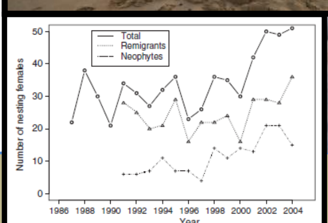
# Designing Surveys of Abundance at Sea Turtle Nesting Beaches

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**Cover Photo inserts** (top to bottom): Seth Stapleton (Dominica), Wildlife Trust (Belize), Scott Eckert (Georgia, USA), Guillaume Feuillet (French Guiana), annual numbers of hawksbills nesting at Jumby Bay, Antigua (Richardson et al., 2006)

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# Designing Surveys of Abundance at Sea Turtle Nesting Beaches


Karen L. Eckert
Scott A. Eckert


2012

WIDECAST
Wider Caribbean Sea Turtle Conservation Network

# PREFACE AND INTENT

For nearly three decades, the Wider Caribbean Sea Turtle Conservation Network (WIDECAST), with Country Coordinators resident in more than 40 Caribbean nations and territories, has linked scientists, conservationists, natural resource users and managers, policy-makers, industry groups, educators, and other stakeholders together in a collective effort to develop a unified management framework, and to promote a region-wide capacity to design and implement science-based sea turtle conservation actions.

As a Partner Organization of the UNEP Caribbean Environment Programme and its Regional Programme for Specially Protected Areas and Wildlife (SPAW), WIDECAST is designed to address research and management priorities at national and regional levels, both for sea turtles and for the habitats upon which they depend. We focus on bringing the best available science to bear on contemporary management and conservation issues, empowering stakeholders to make effective use of that science in the policy-making process, and providing an operational mechanism and a framework for cooperation within and among nations.

Network participants are committed to working collaboratively to develop their collective capacity to manage shared sea turtle populations. By bringing people together and encouraging inclusive management planning, WIDECAST is helping to ensure that utilization practices, whether consumptive or non-consumptive, do not undermine sea turtle survival in the long term. However, the recovery of remnant populations of Caribbean sea turtles will require more than a precautionary approach to sustainable use, it will require thoughtful attention to both acute and chronic threats to important nesting and foraging habitats and the capacity to monitor population trends in order to evaluate the success (or failure) of conservation and management actions taken.

Following on the publication of WIDECAST's "Atlas of Sea Turtle Nesting Habitat for the Wider Caribbean Region"[1], the purpose of this Technical Report is to help sea turtle project directors and natural resource managers define their objectives in monitoring sea turtle nesting beaches, and then to develop and implement methodologies, including statistical treatments and data analyses, to meet those objectives. Best practices are discussed relative to determining the geography and phenology of nesting (and how these might be changing over time), selecting index monitoring sites, evaluating survey timing and duration, and deciding what (and how often) to count. Links to database management software (including standardized data reporting forms) and online analysis programs to generate seasonal abundance estimates are provided.

By encouraging a unified approach to sea turtle population monitoring at national and international levels, we strive to ensure that data are compatible and comparable at ecological scales, furthering the intent of the SPAW Protocol to establish "regional co-operation to protect and, as appropriate, to restore and improve the state of ecosystems, as well as threatened and endangered species and their habitats in the Wider Caribbean Region..."

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*Executive Director*
*WIDECAST*

[1] Dow, W., K. Eckert, M. Palmer and P. Kramer. 2007. An Atlas of Sea Turtle Nesting Habitat for the Wider Caribbean Region. The Wider Caribbean Sea Turtle Conservation Network and The Nature Conservancy. WIDECAST Technical Report No. 6. Beaufort, North Carolina. 267 pp. + electronic Appendices.

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# EXECUTIVE SUMMARY

Concern over the plight of sea turtles in the Wider Caribbean Region (WCR) has led to the adoption of protective legislation and the widespread implementation of conservation programs. Evaluating the success or failure of these efforts relies on accurate information concerning the status of target populations, especially whether the population is increasing or decreasing. Accurately assessing status and trend requires careful attention to the design and implementation of long-term surveys of abundance. Because sea turtles are highly migratory at all life stages, such surveys are typically aimed at adult females seasonally accessible at nesting beaches.

Assessing population status is a priority recommendation of sea turtle recovery plans in the WCR (e.g., see http://www.widecast.org/widecast-publications/national-recovery-plans/); moreover, Parties to the Convention on the Protection and Development of the Marine Environment of the Wider Caribbean Region (and its Protocol on Specially Protected Areas and Wildlife, SPAW), as well as to the InterAmerican Convention for the Protection and Conservation of Sea Turtles (IAC), are obliged to monitor the sea turtle resource to ensure its sustained recovery.

Surveys of abundance serve duel objectives: first, to meaningfully inform national management policy based on trends at local index nesting beaches (see *Definitions*) and, second, to estimate population-level trends (including males and non-reproductive life stages) from data collected at index sites over regional scales and pooled for analysis among range States. Place-based decisions regarding where and when to survey, how and what to count, and how to analyze and report data should always follow methodological and analytical best practices.

The objective of this handbook is to guide managers in achieving an accurate tally of the number of females nesting each year. A complete count of every individual turtle successfully nesting each year on the full inventory of beaches used by a particular stock is ideal. However, this may not be practical because of any number of logistic and human resource issues, including the reality that adult female members of a particular stock may nest on multiple beaches in remote locations or routinely cross national boundaries. For this reason, we specifically focus on making decisions about where and when to monitor index nesting beaches, what to count, and how to analyze the data in order to detect and interpret changes in abundance over time.

This handbook does not duplicate existing resources describing field procedures and protocols related to working on sea turtle nesting beaches (e.g., patrol schedules, measuring turtles, nest protection/relocation, nest excavation and assessing hatch success, completing data forms, training and evaluating staff, processing stranded turtles). Tagging, however, is described because it directly relates to some index measures.

## CHECK LIST FOR MANAGERS

- ☐ Define the management question(s) – e.g., "How many leatherback turtles arrive each year at the nation's most important nesting grounds? Are these populations increasing or decreasing over time?"

- ☐ Identify stakeholders and partners[2] necessary to sustain a *long-term (10 years+) monitoring effort* at selected index beaches.

[2] Management authority(ies), police/rangers/Coast Guard, researchers, volunteers, community groups, coastal landowners (including hotel managers and staff), and fishers, divers or tour guides that regularly visit remote cays

- ☐ Convene a meeting of stakeholders and partners to review what's known, identify gaps, discuss methodological approaches, draft a monitoring plan (including training, implementation, evaluation, and reporting), and develop a funding strategy, if needed.

- ☐ Develop a logistical and quality control plan for data collection; data handling, checking (for accuracy), and storage procedures; and data fate, ownership and access, including who will be responsible at each stage and for each procedure.

- ☐ Design data sheets that prompt the observer for each measurement, keeping the procedures and requirements of data recording, computer entry, and data analyses in mind.

- ☐ Establish the geography of nesting.[3]

- ☐ Establish the phenology (timing) of nesting – most methodological approaches and analytical models require that the beginning, peak, and end of the nesting season be known.

- ☐ Decide what to monitor – select index sites (generally your most accessible high-density nesting beaches) for intensive monitoring and identify remote, less accessible, and/or lower density sites (known or suspected to be visited by the same sea turtle population) for less frequent assessment; be aware and take advantage of ongoing research or other visitation to lower density sites that could accommodate a minimum level of data collection for management purposes.

- ☐ Decide what to count – activities (defined as both successful and unsuccessful nesting attempts), nests (successful attempts [egg-laying] only), or individual turtles; know the advantages and disadvantages of each index measure and how to make site-specific conversions (e.g., convert number of nests to number of females).

- ☐ Decide how often to count – if complete nightly patrols to document all nesting turtles are not practical, select a sampling scenario that presents a good "fit" for your situation.

- ☐ Implement the monitoring program – including staff/volunteer training and evaluation, scheduling and supervision, transportation and security, data collection and reporting, and so on. *Note*: these should be reviewed/evaluated annually, pre- and post-season.

- ☐ Validate selection of your index beaches at regular intervals to confirm that data collected there reflect trends in the target population – e.g., if hawksbills are nesting on 20 offshore cays and five cays are selected for intensive monitoring, you need to assure yourself that trends at the other 15 cays are in sync with the index.

- ☐ Analyze the data for estimates of abundance on an annual basis; free analytical software and other online tools are described in this handbook.

- ☐ Document survey results in an Annual Report – including methodology used, as well as a measure of accuracy (e.g., standard deviation) for any calculated results.

- ☐ Share the results on a regular basis with regional and global sea turtle assessment databanks; e.g., State of the World's Sea Turtles (SWOT) http://seaturtlestatus.org/

[3] This can be done through direct reconnaissance surveys, interviews, or a review of previous documentation, such as Dow et al. (2007), an atlas with interactive features that identifies all known nesting beaches in WCR countries.

