Sea Turtle Nesting Beach Characterization Manual

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2009

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Cover photo: Hawksbill sea turtle laying her eggs, photo courtesy of Darren Browne

Preface and Intent

This Manual, developed as part of the senior author's Master's Project at Duke University (Varela-Acevedo 2009) and facilitated by a summer (2008) internship with the Barbados Sea Turtle Project (Dr. Julia Horrocks, Director), discusses the relationship between coastal geomorphology and the reproductive success of endangered Caribbean sea turtles. Specifically, we address coastline seascape change as affected by climate change and human development, and the potential effect such change may have on the nesting behavior of the hawksbill sea turtle (*Eretmochelys imbricata*).

Long-term concerns about the ability of coastal sandy beaches to sustain sea turtle nesting are confounded by a general lack of understanding of what characteristics are important to sea turtles during the nest site selection process. From a global climate change perspective, understanding how vulnerable these characteristics are to, for example, sea level rise is vital to sea turtle management and policy decisions, land use planning, and so on.

The objective of this project was to develop a methodology for evaluating the vulnerability of sea turtle nesting beaches to climate change. That methodology now forms the basis of this *Sea Turtle Nesting Beach Characterization Manual*. The Manual is designed to inform and educate coastal communities about how changing coastlines affect biodiversity and beaches, with a focus on hawksbill sea turtles.

It is hoped that the Manual will encourage and empower Caribbean communities to define, implement, and monitor actions to conserve sea turtle habitats determined to be most vulnerable to erosion and degradation related to short-term coastal processes and longer term threats posed to Small Island Developing States, in particular, by climate change scenarios .

Acknowledgements

Many thanks are extended to my academic advisors Dr. Karen Eckert (Executive Director) and Dr. Scott Eckert (Director of Science) of the Wider Caribbean Sea Turtle Conservation Network (WIDECAST) and Dr. Andy Read, Rachel Carson Associate Professor of Marine Conservation Biology at Duke University.

I am grateful to the Eckerts who assisted in the design and execution of my summer internship in Barbados and guided me through my Master's Project. Without them, the quality of this Manual would not be what it is. My understanding of sea turtle management and conservation multiplied under their direction.

I would also like to thank my Advisors in Barbados, Dr. Julia Horrocks (Barbados Sea Turtle Project at the University of the West Indies) and Dr. Gillian Cambers (Caribbean Development Bank), for their guidance and for sharing their knowledge about Barbados, hawksbill sea turtles, and beach geomorphology with me. I thank them for fostering my growth as a researcher, and for their friendship and patience as I field-tested the Manual in Barbados.

The Coastal Zone Management Unit (CZMU) in Barbados kindly shared their library and unpublished data with me, and I am grateful to the CZMU staff for answering my many questions about beach processes. I am particularly grateful to Ricardo Arthur, who was my main contact at the CZMU office, as he ensured that I had access to all of these resources.

Finally, I appreciated the Dr. Andy Read's support and constructive feedback during the writing stage of my Master's Project, and Dr. Karen Eckert's detailed review of this *Sea Turtle Nesting Beach Characterization Manual*.

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Introduction

Human activity along the coast leads to pressures from factors such as population growth, industrialization, and resource exploitation, leaving shorelines more susceptible to extreme weather events (e.g., Pelling and Uitto 2001). As human populations increase along the coast, so does the potential for coastline change and its impact on human settlement and investment.

While the need to monitor coastline processes has long been understood, most such efforts have been primarily in regard to the endangerment of man-made habitation and investment. Within many countries, there has been a net residential migration to the coasts, as well as high density tourism development. Worldwide, including the Caribbean and Latin America, the coasts are the most heavily populated areas (Hinrichsen 1999).

The 2007 IPCC Fourth Assessment Report (Pachauri and Reisinger 2007) warns that in addition to documented levels of contemporary shoreline erosion, climate change is expected to endanger heavily populated coastal areas by bringing:

- More severe and more frequent storm damage and flooding
- Inundation, erosion, and recession of barrier beaches and shoreline
- Destruction and drowning of coral reefs and atolls
- Reduction in biological diversity and possible wildlife extinctions
- Loss of beaches, low islands, and spits
- Loss of coastal structures, both natural and man-made, and
- Changes in the biophysical and biochemical properties of the coastal zone

Methods for evaluating such processes and results have ranged from very simple to very complex. Historically, records on changing coastlines have been created by using mapping techniques such as surveys, permanent fixed markers, and aerial photography. Most such methods require a fairly high level of expertise and often substantial costs. With the advent of inexpensive GPS systems, costs are much lower, but may still require expertise beyond the capacity of largely rural communities in developing countries.

The development of simple coastline monitoring methods, using readily available tools and methods, shows promise in providing useful data to managers and policy-makers, as well as informing local residents and property owners concerning how environmental change may influence the habitability of coastal areas. One such methodology is UNESCO's (2005) *Sandwatch Manual*, which features straightforward data collection and monitoring methods designed to be accessible to every type of coastal community. For additional background on the issues associated with managing beach resources and coping with erosion, see Cambers (1996, 2003).

Existing tools, including the *Sandwatch Manual*, are limited to determining how environmental change will affect human habitation. Less effort has been put into the development of tools and methods that might enable a better understanding of how coastline change will affect biodiversity or natural habitats. The development of rapid assessment methods to increase our understanding of how climate change will affect coastal species, and particularly endangered or exploited species, is needed.

Hawksbill sea turtles (*Eretmochelys imbricata*) are severely reduced from historical levels and classified by the World Conservation Union (IUCN) as Critically Endangered on the Red List of Threatened Species (http://www.iucnredlist.org/). Their endangered status is largely due to over-exploitation, primarily for international trade in shell products and local consumption of meat and eggs, as well as habitat loss or degradation in Barbados (Beggs et al. 2007) and throughout the world (e.g., Meylan and Donnelly 1999; Mortimer and Donnelly 2007).

Climate change, which is predicted to bring a rise in sea level and stronger storms (Pachauri and Reisinger 2007), presents a unique challenge for this species which relies for egg-laying on sandy beaches in tropical climes and on imperiled nearshore coral reefs for food and forage (e.g., Witzell 1983; Horrocks 1992; León and Bjorndal 2002; Bjorndal and Bolten 2003). Standardized methods for assessing the physical features of hawksbill nesting habitat – and how changes to this habitat may affect reproductive success – are necessary in order to inform conservation and management.

Effects of Coastal Development: Barbados

The International Panel on Climate Change (IPCC) has concluded that Small Island Developing States (SIDS) have a low adaptive capacity to the adverse effects of climate change, terming them a “very high-risk group of countries” (Belle and Bramwell 2005). The Wider Caribbean Region embraces the world’s greatest concentration of SIDS, which are also recognized as having particularly vulnerable economies while bearing responsibility for a “significant portion of the world’s oceans and seas and their resources” (UNGA 1994).

Many Caribbean SIDS have tourism-dependant economies, including Barbados (Levy and Lerch 1991; Belle and Bramwell 2005). Because tourism dependant island economies tend to be heavily developed along the coast, growth in this sector can exacerbate threats to coastal environments and biodiversity. Beaches with hotels adjacent to them are most vulnerable to the predicted effects of sea-level rise, which coincide with the lowest and narrowest beaches (Fish et al. 2005, 2008). If small island nations fail to prioritize preventive management measures now, they may become even more vulnerable to the consequences of climate change (Lewsey et al. 2004; Belle and Bramwell 2005).

This Manual was both developed and field-tested in Barbados, where a favorably warm climate and sheltered, leeward sandy beaches characterized by steep slopes and calm sea entries are preferred for nesting by hawksbill sea turtles (Horrocks and Scott 2001; Fish 2005; Belle and Bramwell 2005). As a result, more than 2,000 nests were laid per year in 2003 and 2004 (Beggs et al. 2007).

The same features that are attractive to sea turtles are also attractive for tourism, and built development can result in highly modified coastlines tailored largely to the tourism industry (Horrocks et al. 2001; Uyarra et al. 2005). The Barbados economy, being largely tourism-dependent, has an understandably pro-development government that supports the jobs and income equated with growth in the tourism sector. Similarly, public perception of the benefits of job creation through tourism favors continued development. The not unexpected result is that development projects are favored over the preservation of sandy beaches in their natural state (UNEP 1996).

Among the most obvious results of built development along the coast are physical barriers, such as sea walls and pavement (Lewis 2002), that obstruct and may deter sea turtle efforts to nest on a given beach (summarized by Choi and Eckert 2009). Also detrimental is the removal of fringe landforms and native vegetation that usually helps stabilize beaches. Urban and coastal developments have been implicated in the complete loss of native forest, causing, among other things, increased runoff of polluted effluent into the near-shore environment (Lewsey et al. 2004).

Less obvious results include reduced hatchling emergence with beach development (Richardson et al. 1999), the avoidance of artificially lit beach sections by gravid females, potentially forcing them into less suitable nesting habitat (Witherington 1992; Salmon 2003), increased predation of hatchlings by dogs, mongoose and other introduced species (e.g., Leighton et al. 2008), and lowered hatch success due to vehicle traffic on the beach, litter and debris, etc. (Choi and Eckert 2009).

