Vol. 15: 129–141, 2011
doi: 10.3354/esr00375

ENDANGERED SPECIES RESEARCH
Endang Species Res

Published online November 10

OPEN ACCESS

Sea turtle nesting habitat in the Wider Caribbean Region

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ABSTRACT: Incomplete baseline data on population demographics and patterns of habitat use and the unmet need for international coordination of conservation actions are among the challenges inherent in promoting the recovery of endangered, migratory marine species. Working with field researchers, government officials and conservationists we developed a comprehensive atlas of all known sea turtle nesting grounds (n = 1311 discrete sites), including colony size and protection frameworks, in the 43 nations and territories in the Wider Caribbean Region (WCR). The majority of sites hosted extremely small colonies characterized by <25 nesting crawls yr^{-1} per species. Large nesting colonies were rare. Sites with >500 nesting crawls yr^{-1}comprised between <1 and 8% of species-specific nesting site totals. We identified information gaps, including sites where nesting was known to occur but data were insufficient to categorize nesting colony size. The database allows users to identify and rank critical habitat, fill data gaps, inform policy-making, promote the implementation of regional agreements, and strengthen national and international conservation planning and research. This research highlights the value of international networking and data sharing, the benefits of collecting baseline information on the distribution and abundance of populations, and the usefulness of long-term, systematic monitoring of sea turtle nesting grounds.

KEY WORDS: Sea turtle · Caribbean · Nesting · Nesting habitat · Endangered species · Migratory marine species

INTRODUCTION

Data on species distribution and range are fundamental to priority-setting exercises aimed at evaluating the status and trends of migratory populations over time (Crowder & Norse 2008, NRC 2010), but such data are rarely assembled in sufficient detail at Large Marine Ecosystem (LME) scales (Sherman et al. 1993, Sherman & Hempel 2009). In the Caribbean Sea, 1 of 64 LMEs (Richards & Bohnsack 1992), the development, implementation, and evaluation of management plans designed to achieve sea turtle population recovery objectives has been hampered by a lack of baseline data on present and historic patterns of habitat use, population size and trend, and threats to survival at all life stages. Sea turtles range across multiple geopolitical boundaries and may traverse ocean basins on an annual basis, further confounding management by engaging a complex landscape of dissimilar and often contradictory regulatory regimes.

Caribbean sea turtle species — loggerhead *Caretta caretta*, green *Chelonia mydas*, leatherback *Dermochelys coriacea*, hawksbill *Eretmochelys imbricata*, Kemp's ridley *Lepidochelys kempii* and olive ridley *Lepidochelys olivacea* (Table 1) — are classified by the International Union for the Conservation of Nature's Red List of Threatened Species as Criti-

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Table 1. Presence of sea turtles in the Wider Caribbean Region. N = nesting; F = foraging; F? = in-water presence, foraging status unknown; IN = infrequent nesting; IF = infrequent foraging; IF? = infrequent in-water presence, foraging status unknown; I = infrequent (further details unavailable); A = absent; A? = unconfirmed reports of presence

Country/territory	Loggerhead turtle *Caretta caretta*	Green turtle *Chelonia mydas*	Leatherback turtle *Dermochelys coriacea*	Hawksbill turtle *Eretmochelys imbricata*	Kemp's ridley turtle *Lepidochelys kempii*	Olive ridley turtle *Lepidochelys olivacea*
Anguilla	F	N, F	N	N, F	A	A
Antigua & Barbuda	I	N, F	N	N, F	A	A
Aruba	N, IF	N, F	N	N, F	A	I
Bahamas	N, F	N, F	N	N, F	A	I
Barbados	I, F?	N, F	N	N, F	A	A
Belize	N, F	N, F	I	N, F	A?	IA
Bermuda	IN, IF	IN, F	IF	F	I	A
Bonaire	N	N, F	IN	N, F	A	A
Brazil	N, F	N, F	N, F?	N, F	A	N, F
British Virgin Islands	IN, IF	N, F	N	N, F	A	A
Cayman Islands	N, IF	N, F	A	F	A	A
Colombia	N, F	N, F	N, F?	N, F	A	I
Costa Rica	N, F	N, F	N	N, F	A	A
Cuba	N, F	N, F	IN, IF	N, F	A	I
Curacao	N, F	N, F	N, IF	N, F	A	I
Dominica	I	N, F	N	N, F	A	A
Dominican Republic	N, IF	N, F	N	N, F	A	A
French Guiana	I	N, F	N	IN	A	N
Grenada	F	F	N	N, F	A	I
Guadeloupe	F	N, F	N, IF	N, F	A	I
Guatemala	N, F	N, F	N	N, F	A	A
Guyana	I	N, F	N	N	A	IN,IF
Haiti	N, F	N, F	N, F?	N, F	A	A
Honduras	N, F	N, F	N	N, F	A	A
Jamaica	N, IF	N, F	N	N, F	A?	I
Martinique	F	IN, F	N, F?	N, F	A	I
Mexico	N, F	N, F	N, F	N, F	N, F	A
Montserrat	IN, F?	N, F	IN, F?	N, F	A	A
Nicaragua	F	N, F	N, IF?	N, F	A	A
Panama	IN, F	IN, F	N	N, F	A	A
Puerto Rico	I	N, F	N, F	N, F	A	I
Saba	I	IN, F	I	IN, F	A	A
Saint Kitts & Nevis	I	N, F	N	N, F	A	A
Saint Lucia	IN	N, F	N	N, F	A	A
Saint Vincent & Grenadines	IN	N, F	N	N, F	A	A
Sint Eustatius	IN	N, F	N	N, F	A	A
Sint Maarten	I	N, F	N	N, F	A	A
Suriname	IF	N	N	N	A	N, F
Trinidad & Tobago	I	N, F	N, F	N, F	A	IN, IF
Turks & Caicos Islands	N, IF	N, F	I	N, F	A?	A?
US Virgin Islands	I	N, F	N	N, F	A	A
USA	N, F	N, F	N, F	IN, F	N, F	A
Venezuela	N, F	N, F	N, F	N, F	A	A