# I. INTRODUCTION

Concern over the plight of six species of sea turtle inhabiting the Wider Caribbean Region (WCR) has led to the adoption of protective legislation and the implementation of conservation initiatives in most of the region's nations and territories (e.g., Godley et al., 2004; Bräutigam and Eckert, 2006; Dow Piniak and Eckert, 2011). Evaluating the success or failure of these initiatives relies on accurate information concerning the status of target populations and, specifically, whether these populations are increasing or decreasing (Eckert, 1999). Such information empowers managers to respond to changes in population status with mitigation or other options designed to enhance population recovery (Bjorkland, 2001).

Reliably characterizing population status requires careful attention to the design and implementation of abundance surveys, ideally aimed at multiple life stages (e.g., gravid female, oceanic post-hatchling) and habitats (e.g., nesting beach, foraging ground) (Heppell et al., 2003; Mills, 2007; NRC, 2010). This handbook specifically focuses on making decisions about where and when to monitor *sea turtle nesting populations*, what to count, and how to analyze the data to detect changes in population abundance over time. It does not duplicate resources already available that articulate best practices related to research and conservation initiatives on nesting beaches (e.g., Eckert et al., 1999; Wood, 2004; Gorjux et al., 2006; FFWCC, 2007; Chacón et al., 2008; NMFS 2008).

***Surveillance vs. Directed Monitoring –*** There are two common approaches to assessing population status. With the first approach, surveillance (sometimes referred to as "thumb-on-the-pulse") monitoring, the goal is to know "how the population is doing", especially whether it is in decline, and the results may point to the need for more rigorous evaluations. The North American Breeding Bird Survey (BBS) is an example of this type of monitoring. During the annual breeding season (May-June) in the continental USA, volunteers survey pre-established routes and tally all birds seen or heard. This survey is primarily oriented toward passerine species ("song birds") and it generates indices that can be used to estimate population trends (Figure 1). The survey is not designed to inform a particular conservation decision; notwithstanding, such surveys, especially when conducted consistently over time, have a demonstrated usefulness in identifying species or populations that might be of concern (Sauer et al., 2008).

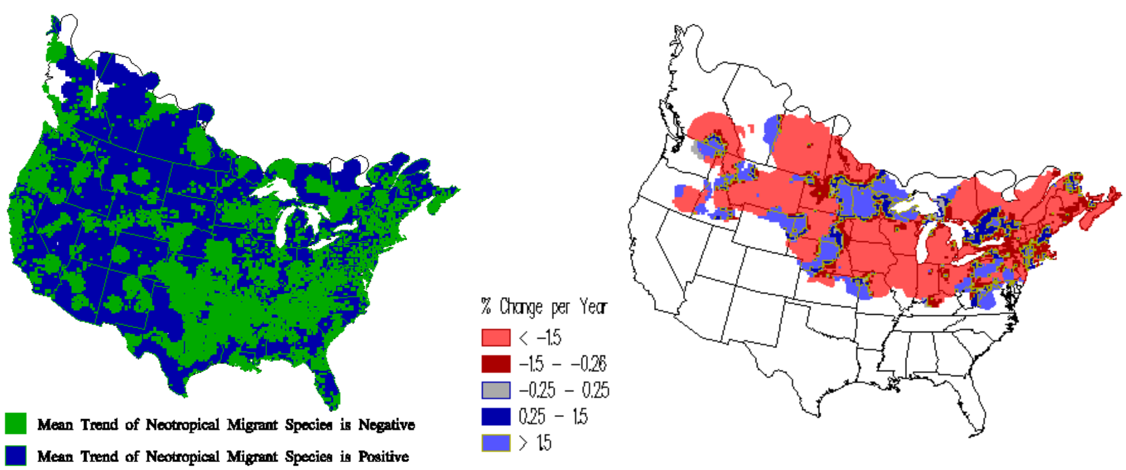



**FIGURE 1**. Map of the continental USA and southern Canada showing where the majority of Neotropical migrants are increasing and where they are decreasing, emphasizing the regional nature of the recent declines within this guild. On the right, the Bobolink (*Dolichonyx oryzivorus*) is typical of BBS trend maps, showing widespread declines in much of its range. Source: Sauer et al. (1997) at http://www.mbr-pwrc.usgs.gov/bbs/genintro.html

In contrast, direct monitoring *is* designed to inform a particular conservation decision – and this approach requires an informed decision-making process with clear and specific conservation/ management objectives, a set of decisions to choose from, predictions about how each decision alternative might affect the population of interest, and a monitoring program (Kendall, 2001; Nichols, 2001; Williams et al., 2002). Stakeholders must first balance potentially competing interests so that the objectives are clear. Logistic or funding limits invariably play a role in deciding which objectives can be achieved. The second element in a decision process is the set of decision alternatives largely determined by a combination of political and economic feasibility, and the third is anticipation or prediction of what types of actions might be helpful to sea turtle conservation. This leads to the fourth component of an informed decision – a monitoring program. Your objective(s) will partially determine what should be monitored. For example, if the objective is to maintain a minimum number of nesting turtles in a population while also permitting a fishing fleet that unintentionally kills sea turtles to take a certain quantity of fish, then the number of nesting turtles, the number of turtles accidentally killed, and the quantity of fish caught should all be monitored in order to evaluate the efficacy of any regulatory or management scheme implemented to balance the two objectives.

Predictions about how particular decisions will affect the population of interest, as well as other aspects expressed in the objective(s), are inherent to an informed decision. Predictions might come from a formal mathematical expression, or they might be done intuitively in the mind of someone familiar with the system. For example, hypothetically, an expert might anticipate that if fishing nets are required to be set at least *x* meters deep, 20% more gravid females will safely arrive to and depart from the nesting beach and the fishing take will exceed the target value by 10%. This anticipated result from the intuition of an expert is a predictive model just as a complex mathematical expression developed from analysis of multiple data sets is also a predictive model. In each case a prediction is made, and along with that should come an expression of uncertainty surrounding that prediction. In this simple example, the expert, whether expressed verbally or not, is really thinking that although s/he predicts a 20% increase in the number of nesting turtles, s/he may have derived this from experience suggesting that there will be at least a 5% increase and no more than a 30% increase. This raises another use for monitoring: to measure pertinent outputs from predictive population or fishery models, to see how well one or more models perform in terms of predicting the outcome of a chosen conservation action.

***Indices vs. Direct Measurement* –** Whether surveillance monitoring or a more focused monitoring program is employed, another decision to make is whether to rely on counts (indices to abundance), or to estimate abundance directly by adjusting those counts for detection probability. Both approaches are supported by a large literature of methods for estimating parameters and their confidence intervals. Direct information on abundance facilitates management decisions (e.g., allowable annual take). In addition, because this approach generally requires marking individuals, vital rates can also be estimated. The advantage of indices is that the data are simpler to collect, and trend estimates from these data are relatively unbiased if there is no systematic pattern in detection probability, or the important factors affecting detection probability are measured and used as covariates. For example, BBS observers vary in ability and therefore are included as a covariate in modeling counts of birds over time and space.

***The Role of Monitoring* –** In a decision context, monitoring is used to determine the current state of the system (e.g., population size, fishery catch) and then to assist in making a decision that is possibly dependent on the state of the system (e.g., population status). It is also used to measure how effective the last decision was in terms of meeting the objective(s), as well as to compare how well each of the possibly competing models (statistical or intuitive) did in making predictions. Finally, although experimentation does a better job of providing information for building predictive models, monitoring program data are often used over time to identify hypotheses for developing new or revised predictive models (Kendall and Moore, 2012; Nichols and Williams, 2006). Because the wide variety of habitats occupied by sea turtles makes it difficult to implement a one-method-fits-all approach to conducting surveys in areas utilized for nesting, foraging, development, transit, etc., in this manual we confine our discussion to approaches used in monitoring nesting populations.

## II. DEFINITIONS

Confusion over essential terminology can undermine the usefulness of a text, thus we will clarify our usage at the outset. The term *nesting population* is used to describe the total number of adult females of the same species using a geographically defined nesting beach (or series of beaches) and, by definition, these females would be of the same *stock* because of natal homing instincts (e.g., Meylan et al., 1990; Dutton et al., 1999; Bowen et al., 2005; Dethmers et al., 2006; NRC, 2010). *Population* and nesting population are not synonymous. A nesting population is but one segment of a population, as the latter includes males and other life stages.

Sea turtles utilizing a geographically defined foraging ground constitute an *aggregation* (vs. a population), since the assembled individuals are most likely drawn from multiple stocks of origin. For example, genetic analyses of foraging sea turtles sampled in Union Creek, Bahamas, found that these turtles had originated from (i.e., were hatched on the beaches of) locations as distant as Costa Rica, Mexico, and the USA, and that the proportion of sampled animals related to

### DEFINITIONS

***Activity (or Nesting Activity)****:* A sea turtle nesting activity refers to any landing by the female on a potential nesting beach, whether or not the landing results in successful egg-laying (see “Nest”).