Interestingly, Uyarra et al. (2005) found that tourists in Barbados are most attracted to terrestrial beach features (wide beach area and sand quality) over marine aspects (coral reef health and fish biodiversity), but they also indicated a strong interest in the continued presence of sea turtles. More than 80% of tourists surveyed reported that they would not return to Barbados for the same vacation price if there were to be a loss in beach area with a rise in sea level (Uyarra et al. 2005).

Figure 1. Hawksbill hatchlings make their first journey to the sea. Photo: Wildlife Trust, Belize

Both a healthy coast and a healthy population of sea turtles would appear to be good for the nation's tourism-based economy.

Sea Turtle Nest Site Selection

Because sea turtles lack parental care, the success of a nest is heavily reliant on the suitability of a site selected by the female (Kamel and Mrosovsky 2005). Hawksbill sea turtles show particularly strong nest site fidelity, with Caribbean females remigrating at ca. 2.5 year intervals (Carr 1967; Richardson et al. 1999; Beggs et al. 2007) to nest on the same beach, or nearly so, throughout their adult lives.

How sea turtles assess the quality of their nesting habitat is unclear, though a few studies have attempted to evaluate key characteristics of successful nesting beaches (e.g., Wood and Bjorndal 2000). Features contributing to hatchling imprinting (Owens et al. 1982) and homing capabilities (Allard et al. 1994) have also been explored but, in the end, as Santos et al. (2006) concluded, "Besides observations of nest site fidelity, little is known about why sea turtles prefer some beaches over others."

Sea turtle nesting along a chosen beach is thought to be random for certain species (Mrosovsky 1983; Eckert 1987) and non-random for others (Hays and Speakman 1993; Hays et al. 1995). Most likely a combination of interacting ecological factors – including sand temperature, particle size, water content, salinity, sand softness, lagoon presence, beach length, and beach height (cf. Miller 1985; Whitmore and Dutton 1985; Kikukawa et al. 1999; Wood and Bjorndal 2000) – play a role in the female's choice. Anthropogenic factors, such as distance from the nearest human settlement (Kikukawa et al. 1999), may also be important.

The following sections explore those features thought to predominate in defining a suitable nesting beach. These characteristics include: elevation and slope, percentage organics and moisture content (Horrocks and Scott 1991; Wood and Bjorndal 2000; Fish et al. 2005), wave energy (Horrocks and Scott 1991; Beggs et al. 2007), rubble-free fore-shores and sandy approaches (Mortimer 1982), predator risk (Fowler 1979; Spencer 2002; Spencer and Thompson 2003), sand compaction (Kikukawa et al. 1999; Miller et al. 2003), vegetation (Horrocks and Scott 1991; Lewsey et al. 2004) and sand temperature (Janzen 1994; Wood and Bjorndal 2000; Janzen and Morjan 2001; Kamel and Mrosovsky 2006).

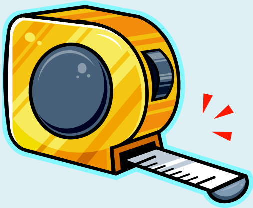
Using the Manual

Natural beach systems are highly dynamic, and the temporal scale of visible change occurs over hours, days, months and years (Cambers 1998a). We suggest that the methodology outlined in the Manual be employed once each month in order to account for short-term changes. If this frequency of use is not attainable, then quarterly measurements can be used to account for seasonal changes that occur at the coast.

Through regular coastal monitoring, information is produced that can be used in evaluating the long- and short-term benefits (or consequences) of beach modification, various resource management options, and other actions taken. Over the short term, with regard to sea turtles, it is important that a beach is able to maintain the integrity of its nest sites for the typical 60 day incubation period (e.g., see Ackerman 1980; Miller 1997). Longer term, female hatchlings that reach reproductive maturity will return to the beaches on which they were born to lay their own clutches of eggs – renewing the population in perpetuity.

Figure 2. Conducting a lighting assessment in Barbados. Photo by Karen L. Eckert

Tools

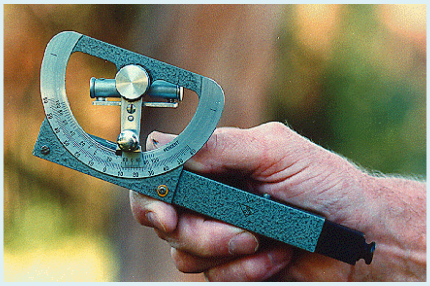


The following tools and supplies are helpful

- Magnifying Glass
- Graduated Staff or Ranging Pole
- Abney Level
- 50 m Measuring (Surveyor) Tape
- Notebook (waterproof pages are ideal)
- Pens, Pencils
- Latex Gloves
- *Sandwatch Manual* (*) Computer Analysis Program
- Clean Plastic Re-sealable Bags
- *Sandwatch Manual* (*) Sediment Analysis Chart
- 1 m^2 PVC Pipe Quadrant
- Data Sheets (see Appendix 1)

  Completed forms should be numbered sequentially, photocopied for insurance against the loss of the originals, and stored in a 3-ring notebook in a safe place.

(*) The *Sandwatch Manual* tools are available free of charge from
http://www.sandwatch.ca/members.htm



1 m^2 PVC Pipe Quadrant

Figure 3. One square meter PVC quadrant.

Equipment:

- 5 m PVC Pipe (the least expensive will suffice)
- 4 ¾-inch PVC Elbows (90°)
- PVC Cement
- Hacksaw or PVC Cutters

Methods:

Cut the PVC pipe into four 1 m length pieces. In a well ventilated area, use PVC glue to attach elbows to one piece of PVC. It is best to do this on a flat surface to ensure that the elbows are in the same plane. Use PVC glue to attach the rest of the PVC together in a square as illustrated in Figure 3.

Data Sheets

Include in your data sheet the following information: Observer Name, Beach Profile, Description, Beach Width, Sand Samples, Comments, and space for Site Name (Location), Date, Beach Segment Measurements (and Slope Angle). A sample data sheet is provided in Appendix 1. Completed data sheets should be numbered sequentially, photocopied for insurance against the loss of the originals, and stored in a 3-ring notebook in a safe place.

Terminology

Certain measurements and activities in the Manual require the identification of a sea turtle nest, or other sea turtle activity, and also the ability to identify the high water mark. As this manual focuses on hawksbill sea turtles, we will begin by explaining how to look for nesting activity on a known nesting beach and how to locate the high water mark. For information on other Caribbean sea turtles, including species identification (Appendix 2) and identifying nesting signs, visit http://www.widecast.org/Biology/BasicBiology.html.

Sea Turtle Tracks and Nest

Hawksbill sea turtles leave an asymmetrical track pattern in the sand about 75-80 cm across (Figure 4, Appendix 3). Follow the tracks to the nesting site, typically a disturbed area biologists call a "body pit". If the tracks ascends the beach and returns to the sea uninterrupted, the turtle did not attempt to lay eggs. However, if a body pit interrupts the tracks, it is possible that eggs were successfully deposited.

In either case, a data form should be completed to archive the relevant information; if a body pit is present, the location should be triangulated or otherwise documented and monitored for hatching.

In many Caribbean countries, a government permit is needed to conduct research and conservation activities with endangered sea turtles. Contact the Fisheries office, or a local sea turtle conservation group, to ensure that proper protocols are being observed (cf. Beggs et al. 2001).

Figure 4. Nesting hawksbill sea turtle crawling into beach vegetation. Note the asymmetrical pattern of the nesting crawl in the sand. Photo: Ana Luque

High Water Mark

The high water mark is defined as the highest point the ocean waves reach, usually identifiable by a dark, wet shadow in the sand and/or by an accumulation of seaweed and debris (Figure 5).

Figure 5. High water mark identified by red arrows (Brighton Beach, Barbados). Photo: Ana Luque

Hand-raking is an environmentally friendly alternative to mechanized beach cleaning when seaweed accumulates at the high water mark. Photo: Turtugaruba Foundation, Aruba

Evaluated Characteristics

Nest Site Selection

The following characteristics are relevant to sea turtle nest site selection, and standard methodology for evaluating and monitoring these characteristics is provided by this Manual.

- Boundary Parameter
- Beach Profile
- Beach Elevation
- Beach Width
- Sand Softness
- Sand Composition
- Sea Defenses
- Vegetation
- Predation Risk
- Beachfront Lighting
- General Observations

Figure 6. In the Caribbean region, egg-bearing hawksbill sea turtles emerge from the sea, traverse the beach, and quite typically choose to nest in the shelter of dense maritime forest at the beach edge (see arrow). Photos: (l) Alicia Marin, (r) Carol Guy Stapleton

Boundary Parameter

Figure 7. Malibu Beach Bar serves as a boundary parameter on Brighton Beach, Barbados. Photo: Ana Luque

Boundary parameters are defined by the nearest built structures at the landward edge of a sandy beach.

Equipment:

- ❑ (None)

Methods:

- ❖ Locate the first structure or obstacle that faces seaward, located at the landward edge of the sandy beach platform. This may be a wall, fence, or other sort of construction (Figure 7) or it may be a natural landmark.

- ❖ Describe/name this structure on the data sheet.

Beach Profile

Beach profiles track erosion and accretion patterns on the beach with respect to the boundary parameter, and reveal beach topography over time (Figure 8). The data collected may also be used to calculate beach elevation.

Developing a detailed map of beach profile locations (Appendix 4) is important, and will ensure transparency and continuity over time as field staff change.