cally Endangered, Endangered, or Vulnerable (IUCN 2011), and recovery and management planning, including ongoing population and habitat assessment, are mandated by multilateral environmental agreements ratified by the majority of Wider Caribbean Region (WCR) governments (Wold 2002, Eckert & Hemphill 2005).

Notwithstanding signs of population increases at some sites (green: Troëng & Rankin 2005; hawksbill: Beggs et al. 2007, Richardson et al. 2006; Kemp's ridley: Márquez et al. 2005, Heppell et al. 2007; leatherback: Dutton et al. 2005; olive ridley: da Silva et al. 2007, NMFS & USFWS 2007a), WCR sea turtle populations are, in general, so severely reduced from historical levels (e.g. Carr 1955, Rebel 1974, King 1982, Groombridge & Luxmoore 1989, Ross et al. 1989, Reichart 1993, Jackson 1997, Aiken et al. 2001, Fleming 2001, Godley et al. 2004, McClenachan et al.

2006, Mortimer & Donnelly 2007) as to be considered by Bjorndal & Jackson (2003) as 'virtually extinct' from the standpoint of their role in Caribbean marine ecosystems, lending further impetus to defining the distribution of critical habitat.

A variety of habitats are known to be important to sea turtles and habitat requirements vary across species (Bjorndal 1997, Musick & Limpus 1997, Bolten 2003, Plotkin 2003). In addition to sandy beaches for egg-laying, sea turtles require healthy coral reef, seagrass and hard-bottom habitats for food and refuge, as well as safe passage through coastal and high-seas migration corridors. In the WCR, these habitats are widely characterized as degraded, mainly due to intense pressures arising from changes in water quality, patterns of coastal development and land use, and fisheries and other extractive industries (UNEP 1989, 2005, Sullivan-Sealey & Bustamante 1999, Burke & Maidens 2004, UNEP/GPA/CATHALAC 2004, UNEP/GPA 2006). These and other physical threats to the integrity and persistence of sea turtle habitats are likely to be exacerbated by climate change predictions in the WCR (Fish et al. 2005, 2008, 2009, IPCC 2007, Hawkes et al. 2009).

Several international conservation instruments and organizations include sea turtles and their habitats, and provide guidance on their conservation and management in the WCR. For example, all 6 species are listed on Annex II of the Protocol concerning Specially Protected Areas and Wildlife (SPAW) to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region; in Appendix I of the Convention on Migratory Species (CMS); and in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Further, all 6 are recognized as being in need of 'protection, conservation and recovery' throughout the hemisphere by the Interamerican Convention for the Protection and Conservation of Sea Turtles (Wold 2002).

Mindful of a long-standing conservation imperative, intergovernmental meetings devoted to addressing shared management concerns have been convening in the WCR for nearly 3 decades (e.g. Bacon et al. 1984, Ogren 1989, Eckert & Abreu Grobois 2001, IUCN 2002). In November 1999, resource managers and scientists from 29 WCR nations and territories met in the Dominican Republic and unanimously recommended that 'appropriate authorities, organizations, civic groups and other stakeholders promote scientific research, assessment and monitoring of marine turtles and their habitats, and standardize methods of data collection and analysis.' To this end, delegates agreed inter alia on the need to 'identify (locate), characterize, and rank (as to intensity of use and importance for management) marine turtle nesting and foraging sites', and to 'identify, evaluate and rank threats to marine turtles and their habitats — both domestic and, to the extent practicable, throughout their ranges' (Santo Domingo Declaration: Eckert & Abreu Grobois 2001, p. vi, viii).

The objective of this research was to create the first geographically comprehensive spatial database of sea turtle nesting beaches in the WCR and to make it freely available to stakeholders in an interactive online electronic format. The atlas is designed to inform population assessments and assist users in evaluating the status and trends of populations at biologically relevant scales, strengthen conservation planning exercises, promote the implementation of regional agreements that protect sea turtles and their habitats, identify gaps in existing information, support implementation of marine spatial planning, and contribute to a more integrated information base and management framework for the region.

MATERIALS AND METHODS

The WCR is defined as comprising the States and territories of the insular Caribbean (including the Bahamas), the north-eastern sector of South America (Colombia, Venezuela, the Guianas), Central America, Mexico and the USA to 30° N latitude, including the waters of the Caribbean Sea, the Gulf of Mexico, and the Atlantic Ocean adjacent to these States and territories (UNEP 1983). Because this research was undertaken by the Wider Caribbean Sea Turtle Conservation Network (WIDECAST), we embraced the full geography of the network, including the nations and territories of the WCR and additionally Bermuda to the north and Brazil to the south (Frazer 1985, Eckert & Hemphill 2005).