***Aggregation***: An assembly of individuals of the same species (but not necessarily of the same genetic stock) occupying a particular area; for example, sea turtles encountered at a preferred foraging ground or other developmental habitat.

***Index****:* A statistical indicator providing a representation of the size and/or trend of the nesting population from which the indicator is sampled.

***Index Site/Beach:*** A nesting beach (or series of nesting beaches) where the consistent application of standardized population monitoring protocols ensures that data collected are suitable for long-term analyses of population abundance and/or trend. Sampling strategies at each index site should be structured in a manner that allows inference to the entire nesting population of interest.

***Nest****:* A hole dug by an adult female turtle in which the presence of eggs has been observed or verified.

***Nesting Population:*** Reproductively active adult females of the same species returning predictably to lay eggs at a particular location, by which we mean a geographically defined nesting beach or series of nesting beaches.

***Stock:*** Population(s) that can be characterized as isolated (geographically or temporally) and genetically self-sustaining; for example, North Atlantic loggerheads vs. South Atlantic loggerheads. Nesting stocks (based on mtDNA) are often distinguished from breeding stocks (based on nDNA).

***Survey***: An assessment of the abundance of individuals in a certain area; for example, a count of sea turtles on a nesting beach or a count of sea turtles observed along a transect line in a foraging habitat.

various points of origin varied annually (Bjorndal and Bolten, 2008). A complete census of stock abundance is challenging because populations associated with a particular stock may frequent widespread foraging grounds and visit nesting beaches distributed over large geographic areas, often involving several sovereign nations.

The specific focus of this manual is the design of surveys of abundance at nesting beaches, including but not limited to the collection of data at *index sites* (accessible sites that host significant and predictable nesting) as a proxy to assess overall population or stock status.

## III. ARRIBADAS: A SPECIAL CASE

An *arribada* ("arrival" in Spanish) is characterized by very large numbers of gravid sea turtles coming ashore to nest in a synchronous fashion over a period of typically 2-7 days and nights. The phenomenon is unique to the genus *Lepidochelys* – i.e., Kemp's ridley (*L. kempii*) and olive ridley (*L. olivacea*) sea turtles (see Plotkin, 2007, for a comprehensive discussion). Multiple *arribadas* usually characterize an annual nesting season, with some females participating in more than one event. In general, *arribadas* occur once each month, but the event can also occur more (Hirth, 1980; Ballestero, 1996) or less (Plotkin et al., 1997) frequently.

Conducting a population survey under *arribada* conditions, with hundreds (or thousands) of animals crawling over one another on limited stretches of sandy beach coastline (Figure 2), is challenging at best. Counting turtles comprehensively is impossible, and the tangle of crawls left behind in the sand is generally undecipherable. In the WCR, large *arribadas* once characterized Kemp's ridley nesting in the Gulf of Mexico; e.g., 40,000 or more females are known to have nested in a single day at Rancho Nuevo in Tamaulipas, Mexico, in 1947 (Carr, 1963). Following several decades of over-exploitation and mortality in fisheries, strict conservation measures were implemented to save the species from extinction. Today, remnant populations are rising. More than 10,000 nests have been laid annually at index nesting beaches in Tamaulipas and Veracruz, Mexico, since 2005 (National Marine Fisheries Service et al., 2011).

***Recommendations –*** For details on conducting surveys of abundance and trend, including methodology and analysis, at *arribada* nesting beaches, we recommend the "strip transect in time" method described by Valverde and Gates (1999). See also Gates et al. (1996), Valverde et al. (1998), Fonseca et al. (2009), and Shanker et al. (2003). For insights into monitoring strategies suitable for implementation at very high-density nesting beaches utilized by other species, see Limpus et al. (2003), Jackson et al. (2008), and Sims et al. (2008).

**FIGURE 2.** Olive ridley (*Lepidochelys olivacea*) *arribada* at Playa Ostional on the Pacific coast of Costa Rica, and a close-up from French Guiana. Photos: (left) Michael Jensen; (right) Guillaume Feuillet.

# IV. SURVEY DESIGN

To ensure that the data collected are suitable for decision-making processes, the design of the nesting beach survey is critically important. A useful guide by Congdon and Dunham (1999) may be adapted for our purposes, as follows:

***Research and Review –*** Review the literature and talk to other investigators currently engaged in similar types of studies about logistics, research protocols, quality control plans, and types of data analyses.

- Become familiar with past or similar ongoing research or monitoring programs to learn from their successes and failures, and to avoid duplication of effort;
- Become familiar with the areas of biology, technology, and law and policy that may strengthen (or constrain) your monitoring program; and
- Explore how best to integrate your monitoring effort into a larger research framework, including finding ways to collect, analyze and present data to ensure that the information is useful to others (e.g., for comparison among populations or to use in population models).

***Define the Management Question(s) –*** Carefully and clearly state the problem in the form of a precise question or working hypothesis. The question might be: "What is the trend in the number of turtles nesting on this beach?" Translated into a working hypothesis, the question might read: "The number of adult females arriving each year to nest at this site [beach] is increasing."

***Evaluate Approaches –*** List the potential methodological approaches that might be useful in addressing your question and then rank them based on feasibility, including logistical and financial constraints, available human resources, and so on. Identify and seek to fill gaps in statistical and analytical capacity.

***Make a Plan –*** Write a detailed proposal designed to meet your objectives, implement the approach you have selected, and test your working hypothesis. In this case the proposal will take the form of a population monitoring plan suitable for peer-review and comment, fund-raising, soliciting the necessary permits and/or beach access, and so on.

***Prepare for Data Collection –*** Identify what information needs to be collected, how it will be collected, how it will be evaluated, and how it will be stored and accessed.

- Develop a logistical and quality control plan for data collection; data handling, checking for accuracy, and storage procedures; and data fate, ownership and access, including who will be responsible at each stage and for each procedure;
- Design data sheets that prompt the person collecting data for each measurement (data sheets should be designed with data recording, data entry to a computer file, and data analyses in mind);
- Agree to procedures related to data entry (e.g., enter the data into computer files as soon as possible following its collection in the field), review (e.g., regularly review computer files to detect problems associated with data form design, data entry protocols, and/or with computer files themselves), and correction (e.g., evaluate incoming data for recurring errors – frequent review may reveal unsuspected patterns that, if identified and responded to quickly, provide opportunities to improve research protocol or direction); and
- "Walk through," prior to the actual data collection, as many of the techniques and procedures as possible in order to detect problems with protocols and/or equipment.

***Prepare for Field Work –*** Order needed equipment, including expendable field supplies, as early as possible. Always plan and prepare for the unexpected, such as equipment failure, loss of transportation, accidents, illness, or severe weather, and have emergency plans in place.

In addition to the recommendations made by Congdon and Dunham (1999), Legg and Nagy (2006) also provide an excellent perspective on the design of long-term monitoring in an article aptly entitled: "Why most conservation monitoring is, but need not be, a waste of time." They strongly advocate for an analytical approach and the collection of quantitative rather than qualitative data, and argue for a project design that takes into account the need to measure the accuracy or resolution of data through the use of statistical power analysis[4]. Finally, they provide valuable considerations for the management and execution of a monitoring program, as follows:

***Program Management***

- Secure long-term funding and commitment (e.g., institutional, political);
- Develop flexible short- and long-term goals;
- Refine your objectives based on changing circumstances, including new information;
- Pay adequate attention to information management;
- Train personnel, including volunteers, on a regular basis to emphasize careful, consistent data collection and entry;
- Describe monitoring sites, objectives, methods and recording protocols in an Annual Report;
- Obtain peer-review and statistical review of research proposals and publications;
- Obtain periodic research program evaluations, and adjust sampling frequency and methodology accordingly; and
- Develop an extensive outreach program; evaluate and build on successes.

***Project Design and Field Methodology***

- Take an experimental approach to sampling design (e.g., field-test your theories, manipulate variables to test hypotheses, document your results);
- Select methods appropriate to the project's objectives and habitat type(s);
- Minimize physical impact to the monitoring site(s);
- Avoid bias in the selection of long-term monitoring site(s);
- Ensure that field markings are adequate to guard against loss;
- Be assured that you can safely repeat the survey at the same location;
- Be assured that you can safely repeat the survey at the required interval: daily, weekly, monthly, annually – see *Survey Implementation, Decide How Often to Count*;
- Blend theoretical and empirical models with the means (including experiments) to validate both;
- Synthesize retrospective, experimental and related studies; and
- Integrate and synthesize with larger and smaller scale research, inventory, and monitoring programs.