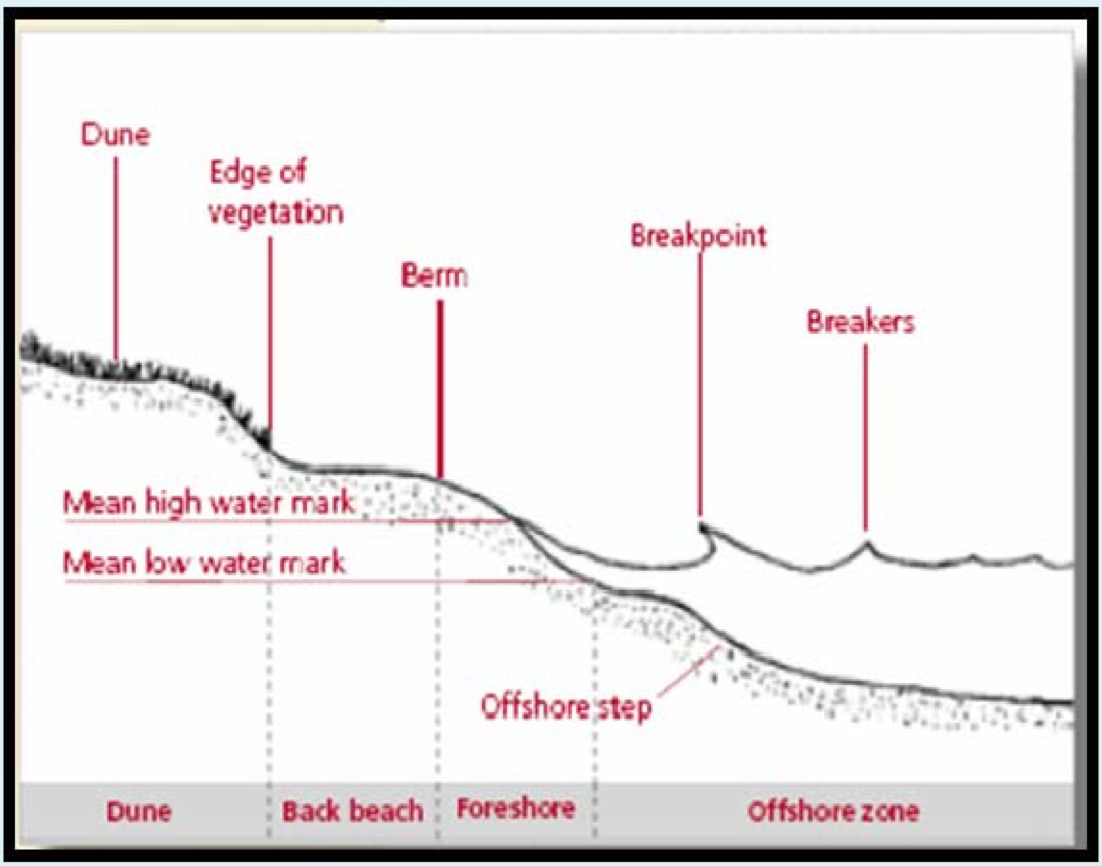


Figure 8. Beach profile graphic illustrating certain beach characteristics. Source: UNESCO (2005)

Beach Profile

Methods:

The step-by-step field methodology described in steps (a) to (n) is adapted from the *Sandwatch Manual* (UNESCO 2005 http://www.sandwatch.ca/members.htm):

- (a) Select a reference point behind the beach from which to begin beach width measurements. A stationed beach feature that would likely remain in place even in the event of a hurricane, often a building or mature tree, is a good choice. To facilitate identification of the reference point for future measurements and replication, take a photograph of each selected feature.

- (b) Lay out the profile in segments, place a ranging pole at each break of slope, ensure the line of the profile follows the fixed orientation (Figure 9). The end point of the profile is the "offshore step" marked in Figure 8. This is near where the waves break and there is usually a marked downward step. If no offshore step exists at that location or time, and/or the wave conditions are too rough, continue the profile as far into the sea as safety permits.

Figure 9. Use of Abney level, ranging pole, and measuring tape. Photo: Ana Luque

Equipment:

- ❑ Data Sheets
- ❑ Clipboard
- ❑ Pencils, Erasers
- ❑ Abney Level
- ❑ Tape Measure
- ❑ Ranging Pole
- ❑ Masking Tape
- ❑ Digital or 35 mm (with film) Camera

Beach Profile

- (c) Write the beach name and date on the data form, also the names of the people involved in taking the measurements. If you are using a number system for the sites, it helps to add a location name (e.g., "Grand Bay #1, southern site") to reduce the possibility of error when the information is entered into the computer.

- (d) Measure the vertical distance from the top of the reference mark to the ground level with the tape measure. Measure to the nearest cm. Record all measurements in metric units. Write the measurement down on the data form.

- (e) Measure the observer's eye level on both ranging poles, making sure that the surface of the sand just covers the black tip of the pole.

- (f) Place the ranging pole at the first break of slope always making sure the surface of the sand just covers the black metal tip of the pole. Check the profile alignment and re-position the pole if necessary. Always make sure that the pole is vertical.

- (g) The observer stands by the reference mark and uses the Abney level (Figure 10) to sight onto his/ her eye level on the ranging pole.

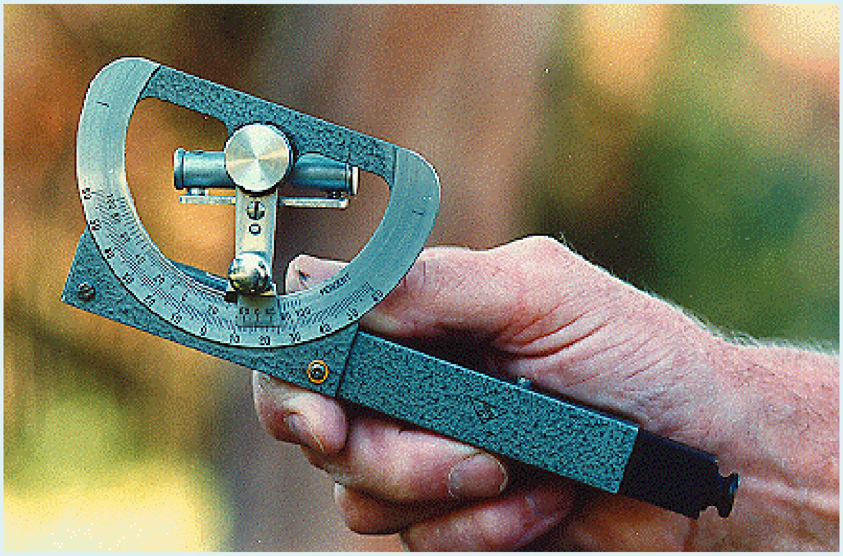


Figure 10. Typical Abney level. Source: http://sres-associated.anu.edu.au/mensuration/BrackandWood1998/g/abney.GIF

Beach Profile

❖ (h) To read the Abney level, refer to Figure 11. As can be seen from Figure 11(a), the Abney level is divided into degrees, every 10 degrees is numbered. Readings to the left of zero are negative or downhill; readings to the right of zero are positive or uphill. To read the angle, determine where the arrow intersects the degrees scale. In the example – Figure 11(b) – the arrow falls midway between -5 and -6 degrees. In this case the degrees would be recorded as -5 degrees. Since the arrow falls approximately midway between -5 and -6 degrees, it is likely that the minutes reading is about 30 minutes. To check the minutes, use the vernier scale – see Figure 11(c). For a downhill slope, use the vernier lines to the left of the arrow. They are at 10-minute intervals and the 30- and 60-minute lines are numbered. Determine which of the vernier lines most closely intersects one of the degree lines below. In this case the 30-minute vernier line almost exactly lines up with the degree line below, so the vernier reading will be 30 minutes. This reading will be recorded as -5 degrees 30 minutes.

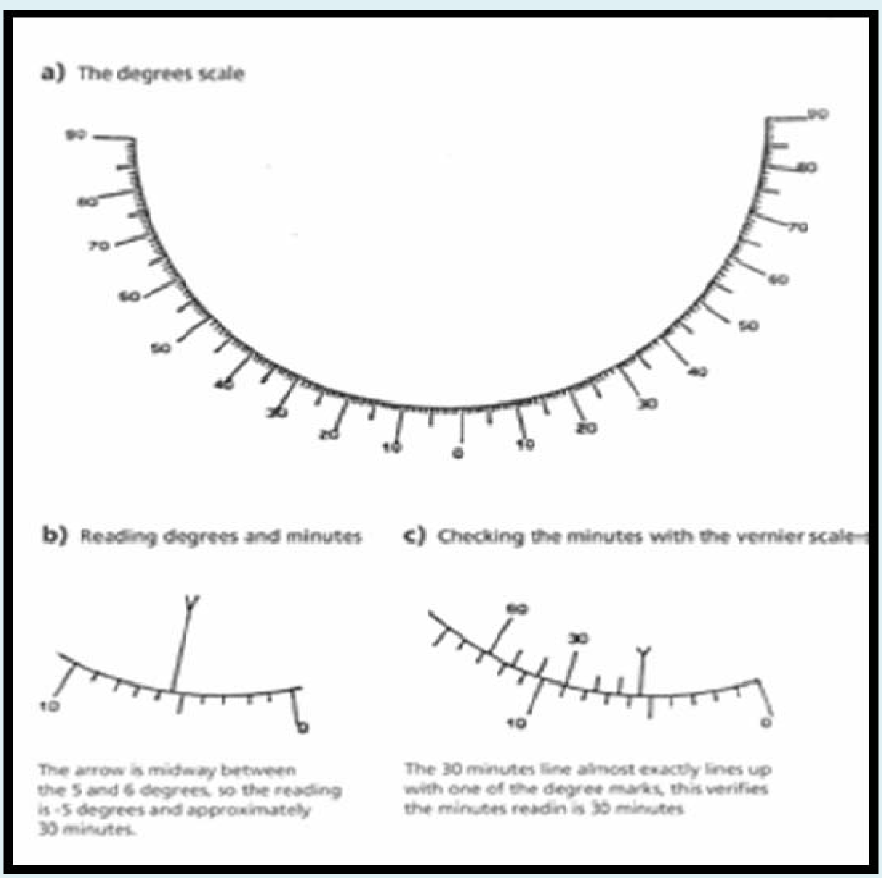


Figure 11. Abney level reading description. Source: UNESCO (2005)

Beach Profile

- (i) Record the segment slope in degrees and minutes, to the nearest ten minutes on the data sheet. Always remember to record whether it is a plus or a minus slope (plus is an uphill slope, minus is a downhill slope).