We utilized data from several different sources to generate the spatial database. The primary sources of information were bilingual (English, Spanish) questionnaires completed by >120 sea turtle researchers, government officials (fisheries and forestry officers, protected areas staff), conservation professionals, and informed community leaders in the 43 nations and territories of the WCR, inclusive of Bermuda and Brazil (a copy of the questionnaire and roster of data providers can be found in Dow et al. 2007). The questionnaire asked each data provider to identify the nesting beaches for each species of sea turtle known to nest in their nation or territory, the location (geographic coordinates) and length of those nesting beaches, the number of nesting crawls (binned to <25, 25–100, 100–500, 500–1000 and >1000, and X for unknown abundance) made by each species per nesting beach per year, and the extent to which the nesting beach is monitored for egg-laying and/or hatching activity. The rate of return on the questionnaires we distributed was 100%.

As nesting sites are defined and monitored differently in different countries/territories, data providers defined nesting sites as 'operational management units', rather than strict geographic entities (e.g. sandy beaches). Sometimes small beaches, proximal but physically separated, are viewed as a single 'nesting beach' and managed or monitored as a group. Conversely, extensive beach strands, extending hundreds of kilometers, are often segmented (e.g. because of limited human resources or the logistics of beach access) for the purpose of monitoring and management. In the former case multiple, typically small and adjoining, habitats might be combined; in the latter case, extensive shorelines might be divided. In order to make the resulting database useful to constituent WCR managers, we chose to use the data providers' definition of their nesting sites (including geographic coordinates and beach length). We worked closely with data providers to be as consistent, realistic and accurate as possible.

Not all sea turtle population monitoring efforts differentiate between successful and unsuccessful nesting, so standardizing on 'crawls' (tracks left in the sand when a gravid female leaves the sea and crawls on a nesting beach, including both successful egg-laying and failed laying attempts) ensured that all countries could participate in the region-wide assessment. Because a visit by the gravid female to her nesting beach does not guarantee the successful deposition of eggs, the number of crawls is typically larger than the number of nests, which, in turn is larger than the number of individual females. Clutch frequency varies with species and locale from approximately 2 to 6 or more (Miller 1997). Therefore, the number of crawls is a baseline metric of reproductive effort not to be confused with the number of nests (successful egg-laying events) or the number of females responsible for those nests. In addition to estimating annual crawl abundance, we asked each data provider to provide information about sea turtle habitat use, protection policies, the effectiveness of those protection policies, and nesting and foraging threats within the jurisdiction of their nation or territory (for detail on threats, not included in this analysis, see Dow et al. 2007).

For each country or territory nesting site the dataset includes: beach name, latitude and longitude, approximate length, number of crawls for each species known to be present, activity status (confirming whether the nesting beach is currently active; historical nesting beaches no longer in use were excluded), beach monitoring status (confirming whether nesting activity is recorded daily, weekly, irregularly, etc.), and the time period over which the data were collected, as well as data provider information, detailed notes on data points, and references for sources of data other than the primary data providers. Finally, we conducted a thorough literature review to compile nesting site location information and analyze data from peer-reviewed literature, project reports, national recovery plans, regional assessments, and unpublished manuscripts.

We gave each nesting site data point a confidence rating of high, moderate or low based on its age and/or source quality. We assigned a high rating to data received and verified directly from active researchers or other local experts, and to datasets derived from peer-reviewed published literature or published project reports <10 yr old. We assigned a moderate rating to datasets where population monitoring was less than comprehensive, where we received incomplete information on how the data were collected, and to datasets 10 to 20 yr old. Finally, we assigned a low rating to datasets derived from non-expert or opportunistic observations, and to datasets >20 to 25 yr old.

We combined data for individual countries and territories to generate regional shapefiles for nesting habitat using ESRI ArcGIS9.1. Point shapefiles were generated using latitude and longitude coordinates for each nesting beach. Nesting site coordinates should be considered approximate, as beach boundaries may change within and between years. Coordinates are located at the approximate midpoint of each beach.

Inevitably more information was available for some countries than for others. We collected supplemental data through comprehensive literature reviews, but in some cases (e.g. Haiti, St. Vincent and the Grenadines) we found relevant data to be scarce from any source. To ensure accuracy, every data provider reviewed all resulting database files and maps from their data collection region and the entire atlas was subject to peer-review. Finally, we created national summaries for each country/territory and archived the entire nesting atlas database in an interactive website as part of the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) database (Halpin et al. 2009, Dow et al. 2007; http://seamap.env.duke.edu/widecast).

RESULTS

Based on site-specific data largely defined as being of medium (33%) and high (57%) quality, we identified and characterized 1311 sea turtle nesting sites in 43 countries and territories extending from Bermuda, a British Overseas Territory in the North Atlantic, south to Brazil (Fig. 1). Because 56% of these sites are associated with the nesting of multiple sea turtle species, we identified a total of 2535 species-specific nesting sites (Table 2). We found large nesting colonies to be very rare. Sites with >500 crawls yr^{-1} comprised between <1 and 8% of species-specific totals. The largest majority of sites hosted very small colonies characterized by <25 crawls yr^{-1}.

Collectively, two-thirds of the identified nesting sites supported hawksbill sea turtles, while approximately 42.1% supported loggerheads, 45.2% green, and 35.8% leatherback sea turtles. In contrast, comparatively few sites, <5%, supported nesting by Kemp's ridley or olive ridley sea turtles. A variable number (0 to 33%) of sites for each species were known to support nesting, but reliable data pertaining to colony size were not available (Table 2, Fig. 2).