[4] The techniques of statistical power analysis and sample size estimation allow you to decide, while in the process of designing an experiment, (a) how large a sample is needed to enable statistical judgments that are accurate and reliable and (b) how likely your statistical test will be to detect effects of a given size in a particular situation. Performing power analysis and sample size estimation is an important aspect of monitoring because without these calculations, sample size may be too high or too low. If sample size is too low, the experiment will lack the precision to provide reliable answers to the questions it is investigating. If sample size is too large, time and resources will be wasted, often for minimal gain. For additional detail, see http://www.statsoft.com/textbook/power-analysis/?button=2

# V. SURVEY IMPLEMENTATION

## ESTABLISH THE GEOGRAPHY OF NESTING

***Objectives and Constraints –*** Keeping in mind the goal of collecting data that is useful to decision-makers, the primary reason to monitor a sea turtle nesting population is to determine size and/or trend. Thus, the survey should aim to produce an accurate estimate of the number of females nesting each year so that data among years can be compared. A complete count of every individual turtle successfully nesting each year is ideal, but may not be practical because of any number of logistic and human resource issues, including the reality that turtles may nest on multiple beaches in remote locations or routinely cross national boundaries. Project managers generally have an incomplete understanding of the full geographic range of nesting activity, and the extent to which nesting takes place outside the data collection area (or survey period).

***Stock Definitions –*** According to our definition of a nesting population, members have a greater measure of relatedness in that they are of the same stock. Upon reaching sexual maturity, females exhibit natal homing, returning to lay their eggs on the same beach or coastal region where they were born decades earlier (e.g., Meylan et al., 1990; Bowen et al., 1992, 1993; Lohmann et al., 2008; Browne et al., 2010). Because their daughters, granddaughters, and so on, return to the same beach or coastal region generation after generation, the lineage creates a genetic "signature" (haplotype frequency) associated with the nesting site. This signature is read in maternally-inherited mitochondrial DNA (mtDNA), which is genetic material passed from mother to daughter. Genetic analysis can determine these genomic signatures (e.g., Moritz, 1994; Dutton et al., 1996, 2007), so that one approach to determining the geographic range of the stock to which your nesting population belongs is to conduct a genetic survey of all nesting sites in your region to determine the degree of relatedness among nesting populations.

There are other methods, besides genetic analysis, that may be useful in evaluating the geographic bounds of a nesting population. For example, monitoring the movements of individual turtles using unique marks (e.g., flipper tags or Passive Integrated Transponder [PIT] tags that can be read and reported by colleagues working in other areas) or biotelemetry may provide valuable insight into the full geographic range of a nesting population. In Florida, nesting beach monitoring combined with tagging confirms that leatherback turtles favor expansive continental beaches with open ocean access, and that consecutive nests are laid as much as 80 km apart (Stewart and Johnson, 2006). Thus, evaluating the entire nesting range for this population of leatherbacks would require coverage of a significant area. In contrast, individual hawksbill turtles tend to show greater site fidelity (Horrocks and Scott, 1991; Richardson et al., 1999, 2006), meaning that monitoring a few closely distributed beaches (or cays) may provide access to a majority of members of the target nesting population.

***Assumptions –*** It is often assumed, though seldom demonstrated, that the status of a particular nesting population is an indication of overall stock status; in other words, if the number of reproductively active females is increasing (as determined by nesting beach surveys), the stock at large is also increasing (Figure 3). In the short term this particular assumption is highly unsatisfactory because most females do not nest every year, and the proportion of those that do fluctuates widely among years. These fluctuations are not entirely predictable, but seem to be influenced by the quality of foraging during non-nesting periods (e.g., Limpus and Nicholls, 1988; Saba et al., 2007). Another challenge to relating the status of the nesting population to overall stock status is that a nesting beach survey is, by definition, a tally of reproductively active females, a statistically minor segment of the entire stock (which would include all ages and genders).

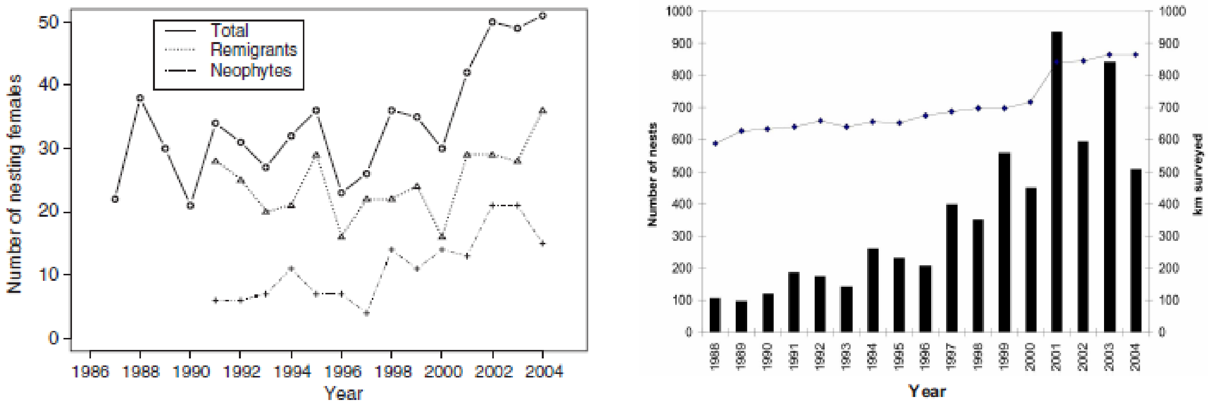



**FIGURE 3.** If, over time, the number of adult females successfully nesting in your survey area each year is significantly increasing, the hope is that the stock at large is rising, as well. But the correlation is confounded by sea turtle life history traits (slow growth, late maturity, long life – meaning that the current cohort of adult females may be subject to very different survival pressures than decades-younger juvenile age classes), inconsistent survey data, and an incomplete understanding of population dynamics, including survival rates, of males and other life history stages. Shown are increasing numbers of hawksbills nesting at Jumby Bay, Antigua (Richardson et al., 2006) and increasing numbers of leatherbacks nesting at index beaches in Florida (Stewart and Johnson, 2006).

***Other Considerations –*** In the end, establishing the geography of nesting is a mapping exercise. Known nesting beaches in the WCR have been spatially described (Dow et al., 2007) and, all things being equal, the greatest amount of survey effort is generally directed toward beaches with the most nesting, thereby generating the most data and reducing uncertainty during analytical processes. Rarely can all nesting beaches be monitored for all species on an annual basis, however, so strategic decisions must be made based on nesting density and phenology (timing), beach accessibility, beach condition, remoteness (deploying survey personnel to remote areas can be expensive, time-consuming, and logistically challenging), and security concerns. Data analysis must also be considered. Factors such as the required sample size and annual variance in data influence which analytical approaches can be used to evaluate the data.

## SELECT THE AREA(S) TO BE MONITORED

All nesting beaches cannot be monitored at all times. Ideally, a manager is able to identify one or more accessible, high-density nesting grounds for long-term assessment. Various methods have been reported for determining “high-density” nesting in WCR countries. The methods employed by Moncada et al. (1999) in Cuba are typical, where a preliminary survey of “turtle fishermen and coastal people” was used to identify known nesting areas and these results led to site visits (by land or boat) to, or aerial surveys of, promising areas; finally, “identification of significant nesting in the Doce Leguas Cays” resulted in a program of annual index surveys there. In Barbados, Beggs et al. (2007) relied, in part, on public reports of nesting to a national *Sea Turtle Hotline* to evaluate nesting density at a national scale. In Guadeloupe, potential nesting beaches were first cataloged using aerial photography, then further detail was obtained through interviews and site visits; each beach was given a unique integer identification based on a central GPS position because several beaches have the same local name (Delcroix et al., in review).

***Bigger is Better –*** Remembering the dual objectives of informing national management policy and contributing to broader assessments at population (including males and non-reproductive life stages) and stock (e.g., North Atlantic loggerheads) levels, monitoring efforts should be sufficient to detect trends in nesting population size over time and, ideally, to relate those trends to the status of the stock as a whole. Because the annual reproductive effort of a particular stock takes place at a large but incompletely known number of nesting beaches, the survey area should encompass as much nesting activity as practicable, given place-based constraints. As large as this area might be, however, it is unlikely to encompass the totality of the reproductive effort. A common approach to this dilemma is to identify the highest density, logistically feasible nesting beach(es) for long-term monitoring as index sites, while also adopting a protocol for less frequent assessment of remote and/or lower density sites known to be frequented by members of the same population or stock (Figure 4) (see *Cautionary Note* on the next page).

What constitutes a "stock" is not always well defined for sea turtles, and the geographic range over which a stock is distributed is both species-specific (e.g., different for leatherbacks than for hawksbills) and almost certainly spans national borders. In contrast, the legislative framework is national, typically articulated in fisheries or wildlife legislation. Therefore, for legal and practical reasons, the index beach and lower density nesting beaches that you select to monitor are most likely to be under national jurisdiction, even if major nesting beaches for a particular stock are known to be in another country. For this reason, harmonized approaches to population monitoring, tagging and reporting, and data collection, archival, and sharing are important. Whenever possible, major nesting grounds that span national borders should be monitored collaboratively by groups in both countries. For Western Atlantic sea turtle stocks, such collaboration is often facilitated by the Wider Caribbean Sea Turtle Conservation Network (e.g., Eckert and Hemphill, 2005; Bräutigam and Eckert, 2006; Chacón and Eckert, 2007; Dow Piniak and Eckert, 2011; Horrocks et al., 2011).