- (j) Measure the ground distance from the base of the reference point to the first ranging pole with the tape measure, to the nearest cm; record this measurement on the data form. Measure along the slope, not the horizontal distance.

- (k) The observer then proceeds to the ranging pole at the first break of slope and sights onto the ranging pole which has been placed at the second break of slope (Figure 12) – remember to check for profile alignment – and repeats steps (g) through (j). This is continued until the endpoint of the profile, see step (b).

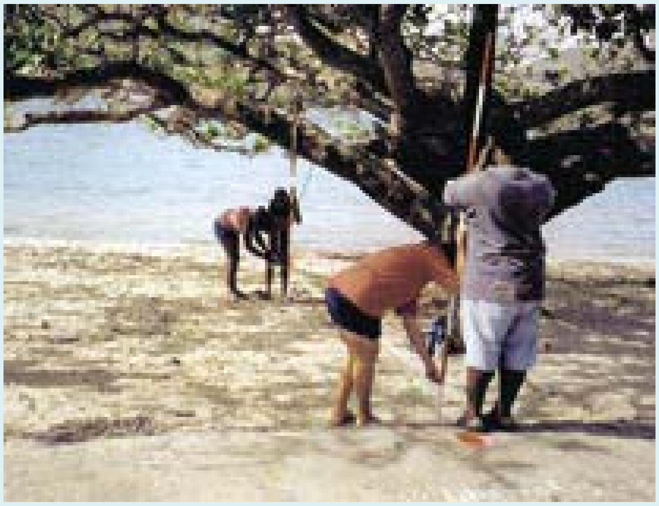


Figure 12. Profile measurements being taken with ranging poles. Source: UNESCO (2005)

- (l) Record all measurements very carefully and accurately (see Appendix 1).

- (m) Record on the data sheet under 'Observations' anything else of interest; for example, recent sand mining pits or storm damage. Take photographs if possible.

- (n) As paint squares (reference marks) begin to fade, touch-up with spray paint.

Beach Elevation

Elevation is thought to be the single most influential factor in sea turtle nest site selection in Barbados – researchers note that elevation serves as a trade-off, whereby the cost of exposure to predation and energy extended in search of a nest site is balanced by the reproductive benefit of finding an incubation site with maximum hatchling emergence success (Horrocks and Scott 1991; Wood and Bjorndal 2000). In general, all sea turtle species tend to nest above the high water mark to reduce the risk of tidal inundation or egg wash-out (Fowler 1979; Mortimer 1982).

Hawksbills have been found to be sensitive to elevation when selecting nest, preferring to nest between 0.3 and 1.8 m (mean 1.1 m) above mean sea level (Horrocks and Scott 1991).

The west coast of Barbados, characterized by steeply sloping beaches with calm, low wave energy entries (Figure 13), make this area the preferred nesting site for hawksbill sea turtles (Horrocks and Scott 1991; Beggs et al. 2007). These are also the same features found where hotels are located (Fish et al. 2005) (Figure 14).

Figure 13. An area of Reads Beach (west coast of Barbados) characterized by steep slopes and calm waves. Photo: Ana Luque

Beach Elevation

Equipment:

- ❑ Measuring Tape
- ❑ Abney Level
- ❑ Ranging Pole

Methods:

- ❖ Identify a sea turtle nest on the beach
- ❖ Estimate the center of the nest. Place the end of the measuring tape in the center of the nest and measure the distance from there, horizontally, through to the berm.
- ❖ Using the Abney level, measure the slope angle with the ranging pole as described in the “Beach Profile” methodology of this Manual.
- ❖ Measure the distance from the berm to the high water mark. Using the Abney level, measure the slope angle from the berm to the high water mark.

Figure 14. On the Caribbean island of Barbados, a tourism-based economy concentrates human activity on and adjacent to sea turtle nesting beaches. Photo: John E. Knowles

Beach Width

Beach width correlates well with the amount of beach space available for sea turtle nesting. Similarly, wider beaches are more attractive tourism resort locations and may be associated with higher levels of human activity, which, in turn, can disturb nesting sea turtles and their young (Kikukawa et al. 1999).

Equipment:

- ❑ Measuring Tape

Methods:

- ❖ Select three different locations along the beach coast (Figure 15).
- ❖ At each site, select a reference point. The reference point should either be marked with spray paint or documented with photographs to assist future identification.
- ❖ From the reference point, a measuring tape should be used to measure horizontally from the reference point to the end of the vegetation line, if vegetation is present.
- ❖ Continuing from the vegetation line, measure horizontally to the high water mark.
- ❖ Record your data on the data form (Appendix 1).

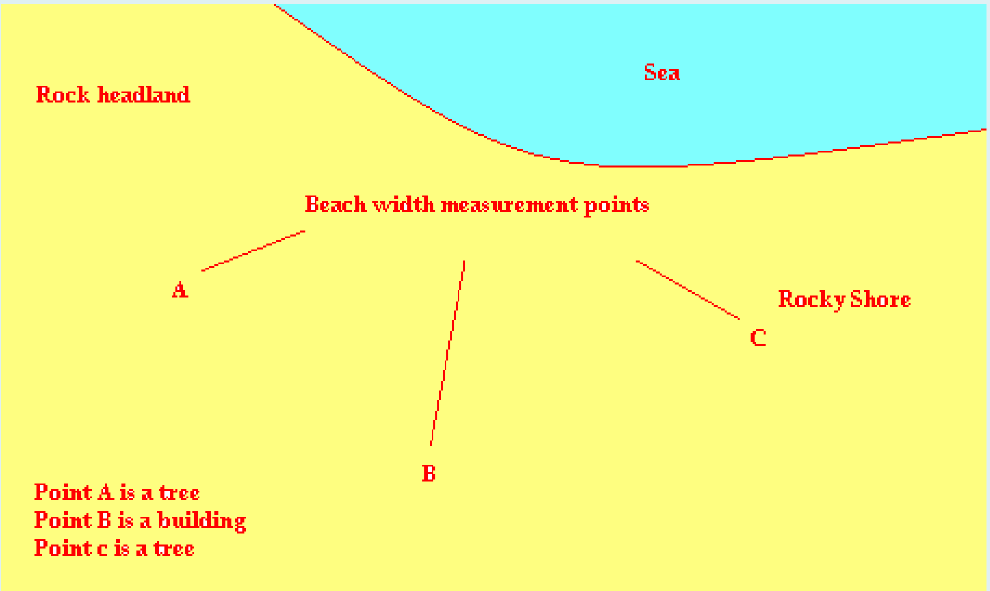


Figure 15. Illustration of three beach width measurement points. Source: adapted from UNESCO (2005)

Sand Softness
("50 cm hole")

Sand softness has been observed to be an important variable in that it may facilitate (or hinder) the excavation of a nest chamber (Kikuklawa et al. 1999). Beaches characterized by dry, coarse sand create difficult digging conditions for a female sea turtle (Mortimer 1990); later, successful hatchling emergence is correlated with nest depth and sand compaction (Miller et al. 2003).

The sand must be of sufficient "softness" and depth to enable excavation of the egg chamber, which for hawksbills in Barbados averages 50 cm deep (J.A. Horrocks, Barbados Sea Turtle Project, pers. comm. 2008). Sometimes what appears to be a wide, vegetated and otherwise "attractive" nesting beach may be nothing more than a veneer of sand overlaying rubble or cement. By digging a 50 cm hole (Figure 16), the surveyor confirms adequate substrate depth (Parrish and Goodman 2002).

Figure 16. Sea turtle nest chamber with eggs, 50 cm deep. Photo: Ana Luque

Sand Softness
(“50 cm hole”)

Figure 17. Replicate nest chamber, dug to a depth of 50 cm. Photo: Ana Luque

Equipment:

- ❑ Latex Gloves (optional)
- ❑ Measuring Tape

Methods:

❖ Lay out the measuring tape starting from the boundary parameter through to the high water mark.

❖ At each meter mark, try to dig a 50 cm hole with a 10 cm diameter; wearing a pair of latex gloves can protect your hands from the roughness of the sand (Figure 17). Use the measuring tape at regular intervals to verify your depth.