Approximately half (50.6%) of species-specific nesting sites received <25 crawls yr^{-1} by any single species. In addition, the 23.4% of beaches where nesting was known to occur but where data were insufficient to estimate colony size are, in the view of local experts, likely to be low density sites in the '<25 crawls yr^{-1}' category. In contrast, 13.9%, 8.0%, 1.9% and 2.3% receive an estimated 25–100, 100–500, 500–1000 or >1000 crawls yr^{-1}, respectively.

Loggerhead sea turtles

We found that loggerhead sea turtles generally nested in more temperate latitudes when compared to other Caribbean sea turtle species (Fig. 1). The majority of WCR nesting occurred in the USA (Florida), where all but 1 of 40 beaches identified as having >500 crawls yr^{-1} were located (the other was located in Brazil). Sites with between 100 and 500 crawls yr^{-1} followed the same pattern and were clustered in the northern (Bahamas, Cuba, Mexico, USA) and southern (Brazil) extremes of the region. Of all known nesting beaches, 41% supported <25 crawls yr^{-1}, and in 14% of identified sites, data were insufficient to estimate annual crawl abundance (Fig. 2).

Green sea turtles

Green sea turtles nested throughout the region (Fig. 1). Tortuguero Beach in Costa Rica is clearly the largest nesting colony in the region, averaging >100 000 nests yr^{-1} (1999–2003: Troëng & Rankin 2005). The 32 beaches with >500 crawls yr^{-1} were broadly distributed along the continental margins of Costa Rica, French Guiana, Mexico, Suriname, and the USA (Florida); the only insular sites in this category were located in Brazil (Atol das Rocas and Ilha da Trindade), Venezuela (Aves Island) and Cuba. More than half (52%) of all known nesting beaches supported <25 crawls yr^{-1}, and in 24% of sites data were insufficient to estimate annual crawl abundance (Fig. 2).

Leatherback sea turtles

Many of the largest leatherback sea turtle nesting colonies in the western hemisphere can be found in the WCR (Turtle Expert Working Group 2007) (Fig. 1). Ten colonies with >1000 crawls yr^{-1} are clustered in the southern (and mostly southeastern) sector of the region (Panama, Trinidad, Suriname, and French Guiana). Four additional sites reported between 500 and 1000 crawls yr^{-1} and were more broadly distributed, located in Costa Rica, Guyana, Suriname, and the US Virgin Islands. More than half (58%) of all known nesting beaches supported very small colonies, with <25 crawls yr^{-1}, and 21% had unknown crawl abundances (Fig. 2).

Hawksbill sea turtles

Hawksbill sea turtles nested in typically low densities throughout the region (Fig. 1). Only 3 sites, Mona Island (Puerto Rico), the west coast of