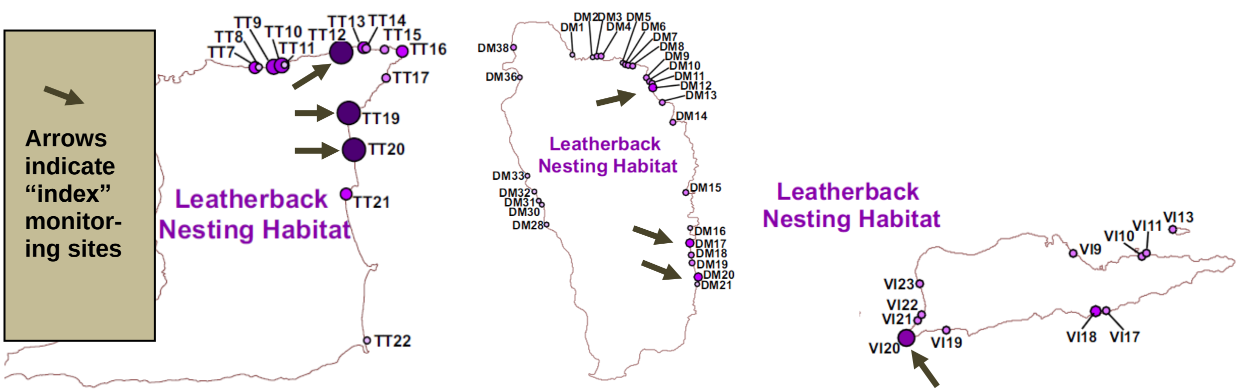



**FIGURE 4.** Comprehensive nesting maps (not to scale) for leatherback sea turtles, *Dermochelys coriacea*, in Trinidad, Dominica, and St. Croix (U.S. Virgin Islands), respectively. The size of the purple circles corresponds to nesting activity (<25, 25-100, 100-500, 500-1000, >1000 crawls per year). In each case, long-term tagging of nesting females demonstrates mixing among rookeries, suggesting that monitoring at large colonies (see arrows) can also provide insight into trends at smaller colonies, assuming similar threat regimes at each site. Map source: Dow et al. (2007).

***Simple is Better –*** Once the general area where the surveys are to be conducted is established (e.g., hawksbills are concentrated on offshore cays; ridleys only nest north of the river; leatherback colonies are largest on the windward coast), practical considerations often determine precise survey locations.

The primary consideration should always be the feasibility of continuing the survey effort at a level necessary to statistically appraise abundance and trend. The value of a population assessment program lies in its continuity over decadal scales and, if using an index beach approach, your knowledge of the proportion of the nesting population sampled at each site. It follows that these long-term efforts face special challenges in terms of staffing, financing, permits, and logistics, and consideration should be given to identifying sustainable funding options, in-kind donations (such as transportation provided by a fisheries or park office), and/or volunteer commitments that can support the survey effort for many years.

Decisions must be made on how best to patrol the beaches (e.g., foot patrol, horseback, all-terrain vehicle), based on factors such as beach topography and length, available staff and vehicles (including capacity for vehicle maintenance and repair and the availability of fuel), and possible effects on other species (e.g., nesting seabirds). Permits to conduct the monitoring must be solicited and approved, and appropriate and legal access to the beach for the duration of the monitoring period must be assured. Other considerations (e.g., security, effects of severe weather on beach access, contingency plans related to illness or injury in a remote location) may also play a role in the final choice of monitored location(s).

***Cautionary Note –*** The necessity of evaluating the relative importance of the index site(s) compared to the overall nesting range cannot be over-emphasized. There has been a tendency to conduct long term surveys of a limited section of nesting beach or a limited number of beaches, with the implicit assumption that consistency alone can provide adequate comparative data for trend analyses. However, because habitat use can shift in unpredictable ways both within and among years (e.g., Girondot et al., 2007), limiting coverage based solely on geography is *not* a valid subsampling method unless it is coupled with measures able to validate the proportion of the population using the index site(s) (see *Survey Data Analysis, Validate Your "Index" Selection*). Moreover, if no beach in the territory clearly dominates in terms of its share of nesting, one or a small number of monitored index beaches may produce datasets with low numbers of nests and little ability to detect a trend (Galimberti, 2002). In that case there may be other reasons to maintain regular patrols at low-density sites (e.g., poaching deterrence), but managers should understand that a useful analysis of population abundance and/or trend is unlikely.

### CONSIDER SURVEY TIMING AND DURATION OPTIONS

Optimal survey timing is based on accurate *a priori* knowledge of nesting phenology (Figure 5), typically defined by twice-monthly surveys (e.g., see "Protocol A" in SWOT Scientific Advisory Board, 2011) throughout the year during a pre-implementation phase. Most monitoring protocols rely on accurate knowledge of the beginning, peak, and end of the nesting season (see *Survey Implementation, Deciding How Often to Count*), so vigilance concerning these parameters is important.

It is normal for the precise timing of nesting to shift from year to year, but sea surface warming related to climate change is implicated in findings that the median day of nesting by loggerhead turtles in Florida (1989-2003) has become earlier by about 10 days (Weishampel et al., 2004). Similarly, Weishampel et al. (2010) concluded that if Caribbean and/or subtropical Atlantic warming over the nesting season occurs as predicted by climate models (Angeles et al., 2007), sea turtles "should respond with earlier nesting and a change in the duration of their nesting seasons." With this in mind, managers should remain flexible and willing to adapt the monitoring program, as needed, to accommodate new information, changing conditions, etc.

The frequency of conducting counts usually follows from the type of survey chosen. In most cases this will be daily, but in some situations where nests remain visible for extended periods of time (as is generally the case for leatherbacks and green turtles, the largest of the sea turtles), a less frequent schedule may be adopted. Regardless, an effort must be made to determine what proportion of nests might be missed due to sampling schedule and/or observer error. For surveys relying on morning counts, occasional all-night patrols of the survey area – which allow for turtles to be counted directly and the ratio of successful to unsuccessful nestings (often referred to as the "nest to false crawl ratio", see *Survey Data Analysis, Calculate Conversion Factors*) to be verified – are necessary to quantify the accuracy of morning survey protocols.

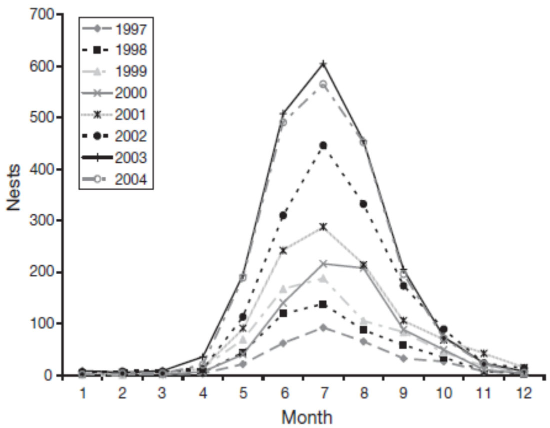



**FIGURE 5.** Accurate information on the seasonality of nesting, illustrated here for hawksbills in Barbados (Beggs et al., 2007), helps to determine the timing and duration of the monitoring effort. All-night patrols designed to encounter nesting females (hawksbill photo: Scott Eckert) provide the most accurate data on the number of turtles and nests laid, but less intensive sampling approaches can provide useful estimates of population trend (if not abundance).

***Sampling Approaches* –** On remote or very long beaches, or when a large number of sites must be monitored, it may be impractical to collect data on a daily basis throughout the nesting season. Girondot (2010a) reviewed existing approaches to estimating population trends from a variety of sampling approaches, including partial counts generated by short periods of intensive monitoring (10-14 consecutive days: Kerr et al., 1999; Jackson et al., 2008; Sims et al., 2008), and concluded that each approach, including his own most recent application (Girondot et al., 2006), suffered from important weaknesses, often associated with unreliable error estimates.

Girondot (2010a) presented a new statistical framework that accounts for variability in survey timing and duration, integrates and improves existing methods, and allows managers to estimate an index of population size (and associated statistical uncertainty) in a way that is "both easy to use and very efficient in answering biological and conservation questions," including determining population size at a particular location (e.g., nesting beach) for migratory species. He concluded that "the strength of this method is to simultaneously use all the information gathered during the monitoring of several beaches, both within a season and between seasons," including counts derived from ground or aerial survey methods (see *Survey Data Analysis, Estimate Abundance*). More recent modeling advances have also been able to address the widespread problem that data collectors do not always distinguish between a record of zero nests (or zero crawls, a "crawl" is the track in the sand left behind by a nesting turtle) and a night (or day) in which no monitoring was conducted (Girondot, 2010b).