❖ Note any obstacles found while digging – these may range from tree roots (note their thickness and abundance) to rocks or buried trash.

❖ The level of difficulty you experience should be recorded by the following levels:

- High difficulty: Cannot dig reach a 50 cm depth hole with a diameter of 10 cm due to the tough nature of the substrate or obstacles such as gravel, cement or rock.
- Medium difficulty: Can dig to 50 cm, but struggle to do so.
- Low difficulty: Can dig to 50 cm with relative ease.

Sand Composition

Sand samples can be evaluated as to color, size, shape and sorting to reveal origin, wave strength, and wave movement (UNESCO 2005). The difference in sediment type could be revealing of whether a beach has been nourished with a different sediment type, or if soil for vegetation has been added. It is possible that nourished beaches are less attractive to females and result in lower numbers of nesting females per season (Steinitz et al. 1998; Rumbold et al. 2001) or affect egg chamber temperatures, effectively altering sex ratios (Hawkes et al. 2007).

Studies have shown that sea turtles prefer areas with softer, looser sand for their nests (Kikukawa 1999; Santos et al. 2006). Softer sand may imply that it is easier for the female to excavate the chamber and easier for the hatchlings to reach the surface of the beach after hatching from their eggs (Horrocks and Scott 1991). This is the reason for recording the 'level of difficulty' you experienced in digging a 50 cm hole (see "Sand Softness").

Equipment:

- ❑ Clean Plastic Re-sealable Bags
- ❑ Magnifying Glass
- ❑ *Sandwatch Manual* Sediment Analysis Chart

Methods:

- ❖ Collect no more than one handful of sand from an identified sea turtle nest; specifically, the body pit area and the last turn visible in sand. If a nest cannot be located, collect sand from a known nesting area on the beach. Immediately place the sand sample into a clean plastic re-sealable bag.

- ❖ When you return to your lab or staging area, transfer any wet sand samples onto a clean paper towel or a dry newspaper until the sand dries.

- ❖ Once dry, the sand size, sorting, sorting size, shape, and color should be determined with the Sand Identification Chart and directions excerpted from the *Sandwatch Manual*, as follows:

Sand Composition

i. Sprinkle a few grains on to a transparent plastic sheet and then place the plastic sheet with sand grains over the chart on Figure 18. If the sand grains collected are light-colored, use the left hand chart (contrasting dark background); if the grains are dark-colored, use the right hand chart (light background).

ii. Using a magnifying glass, determine the size category matching most of the grains and record the results. Then compare the sand grains on the plastic sheet with the sorting chart, and with the magnifying glass determine the best-fit sorting category.

iii. Finally, compare the sand grains in the sample with the angularity charts to determine the shape. If the beach is made up of stones only, these can also be measured. Collect at least 20 stones, picking them randomly, measure the length along the longest axis and then calculate the average. The chart in Figure 18 can also be used for determining the shape of the stones.

Sand Composition

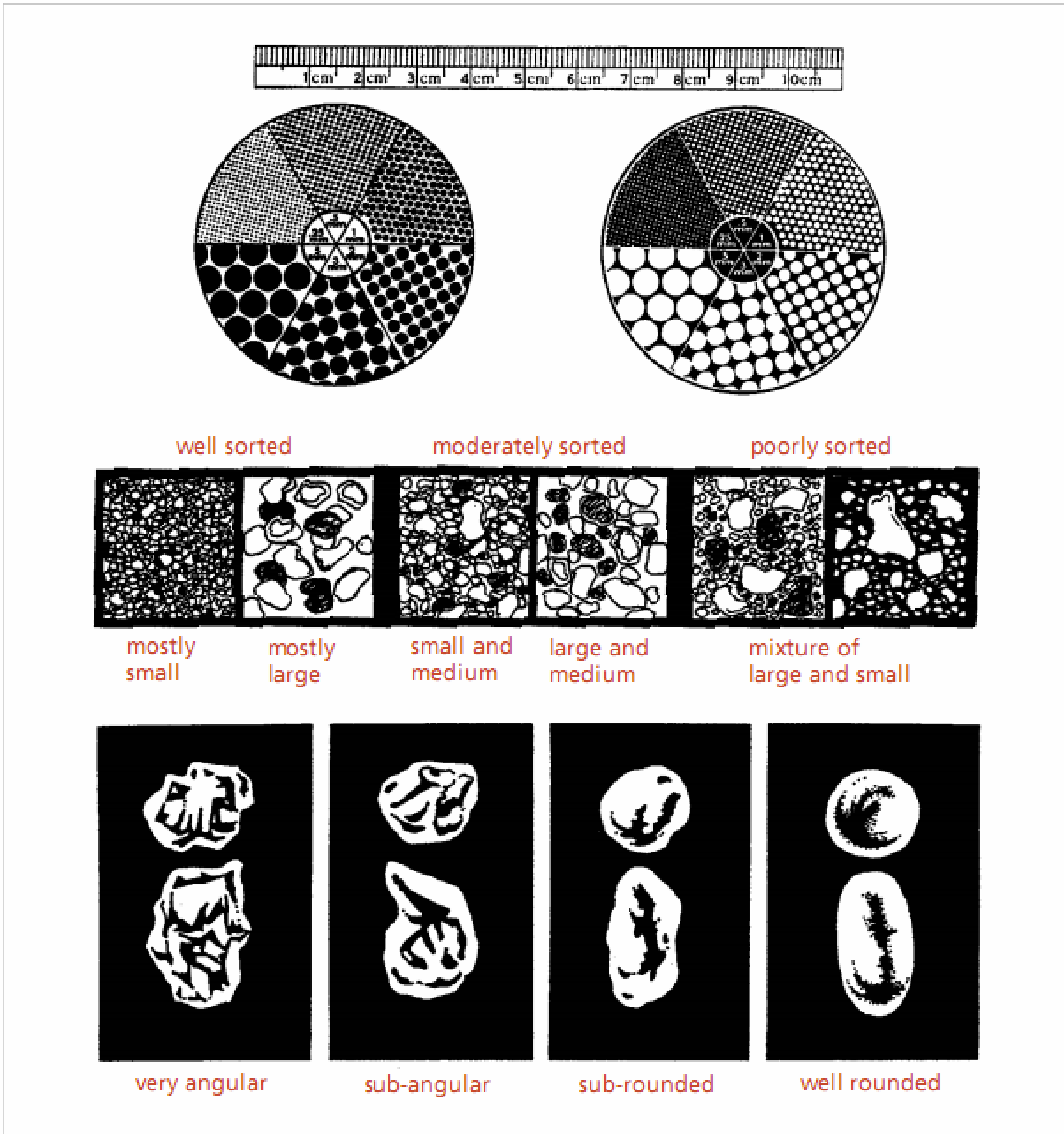


Figure 18. Sand sorting and identification card used in "Sand Type" methodology. Source: UNESCO (2005)

Sea Defenses

Sea defenses are defined as structures meant to preserve beach width, often with the intention of having them contribute to processes of accretion (=sand deposits that make the beach wider). Sea defenses are often constructed by landowners with the intention of protecting their coastal property from erosion, as well as to conserve (or rebuild) sand. The effectiveness, including cost-effectiveness, of such structures is debatable (Tuner et al. 1995; Bray et al. 1997; Klein et al. 1999) and they tend to serve as an obstacle to sea turtles emerging from the water in search of a nesting site (Witham 1982; Choi and Eckert 2009). On some beaches, stabilizing structures have inhibited all sea turtle nesting activity (Steinitz et al. 1998). Structures identified to fall into this category, such as sea walls, groines (Figure 19), and jetties should be noted on the data form.

Equipment:

- ❑ (None)

Methods:

Note the presence, location and type of any sea defenses on your data form.

Figure 19. Groines on Alleynes Beach, Barbados. Photo: Ana Luque

Vegetation

Hawksbills tend to prefer nesting close to or within littoral vegetation (e.g., Horrocks and Scott 1991; Lewsey et al. 2004). Nests in open sand areas have been found to have lower emergence success (Kamel and Mrosovsky 2005). Vegetation may indicate beach stability and a more predictable temperature regime, the latter being a key variable in temperature dependent sex determination (Janzen 1994; Janzen and Morjan 2001; Kamel and Mrosovsky 2006). Documenting plant succession through measuring the distance from the seaward line of permanent vegetation to the high water mark, and any changes in type and condition of vegetation present, provides a useful index of habitat quality.

Figure 20. Seagrape and other vegetation on Crystal Cove Beach, Barbados. Photo: Ana Luque

Figure 21. Highly vegetated mangrove on Heron Bay, Barbados. Photo: Ana Luque

Equipment:

- ❑ Measuring Tape
- ❑ Local Plant Identification Guide

Methods:

- ❖ Using the measuring tape, measure the distance between the high water mark and the seaward edge of the line of permanent vegetation.

- ❖ Identify the types of plants and foliage present, using Caribbean plant identification guides as needed. Take photographs or make written descriptions of unidentified plants.