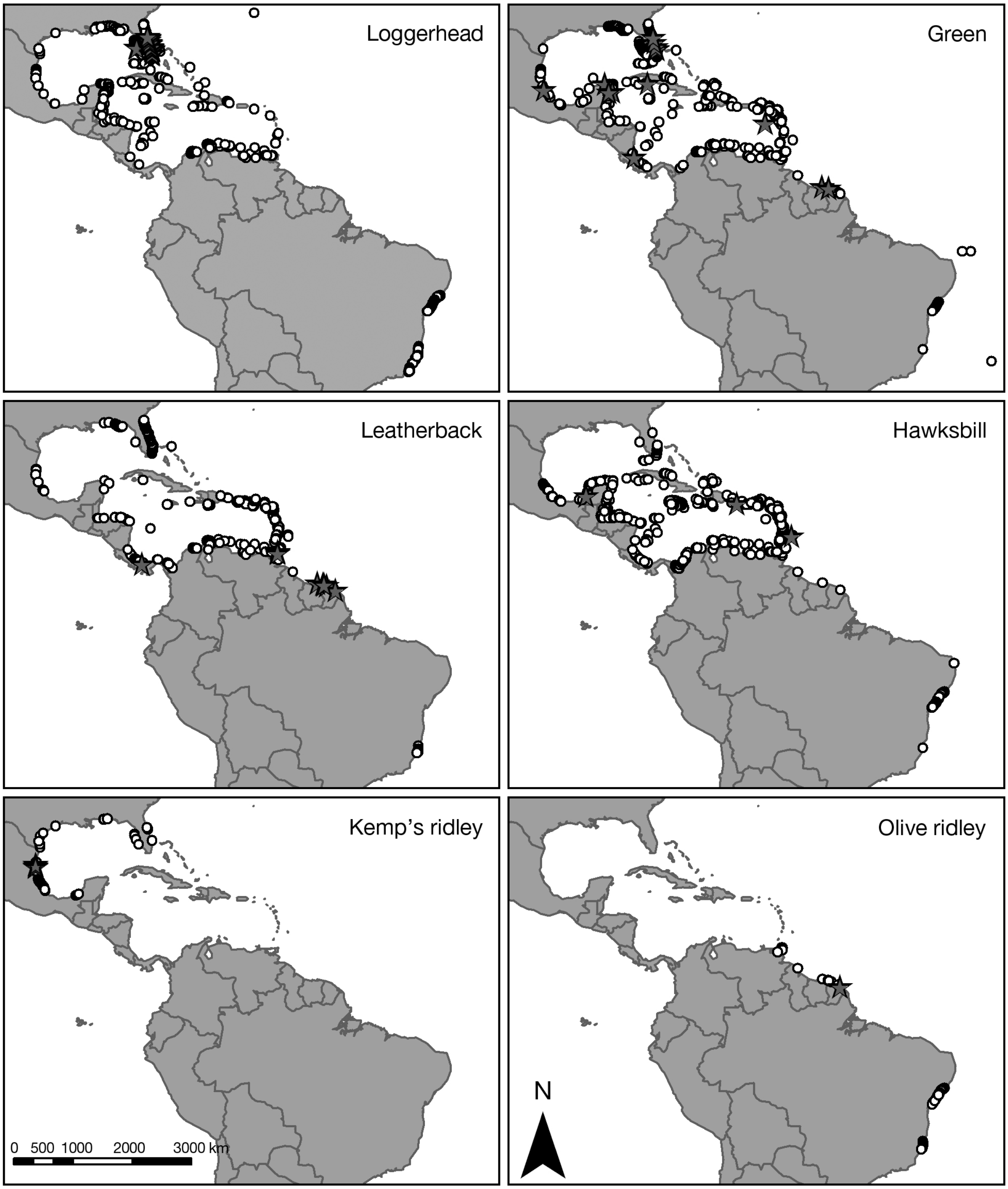

Fig. 1. Six species of sea turtle nest seasonally at 1311 geographically discrete sites in 43 countries and territories of the Wider Caribbean Region (WCR). Circles denote nesting sites and stars denote nesting sites with >1000 nesting crawls yr^{-1}. Visit http://seamap.env.duke.edu/widecast for details

Barbados, and Punta Xen (Mexico), supported >1000 crawls yr^{-1}. Five countries reported nesting beaches with between 500 and 1000 crawls yr^{-1}: half of these sites were situated along the Yucatan Peninsula in Mexico and the others were located in Barbados, Panama, and the US Virgin Islands. Of the 817 nesting beaches, 36 (4.4%) supported >100 crawls yr^{-1}. In contrast, 52% received <25 crawls yr^{-1} and 33% had unknown crawl abundances (Fig. 2).

Table 2. Numbers of sea turtle nesting sites in the Wider Caribbean Region, including Bermuda and Brazil, and distribution of sites across size categories. The species-specific proportion of total nesting sites is shown in parentheses. X = nesting occurs, but the number of nesting crawls yr^{-1} is unknown. See Table 1 for scientific names of species

Species	Total nesting sites	No. of crawls yr^{-1}					
		X	<25	25–100	100–500	500–1000	>1000
Loggerhead turtle	552	76 (0.14)	228 (0.41)	121 (0.22)	87 (0.16)	14 (0.03)	26 (0.05)
Green turtle	593	142 (0.24)	308 (0.52)	66 (0.11)	45 (0.08)	17 (0.03)	15 (0.03)
Leatherback turtle	470	101 (0.21)	271 (0.58)	60 (0.13)	24 (0.05)	4 (0.01)	10 (0.02)
Hawksbill turtle	817	268 (0.33)	423 (0.52)	90 (0.11)	22 (0.03)	11 (0.01)	3 (0.004)
Kemp's ridley turtle	41	0 (0.00)	25 (0.61)	2 (0.05)	11 (0.27)	0 (0.00)	3 (0.07)
Olive ridley turtle	62	5 (0.08)	28 (0.45)	13 (0.21)	13 (0.21)	2 (0.03)	1 (0.02)