In summary, if complete all-night patrol coverage of all nesting habitat during the entirety of the annual nesting season remains an elusive ideal, user-friendly analytical tools are increasingly available to enable the collection of management-relevant data at remote or understaffed sites where 100% beach coverage is impossible.

## DECIDE WHAT TO COUNT

***Species Identification –*** Of obvious importance is the ability to distinguish between species (Annex I) so that data can be tallied, categorized, and analyzed on a species-specific basis. Where individual turtles are observed directly, this is not difficult. When activities or nests are counted, observers must be trained to recognize field signs such as the width and symmetry of the nesting crawl, extent of beach disturbance, and so on. Familiarity with local nesting seasons is also helpful, as some species exhibit non-overlapping nesting seasons and can be excluded based on time of year.

For details on species identification, including nest and crawl (track) characteristics by species, see Pritchard and Mortimer (1999), Schroeder and Murphy (1999), Wood (2004), and Chacón et al. (2008).

***Index Measurements –*** A count of the number of nesting females is the prime objective of the monitoring program, but because it is not always possible to count adult turtles directly, three types of index measurements (counts) are suitable for monitoring nesting populations (Table 1). In order of increasing accuracy, these are activity counts (all nesting attempts, whether or not they result in egg-laying; the data can be further refined by reporting only those activities with a body-pit), verified nest counts (with or without recording unsuccessful nesting attempts as a separate category), and direct counts of individual turtles.

Whatever count is used, precautions need to be taken to avoid errors from double-counting, which results in an over-estimate of population size. For nest and activity counts, marking the nest or crawl will minimize or eliminate this error. Crawls can be marked as counted by drawing a line through the crawl in the sand, and nests can be flagged, triangulated, or identified in some other way (Figure 6). Similarly, if you select turtle counts as your index measure, tag loss (typically of greater concern between, rather than within, survey years) can result in double-counting of turtles and presents a serious analytical problem that must be evaluated at each survey location (Balazs, 1982; Frazer, 1983; Limpus, 1992; Bjorndal et al., 1996; Rivalan et al., 2005; NRC, 2010).


FIGURE 6. A leatherback activity is marked as "counted" by deeply incising (such as by dragging a foot) *both* the approach crawl and the return crawl. Individual nests are marked and labeled at Eagle Beach, Aruba, to prevent disturbance by foot and vehicle traffic. Other methods used to mark the location of a nest include placing a stake in the sand, taking a GPS reading, or recording a precise measurement from two permanent landmarks (without marking the nest directly). Photos: (left) WIDECAST; (right) Turtugaruba Foundation.

**TABLE 1.** Index measures suitable for estimating annual abundance at sea turtle nesting beaches. These measures may be impractical at high-density sites where field signs are obliterated by later nesting females. For *arribada* sites, we recommend the "strip transect in time" method described by Valverde and Gates (1999).

| INDEX MEASURE | ADVANTAGES | DISADVANTAGES |
|---|---|---|
| **Activity counts***<br><br>* An "activity" is defined as any emergence by a sea turtle onto the nesting beach, *whether or not* nesting was successful and eggs were laid. Sometimes authors will use the term "false crawl" (cf. Tucker, 1988) or "dry run" (cf. Talbert et al., 1980) to describe an unsuccessful nesting activity. | Easiest to perform, least effort (and expertise) required<br><br>Not more than once-daily beach coverage is required | Can be negatively influenced by factors that are not associated with population size, including:<br><br>a. the number of attempts required for a successful nest (i.e., the nest to false crawl ratio) can be highly variable between species, as well as within and among nesting beaches and within and among years<br>b. clutch frequency (average number of nests per female per year) varies with species, and can vary among nesting beaches and among years<br>c. evidence of the activity can disappear prior to counting due to wind, heavy rain, wave overwash, vehicle or foot traffic, etc.<br>d. some species leave obscure crawl signs (e.g., hawksbills can traverse a pebble beach, leaving little evidence of a track, to deposit eggs deep within beach vegetation), which can result in an underestimate of nesting activity |
| **Nest counts** | Documents successful egg-laying only<br><br>More accurate than an activity count in describing patterns in reproductive output<br><br>Not more than once-daily beach coverage is required, assuming you can accurately determine a successful nesting (resulting in eggs) after the female has departed | Documenting clutch frequency (i.e., the average number of nests per female per year) can be influenced by factors that are not associated with population size, including:<br><br>a. observer error (varying levels of expertise in distinguishing nests-with-eggs from unsuccessful nesting attempts)<br>b. clutch frequency can vary among nesting beaches, as well as among years<br>c. evidence of the nest can disappear prior to counting due to wind, heavy rain, wave overwash, vehicle or foot traffic, etc.<br>d. some species leave obscure crawl signs (e.g., hawksbills can traverse a pebble beach, leaving little evidence of a track, to deposit eggs deep in the shelter of beach vegetation), leading to an underestimate of nesting activity |
| **Turtle counts** | Most accurate measure for assessing population size and trend, and for describing demographic variables<br><br>Data collected most directly relate to management goals and objectives | A count of the number of nesting females is the prime objective of the monitoring program; however:<br><br>a. maintaining complete nightly beach coverage over long-term, decadal scales can be expensive and labor intensive<br>b. protocols suitable for Capture-Mark-Recapture (CMR) analysis (e.g., flipper or PIT tag, other suitable mark) must be adopted to prevent counting the same turtle more than once<br>c. if the probability of encountering a nesting female is below 20%, the error is large |

***Activity Counts –*** Activity counts require the least amount of observer expertise and, because activity counts are higher than counts of nests or individual turtles, activity count datasets tend to produce lower random error in trend assessment models. However, to achieve a nesting population abundance estimate you must be able to deduce the number of successful nests from the total number of activities. Sea turtles often come ashore more than once prior to successful egg-laying and this ratio – referred to as the "nest to false crawl ratio" – can vary significantly within and among years based on natural beach conditions (erosion/accretion, wood debris, flooding), levels of disturbance (dogs, lights, onlookers), and other factors.

Tucker (1988) showed how the mean ratio of nests to false crawls varied for leatherback turtles at a northern Caribbean nesting beach as the laying season progressed (10:1 in March, 19.5:1 in April, 5.3:1 in May, 4.1:1 in June, and 6.2:1 in July) and implicated a variety of causal factors, including erosion berms and rocks, nest collapse (dry sand), water in the nest cavity, and "flashlight spooked." Because of this variation, the ratio should, ideally, be estimated for the monitored population (rather than using estimates from another population) and on an annual basis. For detail on how to determine the nest to false crawl ratio, see *Survey Data Analysis, Calculate Conversion Factors.*

High-density sites where crawls are obscured by the crawls of later-arriving turtles present a special scenario. In such cases, nightly activity counts are almost a necessity because morning crawl counts are so problematic. Some managers have solved this challenge by assigning a patrol team to each 1 km of the index site. Each is assigned one-half of the night (1800hr – midnight; midnight – 0600hr) and asked to patrol the kilometer once per hour, marking each turtle with water soluble "body paint" (the type used by make-up artists), and reporting the number of marked (=painted) turtles.[5]

***Case Study: Activity Counts*** – Delcroix et al. (in review) describe a situation common in the WCR, where, in the case of the Guadeloupe Archipelago, sea turtles nest on more than 150 beaches, making it impossible to monitor the entire annual reproductive effort. With existing information on the phenology of nesting by three sea turtle species, potential nesting beaches were documented through aerial surveys, interviews, and site visits. With the stated intention of estimating trends in hawksbill turtle nesting, a monitoring protocol was developed that emphasized coverage of about one-third of known nesting beaches (see *Survey Implementation, Decide How Often to Count: Protocol D*).

The Archipelago was first separated into 10 sectors based on 133 groups of beaches with geographic proximity, then each beach for each sector was characterized by the species known to nest there (each beach was used by 0 to 3 species, but at least one species nested in each of the 10 sectors). Higher density "A" beaches were monitored during the entire nesting season, while lower density "B" beaches were monitored only during peak nesting. Based on previous analyses of statistical power for this method (Russo and Girondot, 2008, 2009), 6-7 counts per month were made at "A" beaches before and after the peak period, while 14-22 counts were made during the peak period at "B" beaches. A total of 45 beaches were monitored in 2007 and 59 in 2008, which the authors described as "38% of the total number of beaches in the Guadeloupe Archipelago" and representing all sectors, all species, and all Caribbean and Atlantic insular and mainland shores. Monitoring for 2007 began on March 28 and ended on December 23; monitoring for 2008 began on March 3 and ended on November 11.

[5] This results in an *activity tally* because no effort is made to document egg-laying or to distinguish individual turtles.

In each case, the following information was recorded on the data form: date, beach name, species (based on crawl symmetry and width), age of the crawl (i.e., whether the female had come ashore that night or prior to that night), and if the female had successfully nested or not. Confirmation of egg-laying proved "very difficult to interpret in the field" and the analysis, therefore, focused only on activity counts. From these data, the authors were able to estimate the number of nests for 45 beaches in 2007 as 3,823 (95% CI: 1,925-6,415) and for 59 beaches in 2008 as 2,300 (95% CI: 1,435-4,742), values that can now be used over time to assess trends over this large, diffuse nesting landscape.