Predation risk
(crab holes per m^2)

Beach crabs (e.g., *Gecarcinus ruricola, Ocypode quadrata*) prey on sea turtle hatchlings and can be a hindrance as the hatchlings journey to the sea; crabs have been known to attack as many as 60% of nests in a single nesting may season (Fowler 1979). The number and location of predators influences where a female decides to lay her nest in predator-rich habitats (Spencer 2002; Spencer and Thompson 2003). Although certain predators are natural to a nesting habitat (Figure 23), other predators are invasive or exotic (Figure 22). Counting the number of crabs per m^2, and using that number to calculate crab density, can offer a proxy for the number of predators a hatchling might face. Other indices may be used in areas where crabs are not a major predator.

Figure 22. Mongoose tracks across a sea turtle nest site, Heron Bay, Barbados. Photo: Elda Varela-Acevedo
Mongoose insert: http://a-z-animals.com/images/animals/mongoose7_large.jpg

Figure 23. Crab preying on a hawksbill sea turtle hatchling. Photo: Ulrik Mueller

Predation risk

(crab holes per m^2)

Equipment:

- ❑ One m^2 PVC Pipe Quadrant (see Tools)

Methods:

- ❖ Randomly toss the quadrant close to a sea turtle nest on the beach.
- ❖ As crabs tend to hide in holes (Figure 24) when there is human activity on the beach, proceed to count the number of crab holes within the quadrant in order to estimate crab density in the area.
- ❖ Repeat up to three times and average the number of holes counted on each toss.

Figure 24. A ghost crab disappears into a hole. Source: http://fireflyforest.net/firefly/2006/05/30/ghost-crabs/

Beachfront Lighting

Hatchlings depend largely on a visual response to natural seaward light to guide them to the ocean; in zones of coastal development, sources of artificial light distract hatchlings inland, often to an untimely death. The same can be said for nesting females, who may become confused by, or turn inland toward, bright lighting.

Studies confirm that artificial lighting alters sea turtle nesting patterns on Florida beaches (Witherington 1992; Salmon et al. 1995; Salmon 2003) and disorients hatchlings (e.g., Mortimer 1982; Witherington and Bjorndal 1991). This has also been observed to be true in Barbados (Knowles 2007; Eckert and Horrocks 2002).

Research demonstrates that certain (generally longer) wavelengths are less attractive, and should be considered by coastal developers whenever possible – a comprehensive manual (Witherington and Martin 2000) focuses on this and other recommendations for resolving light-pollution problems on sea turtle nesting beaches.

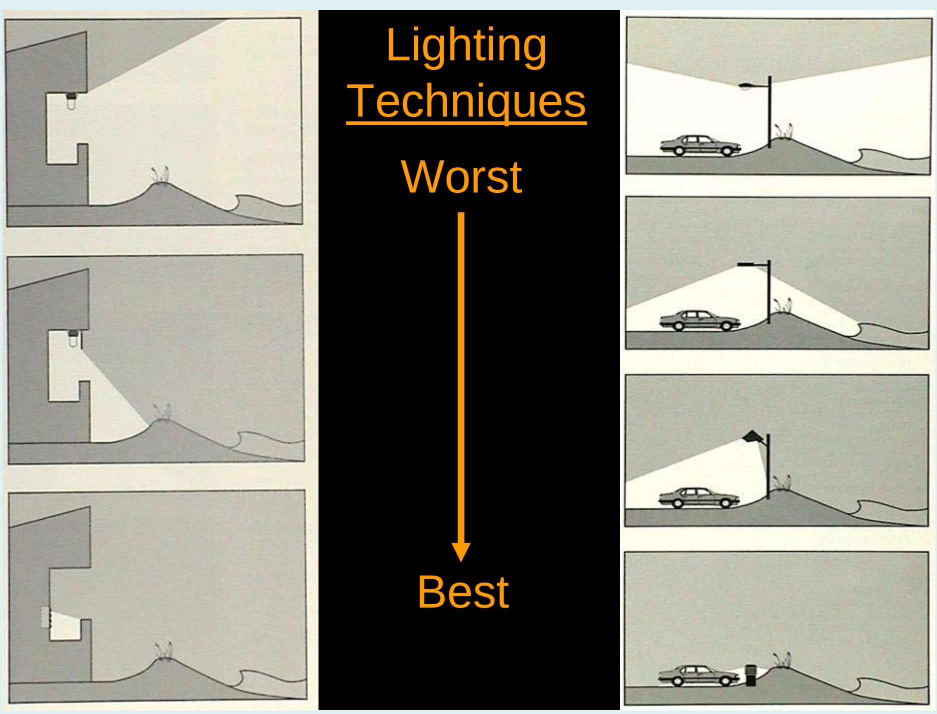
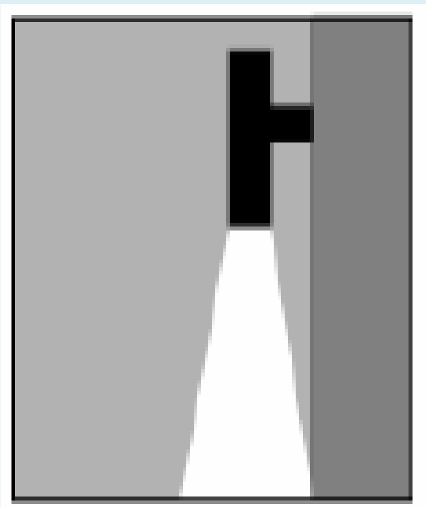


Figure 25. Reducing light pollution is easily accomplished. Consider where light is actually needed, and install lighting to meet that need. For background and detailed recommendations, see Witherington and Martin (2000), Knowles (2007), Choi and Eckert (2009). Graphic source: Witherington and Martin (2000)

Beachfront Lighting



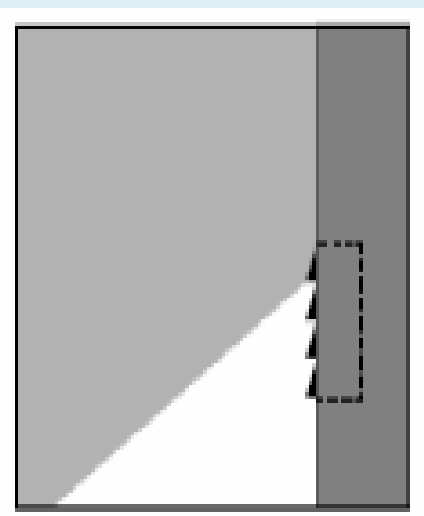


Figure 26. Examples of "sea turtle friendly" lighting, broad-casting light only where it needs to be. Source: Knowles (2007)

Equipment:

- ❑ (None)

Methods:

Beaches with establishments known to have evening and nighttime operational hours should be assessed during those hours in order to observe the amount and type of lights that shine onto the nesting beach. During the nighttime assessment, all illuminated fixtures should be ranked following procedures described by Knowles (2007, downloadable at www.widecast.org):

- ❖ A rank of "1" describes indirect light visible by an observer on the beach, but not likely to present a strong attraction to nesting or hatching turtles.
- ❖ A rank of "2" describes direct light or a visible globe, glowing element, lamp, or reflector likely to disorient turtles.
- ❖ Neither "1" nor "2" ranked lights are strong enough to cast a discernible shadow on the beach during a dark night. A rank of "3" describes a light source strong enough to cast a shadow on the beach regardless of the illumination being direct or indirect.

Beachfront Lighting

Why do we include information on predation risk and beachfront lighting in a Manual designed to help communities evaluate the vulnerability of sea turtle nesting beaches to changing coastlines and climate change? Beachfront lighting, in particular, is a serious threat to sea turtle survival and as beaches erode and become narrower, beachfront lighting is likely to increase. We also hope that the Manual will encourage and empower Caribbean communities to implement coastal monitoring programs, and regular lighting assessments along developed shorelines should be included in these monitoring efforts.

A comprehensive nighttime lighting inspection should occur at least annually, just prior to the nesting season. Two supplementary inspections during peak nesting and hatching periods will alert managers in a timely way to new and/or unexpected lighting problems on their own or adjoining properties.

As summarized by Choi and Eckert (2009), there are a number of corrective measures that beachfront property owners can take to reduce or eliminate light pollution. For example, metal hyalites and high pressure sodium vapor lights have strong negative effects on sea turtles and should be replaced as a priority. Incandescent lights have more moderate effects (except for bug lights, which are tinted yellow) and long-wavelength low pressure sodium vapor lights (LPS) are the least detrimental to sea turtles.

Removing unnecessary or unused lights is an easy first step in creating a "turtle friendly" environment. Lowering lights (lights most visible from the beach are often mounted high on buildings or poles) and using directional fixtures to place light only where it is needed can be both aesthetically pleasing and more cost- and energy-efficient. Shielding an open light source (with aluminum flashing or ornamental plantings) reduces the amount of light directed onto the beach, and installing motion sensitive lights can also reduce the detrimental effect on sea turtles because of the relatively brief duration of illumination.

Finally, time and area restrictions (e.g., restricting usage or extinguishing lights during peak sea turtle nesting and hatching seasons) and installing window treatments (to reduce light from interior sources) black-out draperies, opaque curtains, shade-screens, and/or tinting or using shading film on windows are further ways to reduce energy costs.

If you find during your beach monitoring programs that lighting is affecting sea turtle nesting success, visit http://www.widecast.org/What/ProjectContacts.html to contact the WIDECAST Country Coordinator in your area for more information on how to reduce the threats posed by beachfront lighting.

General Observations

Every sandy beach varies in its specific features and vulnerabilities, and not every feature could be described in this Manual. Any observation that seems applicable to sea turtle nest site selection should be noted and, if possible, measured over time.