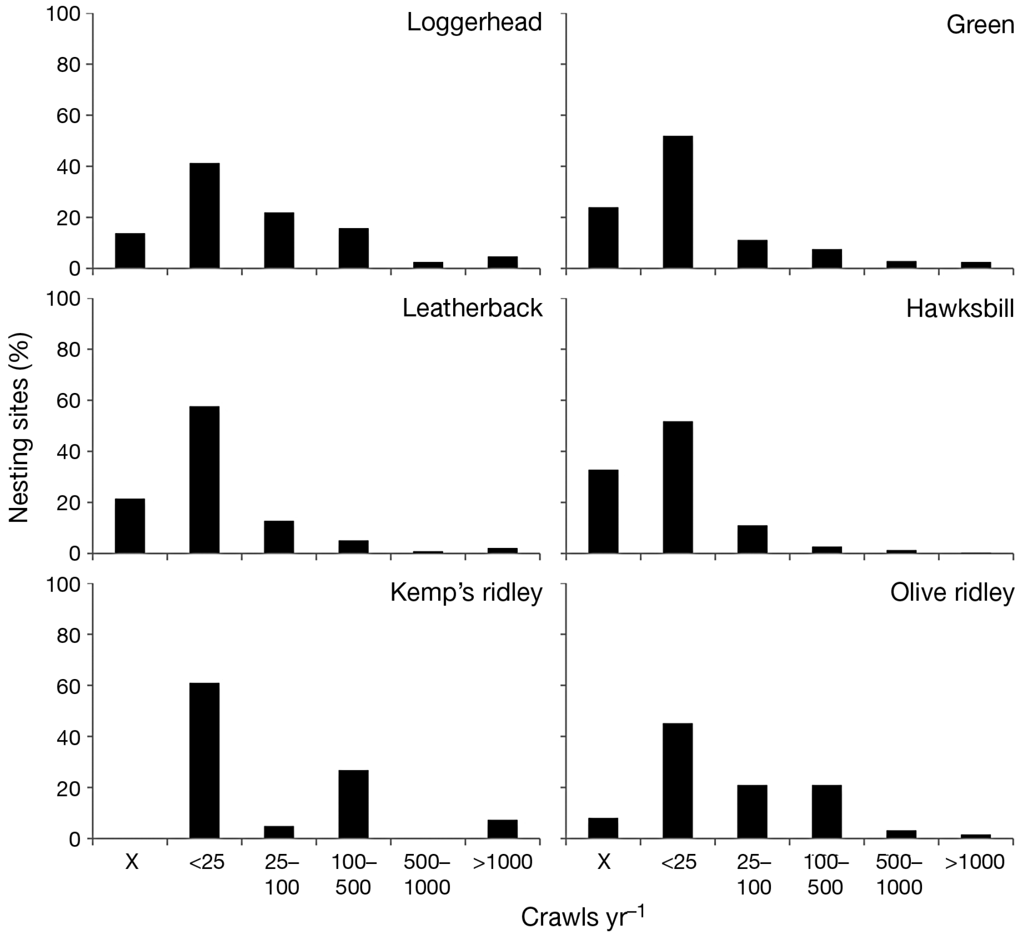

Fig. 2. Frequency distribution of the number of crawls yr^{-1} for each of 6 species of sea turtle nesting the Wider Caribbean Region. X indicates nesting occurrence, but the number of nesting crawls yr^{-1} is unknown

Kemp's ridley sea turtles

Kemp's ridley sea turtles nested exclusively in the northern latitudes of the region, primarily in Mexico and secondarily in the USA (Texas and Florida), where only 3 sites were known to receive >1000 crawls yr^{-1} (Fig. 1). These sites were all located in the state of Tamaulipas, Mexico; the largest of these, Rancho Nuevo, received approximately 7866 nests in 2006 (NMFS & USFWS 2007b). Every known nesting site can be characterized in terms of an estimated number of crawls yr^{-1}; the majority (61%) received <25 crawls yr^{-1}, but many small colonies were reported to be increasing (Fig. 2).

Olive ridley sea turtles

Olive ridley sea turtles nested primarily in the Guianas, with the largest nesting colonies located in Brazil, French Guiana, and Suriname (Fig. 1). Relatively minor nesting occurred in Guyana and occasional nesting was reported in Trinidad and Tobago, Curaçao, and other southern Caribbean locations. Nearly half (45%) of all nesting sites supported <25 crawls yr^{-1} and only 8% of sites were associated with unknown crawl abundances (Fig. 2).

Legal framework

Of the 43 nations and territories, 31 have legislated indefinite complete protection for sea turtles (Fig. 3). In addition to these, Anguilla has adopted a moratorium set to expire in 2020. Seven of the 32 jurisdictions (including Anguilla) where sea turtles are protected year round provide for exceptions relating to traditional, indigenous, and/or subsistence take for one or more sea turtle species. Of these 32 jurisdictions, 24 reported the take of turtles on nesting beaches, 23 reported the take of turtles at sea, and 24 reported the collection of eggs, all in contravention of existing law. Only 5 (Bermuda, Brazil, Cuba, St. Eustatius, and the United States of America) described enforcement of sea turtle protection laws as 'adequate' (see Dow et al. 2007 for additional detail).

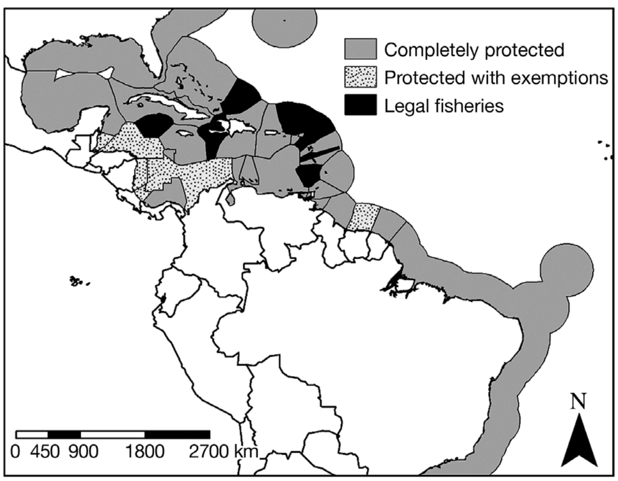

Fig. 3. Summary of legal regimes for sea turtles in the Wider Caribbean Region. Protected regimes include 7 countries (Belize, Colombia, Costa Rica, Guatemala, Honduras, Nicaragua, Suriname) with legal exemption clauses for traditional, subsistence and/or indigenous take of 1 or more sea turtle species

Regulatory regimes operating in 12 nations and territories leave 1 or more species seasonally subject to exploitation. With the exception of the Cayman Islands, which recently legislated maximum size limits and quotas for a green sea turtle fishery (Blumenthal et al. 2010), seasonal sea turtle fisheries are largely restricted through anachronistic minimum size limits (see Fleming 2001, Reichart et al. 2003, Godley et al. 2004, and Bräutigam & Eckert 2006 for reviews of sea turtle legislation in the WCR).

DISCUSSION

This assessment asked a deceptively simple question: 'Where do sea turtles nest in the Wider Caribbean Region?' An accurate answer is critical to the recovery of depleted populations in that it relates directly to the setting of priorities for national and international conservation action, population monitoring and habitat protection, and the larger issues of coastal zone management and land use policy, including meeting national species recovery plans that advocate for protection of a percentage of the annual reproductive effort (NMFS & USFWS 1993), for example through public ownership of primary nesting habitat (NMFS & USFWS 1992). To this end, we created the first geographically comprehensive spatial database of sea turtle nesting beaches in the WCR and made it freely available to policy-makers and other stakeholders in an interactive online electronic format.

