6:70–78.

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