Equipment:

- ❑ Camera
- ❑ Film

Methods:

Document (including with photographs) any features relating to sea turtle nesting success and/or hatch success – or the general state of the coastal shore and factors threatening its integrity – whenever you observe them.

Figure 27. Sandy Lane Beach, Barbados. Photo: Ana Luque

Concluding Remarks

In addition to regular coastal monitoring, there are several ways in which residents and visitors can improve the quality of Caribbean nesting beaches. Cambers (1998b) notes that some activities can be undertaken by individuals, while others are more suitable for group projects, but that both visitors and island residents alike can help to ensure that Caribbean beaches "will be available for future generations to enjoy." She promotes the idea of an "Adopt a Beach" program – where a local community, school, business or service group 'adopts' a particular beach and undertakes various activities over the years to enhance it. The group takes responsibility for the beach and becomes a custodian of its natural resources. These projects are a good way of getting a community or group involved in beach management, and of improving the environment for all.

Activities can be tailored to your location. Some examples are:

- vegetation replanting projects
- beach clean-ups
- provision of litter bins
- warning notices for Manchineel trees
- installation of wooden walkways along public accesses
- demarcation using buoys of swimming-only areas
- involving schoolchildren in beach field trips and conservation projects, and
- ensuring the proper disposal of litter

"It is up to everyone to take responsibility for safeguarding our natural resources!"

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Appendix I:

Sample Data Sheet

Beach Data Sheet
Date: 15 July, 2009
Location: Paynes Bay- by construction site

Beach Profile (BP)		
Reference Point: gate entrance to Seafort House		
Meters Height: 1.64 m (to top of gate pole)		
Beach segment	**Length of segment (m)**	**Slope angle (degrees and minutes)**
A-B	1.7	-4°60
B-C	1.27	-9°20
C-D	3.65	-7°50
D-E	3.35	-8°0
E-F	4.59	-1°30
F-G	2.19	-4°00
G-H	12.95	-7°50

Sand Composition	
Size:	0.50
Sorting:	Well
Sorting Size:	Mostly small
Shape:	Very angular
Color:	Brown

50 cm Hole	**Rank**
Meter 1	very soft
Meter 2	roots
Meter 3	soft; rock at 32 cm down

Comments/ Observations:

*bars and hotels so much human activity
*in construction area
* Treasure Beach Hotel just south of old trees apts.
* boats in BP area

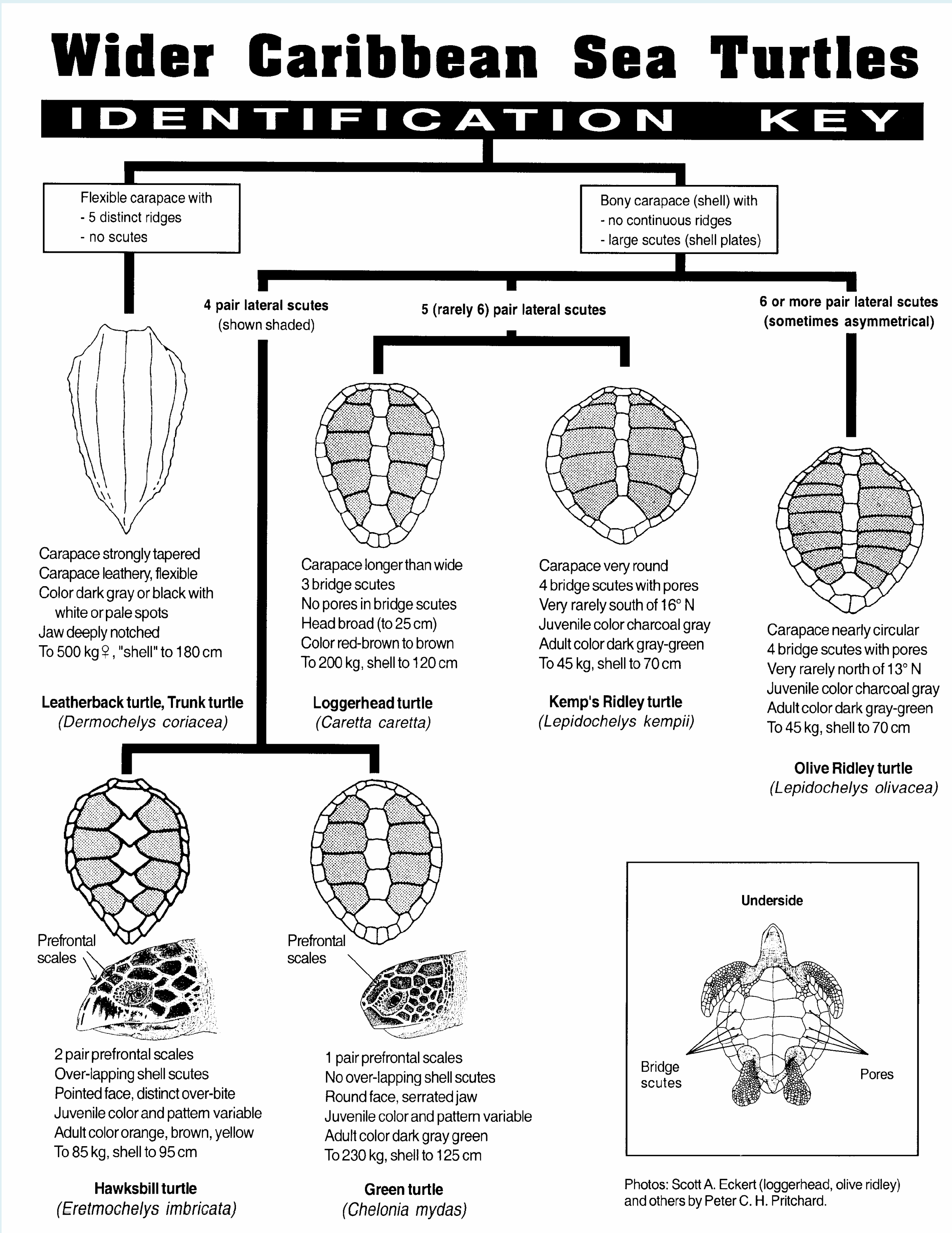
Beach Description	
Beach elevation	
Sea defenses	Breakwaters to south (treasure beach)
Boundary parameter	White wall of house
Vegetation	Sea grape and manchineel on landward side of wall
Sand Samples	X (from nest area)

Beachfront Lighting	**Rank**
Light 1: restaurant roof lights	2
Light 2: by mahoe	1
Light 3: at southern end of hotel's gate	3

Beach Width				
Reference point (North to South)	**Veg (m)**	**HWM (m)**	**Total (m)**	**Sand Softness/ 50 cm Hole**
Point 1 Reference: stump by construction	3.2	12.13	12.13	Soft digging (trash burning area)
Point 2 Reference: BP	1.53	16.75	16.75	No roots in digging
Point 3 Reference: wall of Old Trees Apartments	2.67	14.73	14.73	Soft sand, easy to dig

Appendix II:

Sea Turtle Identification


Wider Caribbean Sea Turtles
IDENTIFICATION KEY
Flexible carapace with
- 5 distinct ridges
- no scutes
Bony carapace (shell) with
- no continuous ridges
- large scutes (shell plates)
4 pair lateral scutes
(shown shaded)
5 (rarely 6) pair lateral scutes
6 or more pair lateral scutes
(sometimes asymmetrical)
Carapace strongly tapered
Carapace leathery, flexible
Color dark gray or black with
white or pale spots
Jaw deeply notched
To 500 kg♀, "shell" to 180 cm
Leatherback turtle, Trunk turtle
(Dermochelys coriacea)
Carapace longer than wide
3 bridge scutes
No pores in bridge scutes
Head broad (to 25 cm)
Color red-brown to brown
To 200 kg, shell to 120 cm
Loggerhead turtle
(Caretta caretta)
Carapace very round
4 bridge scutes with pores
Very rarely south of 16° N
Juvenile color charcoal gray
Adult color dark gray-green
To 45 kg, shell to 70 cm
Kemp's Ridley turtle
(Lepidochelys kempii)
Carapace nearly circular
4 bridge scutes with pores
Very rarely north of 13° N
Juvenile color charcoal gray
Adult color dark gray-green
To 45 kg, shell to 70 cm
Olive Ridley turtle
(Lepidochelys olivacea)
Prefrontal scales
2 pair prefrontal scales
Over-lapping shell scutes
Pointed face, distinct over-bite
Juvenile color and pattern variable
Adult color orange, brown, yellow
To 85 kg, shell to 95 cm
Hawksbill turtle
(Eretmochelys imbricata)
Prefrontal scales
1 pair prefrontal scales
No over-lapping shell scutes
Round face, serrated jaw
Juvenile color and pattern variable
Adult color dark gray green
To 230 kg, shell to 125 cm
Green turtle
(Chelonia mydas)
Underside
Bridge scutes
Pores
Photos: Scott A. Eckert (loggerhead, olive ridley) and others by Peter C. H. Pritchard.