Our research has demonstrated that large nesting colonies in the WCR are rare. Nesting sites receiving >1000 crawls yr^{-1} range from 0.4% (hawksbill) to 7% (Kemp's ridley) of all known sites. For any species, the largest proportion (41 to 61%, see Table 2) of nesting sites support <25 crawls yr^{-1}. Moreover, not all of these crawls will represent successful nesting attempts (e.g. Shoop et al. 1985, Broderick & Godley 1996); for some species, the ratio of unsuccessful to successful nesting attempts may approach 1:1 (Eckert et al. 2011). Taking this into account, and the fact that the average number of successful nesting attempts in a reproductive season varies by species from 2 to >6 (Miller 1997), these minor sites can be assumed to support <10 individual females yr^{-1}. These results suggest that it is not enough to only protect large nesting sites, many of which are already protected in the region (Eckert & Hemphill 2005). Further work is needed to quantify the role of the many small, widely dispersed sites, and potential linkages between them, especially in relation to genetic diversity, adaptive capacity and resilience to climate change, and recovery benchmarks (Bowen et al. 1998, 2005, 2007, Dutton et al. 1999, Blumenthal et al. 2009, Wallace et al. 2010), as well as their contribution to global marine conservation targets (Wabnitz et al. 2010). In addition, our research identified nesting sites that support multiple species, highlighting these areas as potential priorities for management and conservation.

Identifying gaps

Collecting regional datasets, although time and labor intensive, is an important prerequisite to identifying data gaps at large geospatial scales. Wallace et al. (2010) were 'largely unable to differentiate between true absences (i.e. a species is not identified or is no longer present in an area despite thorough search effort) and absence due to lack of monitoring or reporting' in their recent characterization of Regional Management Units (RMU) for sea turtles at a global scale, concluding that data are biased by areas of high monitoring effort and reporting (Wallace et al. 2010, p. 8). Our results reflect these biases, with data being strongest in nations (e.g. Barbados, Mexico, Brazil, the Cayman Islands, Guadeloupe, the USA) that invest in long-term, systematic sea turtle census programs and weakest in nations where organized and consistent sea turtle population monitoring effort is lacking (e.g. St. Lucia, St. Vincent and the Grenadines, Haiti).

Of the 2535 species-specific nesting sites identified in the 43 WCR nations and territories surveyed, 23.4% of these could not be categorized in the simplest terms of abundance (i.e. <25, 25–100, 100–500, 500–1000, or >1000 nesting crawls yr^{-1}) and are marked by an 'X' for 'unknown abundance' in the database. The most noteworthy in this regard are the hawksbill and green turtles, where for 33% and 24%, respectively, of known nesting sites have no estimate of crawl abundances, highlighting significant shortcomings in our understanding of the contemporary biogeography of these species.

Inevitable gaps in monitoring and reporting notwithstanding, the WCR is shown to be a useful model for a comprehensive assessment of sea turtle nesting habitat. Population monitoring is ongoing, at some level, in nearly every national jurisdiction. We found that only 27% (n = 592) of species-specific sites rated as 'X' are associated with data assigned a low confidence rating. Thus, for the large majority of these 'X' sites, sea turtle presence is known; only estimates of abundance are unavailable. In only 6% of all sites (n = 2535) identified by the database is sea turtle presence/absence in question based on the quality of data available. These sites are located primarily in Haiti, St. Lucia, St. Vincent and the Grenadines, Panama and the Dominican Republic. Surveying these countries should be a priority in order to achieve a complete landscape of critical habitat, and to ensure that all major sites are included in integrated, inter-jurisdictional population monitoring programs.

Informing policy

While the majority (72.1%, n = 43) of WCR nations and territories fully protect locally occurring sea turtles, a patchwork approach to protection is not ideal for highly mobile species, such as sea turtles, that routinely pass through the region's dissimilar and even contradictory regulatory regimes (Horrocks et al. 2001, 2011, James et al. 2005, Blumenthal et al. 2006). To achieve national-level management objectives, the legal framework protecting sea turtles should be consistent among States throughout their range. Similarly, habitat protection policies should be geographically inclusive at the population level and embrace both nesting and foraging grounds in order to achieve conservation goals. That this is not presently the case carries consequences for individual turtles swimming between protected and unprotected jurisdictions, and presumably, serves to diminish the effectiveness of moratoria and other conservation measures (Bräutigam & Eckert 2006).

In addition to reinforcing long-standing calls for harmonizing the region's regulatory framework concerning sea turtles (e.g. FAO 1993), the assembled database informs national species level recovery-planning processes (e.g. Ruiz et al. 2007, Forestry Division 2011, Haynes-Sutton et al. 2010) and the federal review of coastal development permits (A. Donaldson pers. comm.), as well as site level conservation action planning, national ecological gap analysis, protected area system master plans, and marine spatial planning projects undertaken in the region by The Nature Conservancy (J. Knowles pers. comm.).