***Nest Counts* –** Nest counts require demonstrated expertise in distinguishing a landing that results in egg-laying from one that may have advanced to the body-pitting or even nest excavation stage, but that did not result in egg-laying. Careful training of survey personnel and diligence in evaluating whether a nesting attempt resulted in egg deposition is essential, and survey personnel should be regularly (at least annually) field-tested for this ability.

There are several ways to confirm the deposition of eggs at a particular location: the observer witnesses the egg-laying, the observer confirms presence of eggs soon after deposition (e.g., skilled personnel carefully locate the nest cavity and remove only a sufficient amount of sand to observe the presence of eggs), the observer confirms eggs post-hatching (e.g., eggs are encountered by excavation [Figure 7], eggs or eggshells are revealed by poaching or predators, eggs are exposed by erosion), or the observer documents hatchlings. It is essential to know clutch frequency for the target population, or to be able to estimate this parameter by on-site means or by using accurate data collected on the same species from a long-term monitoring program in the same geographic region. It is also essential to quantify the annual variation around that average.

**FIGURE 7.** Verifying the successful deposition of eggs (shown here as nest excavation post-hatching) is required if nest counts are used as the index measurement, but beach monitoring need not be conducted on a nightly basis if patrollers become proficient at "reading" field signs associated with successful nesting. In contrast, nightly beach monitoring is unavoidable if direct counts of gravid females are selected as the index measurement. Photos: (left) Hawksbill nest excavation in Belize: Wildlife Trust; (right) Green turtle nesting in Costa Rica: Didiher Chacón.

Finally, factors (see Table 1) that can reduce detection of a nesting event must be quantified as a statistical measure of error (e.g., you should be able to say that the number of nests you think were laid will not differ from the true population value by more than, say, 5% [the margin of error] 90% of the time [the confidence interval]). Error is most pronounced when nightly patrols do not continue until dawn, in which case an early morning patrol is necessary to complete the nesting tally from the previous night; when ambient conditions are such that turtles are missed even during all-night patrols (e.g., pebble shorelines or beaches strewn with seaweed can obscure crawl signs, beaches with narrow sandy platforms can shelter egg-laying females in dense vegetation with little evidence of a crawl, beaches routinely wave-washed can erase crawl signs between regular patrols), in which case daylight patrollers should search carefully for crawl or nest signs and mark potential nest sites to monitor them for hatchling emergence; and in cases where nesting is known to extend beyond the patrol area, in which case regular (but not necessarily daily) surveys of marginal habitats are needed to confirm the percentage of nests missed, and so on.

***Case Study: Nest Counts*** – Tortuguero, a globally important nesting beach for green turtles on the Caribbean coast of Costa Rica (Figure 8), is a classic example of a nesting beach that is too long (35.6 km) to be patrolled on a nightly basis in its entirety for the purpose of tagging every nesting female. The history and logic of subsampling this location to estimate population trends over time is described by Troëng and Rankin (2005), who report that nest transect surveys to record nests laid the previous night had been conducted at ca. weekly intervals along 18 km of the beach since 1971 and, since 1986, nest transect surveys had been conducted along the entire 35.6 km (Tortuguero rivermouth [N10°35.51, W083°31.40] to Parismina [N10°19.04, W083°21.39]). After Jalova lagoon (N10°21.46, W083°23.41) opened up to the sea and the southern 6 km became separated from the main nesting beach in 1994, nest transect surveys were analyzed between 1994-1996 and 1998 that allowed the authors to conclude that <1% of nests had been deposited south of the lagoon since it opened up to the sea. Therefore, 29.6 km surveys (35.6 minus 6 km) were used as “entire beach surveys” since 1994. The authors further noted that “during some surveys in 1995 (*n*=3), 1996 (*n*=8), 1997 (*n*=16) and 1998 (*n*=1), the northern 5.4 km of beach were not surveyed”, so that nest counts had to be corrected by adding the proportion of nests deposited along the northern 5.4 km, during the same month, as determined from 1995-2001 surveys.

By carefully explaining their methodology, making an attempt to field-test their assumptions about when and where nesting was occurring, and using appropriate analytical methods, Troëng and Rankin (2005) were able to show that while green turtle nest numbers show large interannual variation, “nesting along the entire beach has increased with an estimated 61% since 1986” (Troëng and Rankin, 2005). Calculating “a mean of 104,411 green turtle nests per year deposited along the entire Tortuguero beach (range 37,395-149,569 nests)” between 1999 and 2003, the authors then used a range of values published for clutch frequency at Tortuguero (i.e., 2.8-6.0 nests [clutches of eggs] per female per year with the wide range attributed to some authors taking no account of tag loss) to estimate a lower (17,402) and upper (37,290) mean number of nesting females per year (Figure 8 a,b).

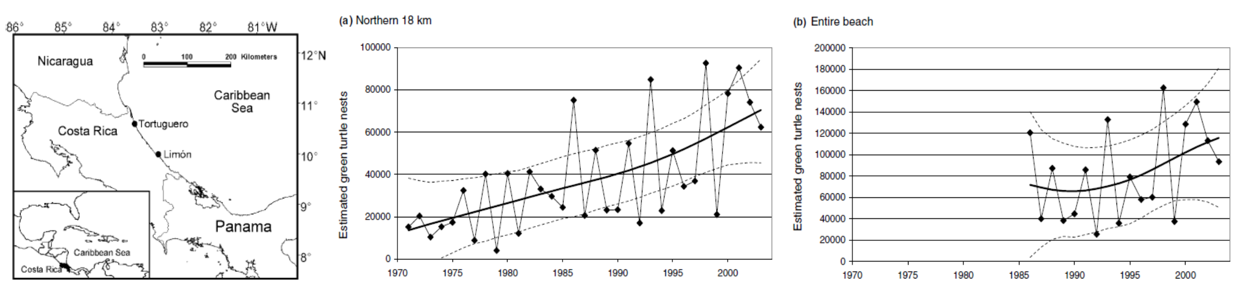



**FIGURE 8.** Location of Tortuguero Beach, Costa Rica, with trends in the number of nests [clutches] deposited by green turtles over time on (a) the northern 18 km and (b) the entire 35.6 km beach. Source: Troëng and Rankin (2005).

***Turtle Counts –*** Complete turtle counts are the most accurate measure of nesting population size, but this option requires the most intensive surveying effort – typically all-night beach patrols designed to encounter every nesting female. For nesting populations with small to moderate numbers of turtles, this is a feasible approach (e.g., Boulon et al., 1996; Starbird et al., 1999; Richardson et al., 2006; Harris et al., 2010). For larger populations, a useful alternative is to focus the tagging effort on an index beach, with less intensive monitoring of lower density sites (see *Case Study: Turtle Counts*, below). In either case, each turtle encountered is uniquely marked for positive identification over time, usually by flipper-tagging and/or by inserting a Passive Integrated Transponder (PIT) tag into the animal (see Annex II).

***Case Study: Turtle Counts*** – Barbados, the easternmost island in the West Indian archipelago, hosts one of the largest hawksbill sea turtle rookeries in the WCR and, given its geographic position and prevailing currents, "is likely to be a significant contributor to foraging grounds throughout the region" (Beggs et al., 2007). Having determined that monitoring nesting on every beach in the nation was impossible, the objective was to assess activity at high-density nesting grounds as an index of national trends. To identify where nest density was greatest, the Barbados Sea Turtle Project (BSTP), based at the University of the West Indies, established a *Sea Turtle Hotline* in 1987 and encouraged citizens to report nesting activity by calling a cell phone number. The advantage of the *Hotline* was that activity was reported island-wide and year-round, but the disadvantage was the input was biased against more isolated beaches. Notwithstanding, it was clear that "the most significant" hawksbill nesting was occurring at Needham's Point (1.5 km, 13°04' 41.33" N, 59°36' 32.69" W) and that additional high-density nesting was concentrated along the western and southwestern coasts (Figure 9).