Appendix III:

Hawksbill Sea Turtle

Sea Turtles of the Wider Caribbean Region

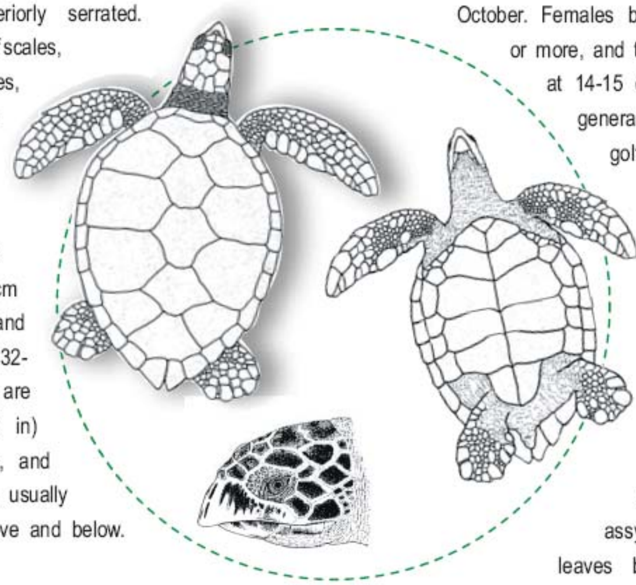
Hawksbill Turtle

Eretmochelys imbricata

General Description

The hawksbill turtle is easily identified by its strikingly beautiful carapace (top shell) which is a mosaic of brown, gold, orange and red speckled scutes that overlap each other like shingles on a roof. The oval carapace is posteriorly serrated. There are two pairs of scales, called prefrontal scales, between the eyes and two claws on each front flipper.

Adult hawksbills grow to 70-95 cm (27.5-37.5 in) and weigh 60-80 kg (132-176 lb). Hatchlings are 40-45 mm (1.6-1.8 in) in carapace length, and are uniform in color, usually grey or brown, above and below.



Nesting Distribution and Behavior

Hawksbills nest in generally low densities throughout the Wider Caribbean. The largest known nesting populations are found in Antigua & Barbuda, Barbados, Cuba, Mexico (Yucatan peninsula), Panama, Puerto Rico, and Venezuela, with important nesting areas in Colombia, the Dominican Republic, Jamaica, and St. Vincent and the Grenadines.

Hawksbills nest at night, often on beaches flanked by coral reefs and rocks, and mainly between June and October. Females breed every 2-3 years or more, and typically nest 4-5 times at 14-15 day intervals. A clutch generally consists of about 150 golf ball-sized, white eggs.

The female hawksbill carefully selects her nesting site well above the high water mark where the eggs will remain dry for the next 8-9 weeks until they hatch. The assymetrical track she leaves behind is 70-85 cm across. Hawksbills like to nest amongst vegetation, perhaps because their nests are quite shallow (≤ 10 cm to top layer of eggs), and vegetation helps to shade the buried eggs from the scorching sun. Unfortunately, shallow nests are also more vulnerable to predators. Hatchlings emerge at night and use natural light to find their way to the sea.

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Did you know that...

•The hawksbill sea turtle is the Caribbeans's only major sponge predator!
•The Caribbean sea supports 20-30% of the world's hawksbill population!
•A female hawksbill is two decades old (or more) before she nests for the first time!

Diet

As the name suggests, the hawksbill has a narrow pointed head and a "beak" which is used to pry prey from reef crevices and take clean bites out of marine sponges. They specialize on sponges in the Caribbean Sea, and to a much lesser degree will also eat hydrozoans, crabs, clams, gastropods, tunicates, and plants.

Why Are They Threatened?

The hawksbill turtle is amongst the most endangered of the six species of sea turtle found in the Wider Caribbean. The beauty of this turtle's shell (also called tortoiseshell, carey or bekko), and its use in the manufacture of hair combs, jewelry and other ornaments, is the main reason for the heavy exploitation of this species over the years. For example, Japanese Customs data show that shells from more than a quarter-million hawksbills were imported from the Caribbean from 1971-1989. Japan ended this trade in 1993. Hawksbill eggs and meat are eaten as delicacies in many Caribbean territories. Destruction of coral reefs (foraging habitats) through pollution, dynamite blasting and careless diving and anchoring, as well as degradation of sandy beaches (nesting habitats) due to increased coastal development, have further contributed to the decline of hawksbill populations in the Caribbean.

WIDECAST
Wider Caribbean Sea Turtle Conservation Network

What Can You Do To Help? Please:

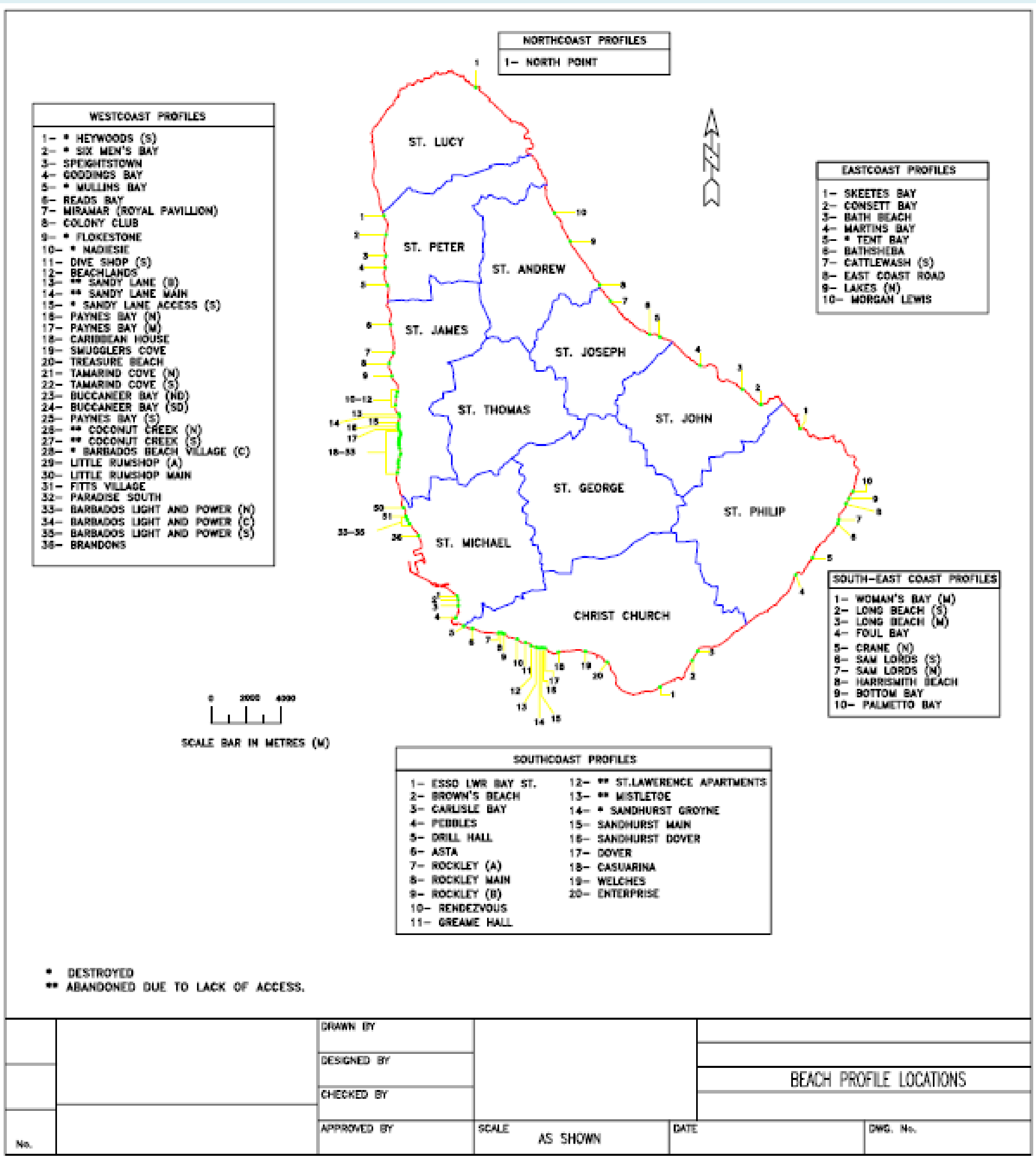
- Do not buy or sell sea turtle products. Remember, international law prevents the transport of sea-turtle parts and products across national borders.
- Do not harass sea turtles at sea or on land. Do not disturb turtles in feeding areas, shine lights on nesting turtles, ride turtles, or collect hatchlings.
- Turn off, shield, or redirect coastal lighting to prevent it from shining on nesting beaches. Artificial lighting can fatally disorient nesting and hatching sea turtles.
- Obey all regulations regarding the protection of coral reefs, seagrass, and natural beach vegetation.
- Do not drive your car on the beach; incubating eggs can be crushed and tire ruts trap crawling hatchlings.
- Support local and national conservation efforts. Be familiar with existing legislation, and encourage new legislation to strengthen protection for sea turtles and their habitats.

WIDECAST

With Country Coordinators and partner organizations in more than 40 Caribbean nations and territories, the Wider Caribbean Sea Turtle Conservation Network (WIDECAST) is an innovative, proactive and inclusive mechanism for sustainable development on a regional scale. By bringing the best available science to bear on decision-making, emphasizing information exchange and training, and encouraging harmonised practices, the network promotes strong linkages between science, policy, and public participation in the design and implementation of sea turtle management programmes.

Appendix IV:

Map of Beach Profile Locations, Barbados



So that they might have a chance.....

Photo: Ana Luque

Photo: Ana Luque