Applications

The identification and characterization of essential habitat is identified as a global research priority for sea turtles (Hamann et al. 2010). The templates we developed for collecting, organizing and representing data provide both visual and digital geo-referenced summaries of sea turtle distribution and abundance in the WCR. An interactive interface (http://seamap.env.duke.edu/widecast/) allows users to view maps of nesting sites and their associated metadata for single or multiple countries/territories and species, and to generate maps using the mapping tool by querying the database by country, species, and crawls per year. Integrating the database with existing geo-referenced data layers, including information on habitat types and habitat uses by other protected or managed species and by humans (shipping, fishing activity, oil and gas exploration and extraction), strengthens marine spatial planning exercises for which knowledge of the distribution of key species is essential (Crowder & Norse 2008).

Knowledge of sea turtle nesting sites and the relative abundance of sea turtles that use that site in relation to the population regionally and globally can assist in the development of a network of marine Key Biological Areas (KBAs) (Eken et al. 2004, Wallace et al. 2011), as well as inform a WCR case study to further develop the criteria used for the development of KBAs in marine environments, including criteria appropriate for the inclusion of wide-ranging species, such as sea turtles, that aggregate during breeding seasons (Bass et al. 2011).

Moving beyond static distribution and abundance, the database will be used to define a network of index nesting beach sites sufficient to monitor sea turtle populations at biologically relevant scales. The resulting information on site-specific population status and trends will enrich national and inter-governmental discussions of conservation needs and priorities in the region, as it has already done in an innovative discussion of regional management units for sea turtles globally (Wallace et al. 2010). Moreover, creating a standardized regional framework and protocols for the monitoring of population trends, including quantitative approaches to characterizing survival threats, using sea turtles as a flagship species (cf. Frazier 2005), could provide a model for other managed species, including migratory species dependent on the success of inter-jurisdictional collaboration and investment.

Finally, quantitative evaluation and monitoring of threats *in situ* are needed to determine whether current sea turtle management efforts and protection policies are measurably reducing threats and protecting critical habitat, and to generate effective mitigation strategies (Hamann et al. 2010, National Academy of Sciences 2010). LME-scale databases of critical habitat have obvious value in threat assessments at regional and global scales, and the database is currently being used to evaluate the risks to nesting habitat due to impacts of climate change through sea level rise (D. Pike pers. comm.) and changing patterns of severe weather (M. Fuentes pers. comm.), as well as to strengthen policy-relevant models of bycatch risk in Caribbean fisheries (Bjorkland 2011).

Summary

Quantitative data on the status and distribution of marine habitats important to sea turtles in the WCR can be scarce (e.g. seagrass: Spalding et al. 2003, Wabnitz et al. 2008; coral: Burke & Maidens 2004). The gap has now been filled, to the extent that data are available, with respect to nesting habitat. By collecting and collating information from field scientists, fisheries officers, conservationists and other data providers and conducting a thorough literature review, the WIDECAST network has created the first comprehensive atlas of sea turtle nesting habitat for a region of this size. Through its partnerships, for example with the State of the World's Sea Turtles (SWOT) (http://seamap.env.duke.edu/swot) (Read et al. 2007, DiMatteo et al. 2009), the database is kept current, ensuring that scientists, policy-makers and conservation practitioners have access to distribution and abundance data relevant to appropriately scaled population monitoring programs, habitat protection policies, and conservation investment decisions.

This research demonstrates the value of maintaining a regional network of collaborators supportive of collective data-sharing across large geospatial scales, and how the outcome of such a willingness to share baseline information on critical habitat, including legal frameworks and contemporary threats, can identify particularly important habitat areas and data gaps, inform conservation ranking exercises, highlight regulatory inconsistencies, and create habitat layers that further inform research in this region and beyond. Maison et al. (2010) credit the atlas with inspiring a compilation of green sea turtle nesting sites throughout Oceania intended to assist governments and other regional stakeholders in prioritizing 'future research, management activities, and international collaborations to advance green turtle conservation and recovery efforts in the Pacific' (Maison et al. 2010, p. 32).

Recommendations for next steps include filling identified gaps (through local habitat surveys) in our knowledge of the geography of the annual reproductive effort of WCR sea turtles, implementing a regionally inclusive index nesting beach monitoring program to report status and trend over time, maintaining the database and atlas through existing partnerships, and advocating for policy changes to improve protection frameworks for sea turtles and habitats, and to integrate information on sea turtle nesting habitats into risk assessments and coastal zone development decisions.

Acknowledgements. An assessment of this magnitude could not have been accomplished without the support and active participation of WIDECAST-affiliated researchers, conservationists, and natural resource managers throughout the WCR, as well as their in-country colleagues. We are deeply grateful to the more than 120 data providers in 43 nations and territories who participated in this project, generously offering their time, expertise, and data. A complete list of data providers and their affiliations is available in Dow et al. (2007) and online at http://seamap.env.duke.edu/widecast. The project was funded by The Nature Conservancy's Caribbean Marine Program, Pegasus Foundation, US Fish and Wildlife Service (Marine Turtle Conservation Fund), and the UNEP-CEP Regional Programme for Specially Protected Areas and Wildlife (SPAW). We gratefully acknowledge the expertise and partnership of Duke University's OBIS-SEAMAP program, E. Fujioka for design of the online interface, and A. DiMatteo for assistance with map creation. The manuscript also benefited from comments submitted by 4 anonymous reviewers.

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Editorial responsibility: Mark Hamann, Townsville, Queensland, Australia

Submitted: August 6, 2009; Accepted: August 11, 2011
Proofs received from author(s): October 16, 2011