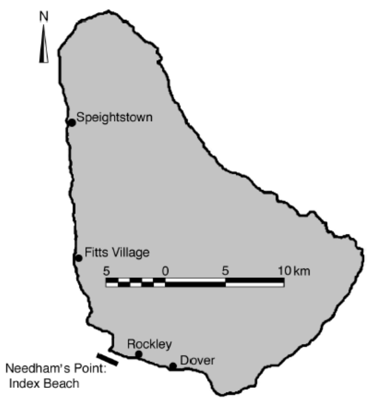
In 1992, year-round, early morning surveys (06:00 to 08:00 hr) of Needham's Point began. In 1997, patrollers initiated an all-night (20:00 to 04:00 hr) hourly patrol of this site during peak nesting (1 June-30 September) and 16 additional high-density beaches were also surveyed either once or twice during the night between 20:00 and 04:00 hr or in the early morning over the same time period (1 June-30 September) every year. Recognizing the constraints[6], the objective was to identify and count "all females [using] the index beach over the monitoring period, and to record all nests made by each female", while the main objective of less consistent monitoring at additional high-density sites was to "reduce the incidence of poaching and to mitigate against threats to nesting females and eggs as a result of extensive coastal development (e.g., artificial lights causing disorientation, coastal armouring resulting in falls and entrapment, narrow beaches adjacent to roads resulting in collisions with vehicles, erosion causing egg exposure *inter alia*)." However, "since day patrols (05:00-17:00 hr) covered beaches that were not patrolled the night before, all high-density nesting beaches were visited at least once in every 24 hr period and nest counts were reliable." Finally, lower density beaches, primarily along the northwest, east, and southeast coasts were patrolled "opportunistically" in order to record nests and the *Hotline* continued to provide additional data on nesting activity.

As a result of this carefully crafted multi-pronged approach, the BSTP was able to flipper-tag 1,179 nesting turtles between 1997 and 2004, enabling an analysis of female morphometrics, internesting periods, observed and estimated clutch frequencies, nest:crawl ratios, and inter-

[6] According to Beggs et al. (2007), "While every effort to witness all nesting activities was made, turtles were occasionally missed. This was because the threat of poaching of nesting females still occurred on Barbados, and protection of nesting females occasionally required observers to remain with a turtle until she left the beach, which sometimes resulted in other turtles being missed. Similarly, when several turtles emerged simultaneously, one may have been missed while data were collected from the other turtles. Females also occasionally nested outside of patrol hours (before 20:00 hr or after 04:00 hr) and were therefore not individually identified, but the tracks could always be identified to species."

annual remigration intervals. Data were analyzed using Microsoft Excel and SPSS Graduate Pack 13.0. All data met normality requirements or were transformed prior to analysis as appropriate (Zar, 1999), the statistical significance level was set at p<0.05, and means were reported with standard deviations (±SD) (Beggs et al., 2007).

The index site monitoring protocol also enabled the authors to estimate nesting population size and trend: "The current estimated total population size of adult females using Barbados as a nesting ground was calculated using a mean annual cohort size calculated from the years 2003 and 2004. The mean number of females estimated to nest annually on the index beach was 94 and on all beaches island-wide (including the index beach) was 506. The accuracy of the estimated annual cohort sizes in 2003 and 2004 in Table [9] was supported by an annual nest count of over 2,000 nests in each of these two years. The cohort estimates were then multiplied by the mean remigration interval for the population [2.47 yr] to give an estimate of 232 females nesting on the index beach alone, and a total of 1,250 females nesting on Barbados as a whole."[7] Finally, the authors were able to conclude that, "Data from the index beach indicate that the number of nests may have increased as much as 8-fold" since 1992.




| Year | Nests documented on index beach | No. of nesting females | Nests documented islandwide | No. of nesting females |
|---|---|---|---|---|
| 1997 | 110 | 27 | 316 | 77 |
| 1998 | 127 | 31 | 501 | 122 |
| 1999 | 155 | 38 | 696 | 170 |
| 2000 | 155 | 38 | 761 | 186 |
| 2001 | 243 | 59 | 1089 | 266 |
| 2002 | 285 | 70 | 1530 | 373 |
| 2003 | 378 | 92 | 2127 | 519 |
| 2004 | 395 | 96 | 2016 | 492 |

**FIGURE 9.** Left: Map of Barbados showing the Needham's Point index beach and high-density nesting zones on the west (Speightstown to Fitts Village) and southwest (Rockley to Dover) coasts. Right: Estimated number of nesting hawksbills utilizing the Needham's Point index beach and the number of hawksbills nesting island-wide (including the index beach) between 1997, when all-night patrols began, and 2004, based on a calculated average clutch frequency of 4.1 clutches per female per year. Source: Beggs et al. (2007).

***Cautionary Note –*** Regardless of what is counted, remember that zero is an important number! If monitoring occurs but no activities (crawl signs), nests, or turtles are observed, a value of zero should always be recorded on the data form.

## DECIDE HOW OFTEN TO COUNT

Because managers do not have access to entire sea turtle populations, they must make important decisions on the basis of a relatively small amount of sample data. To ensure that these sample data are as useful as possible, informed decisions about where, when, what, and how often to count are essential. To this end, the State of the World's Sea Turtles "Minimum Data Standards for Sea Turtle Nesting Beach Monitoring" (SWOT Scientific Advisory Board, 2011) describes four basic monitoring protocols for non-*arribada* sites and identifies analysis tools as-

[7] Online tools are also available to assist managers in generating abundance estimates, see *Survey Data Analysis, Estimate Abundance*.

sociated with each (these tools are online at http://seaturtlestatus.org/data/standards; see *Survey Data Analysis, Estimate Abundance*). In each case, a "count" (once per week, three times per week, etc.) must be a complete count of activities, nests or females for that date, meaning that partial night patrols must be accompanied by comprehensive dawn patrols to record missed events.

Remember that these monitoring protocols describe the *minimum effort* required to generate count data that will produce annual estimates of total abundance (whether the index measure is activities, nests or turtles) with an acceptable level of confidence, and that "increasing your monitoring effort above the levels described will improve confidence in your abundance estimates and will improve your ability to detect trends in the nesting population" (SWOT Scientific Advisory Board, 2011).

The error surrounding your estimate of abundance measures the quality of the estimate. You want this error to be as small as possible. Error can vary a great deal, but the number of days the beach is monitored and the number of turtles nesting apparently explains about 98% of this variation. Delcroix et al. (in review) conclude that when the total number of nests on the beach is about 10, it requires at least 50 days of monitoring to achieve an estimate with a minimally acceptable margin of error (CV[8] <0.25). In contrast, when the total number of nests is higher than 100, 20 monitoring days can be sufficient to estimate abundance with a much higher degree of confidence (CV <0.05).

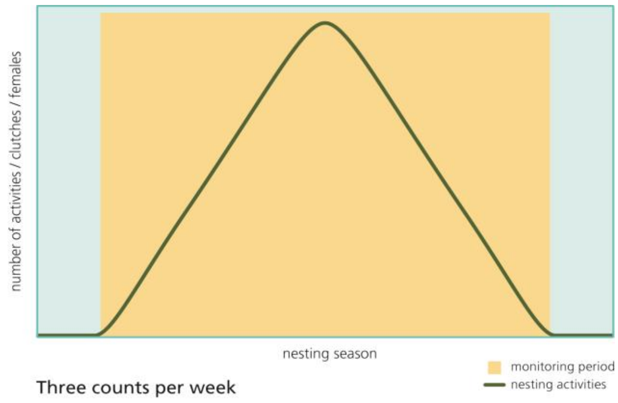
In deciding how often to count, evaluate and select the monitoring protocol (B, C, D, E - see below) that best fits your situation. If no information is available on when the nesting season begins, peaks and/or ends, start by conducting a full-year survey of potentially important habitats. Record evidence of nesting activity "at least once every 15 days or nights throughout the year" ("Protocol A" in SWOT Scientific Advisory Board, 2011) and confirm species present by direct observation or crawl signs. For details on species identification, including nest and crawl (track) characteristics, see Pritchard and Mortimer (1999), Schroeder and Murphy (1999), Wood (2004), Chacón et al. (2008), and Choi and Eckert (2009). See also Annex I and Annex II.

Once you know when the nesting season starts, peaks, and ends and you have selected your index beaches for long-term monitoring (see *Survey Implementation, Select the Area(s) to be Monitored*), the SWOT Scientific Advisory Board (2011) describes four monitoring protocols that can be applied to populations that exhibit a defined "peak season." The choice is typically one of cost, effort and logistics, being careful to select a methodology that you believe is most likely to be maintained over decadal scales. Note that only Protocol B is applied to populations that show no obvious peak in nesting activity during the year (i.e., the best available information suggests that nesting is equally distributed year-around).

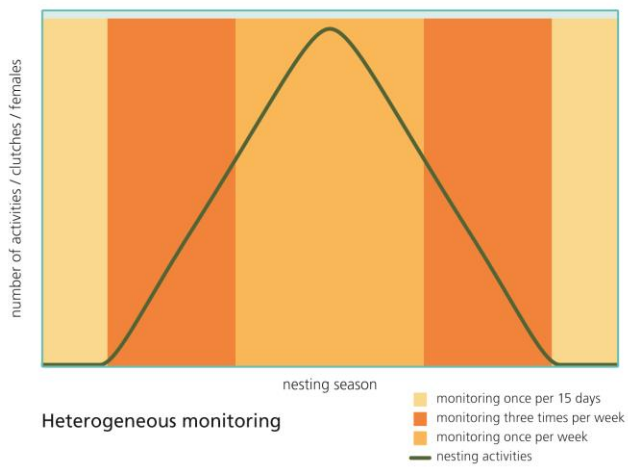
***Protocol B: The timing of the annual reproductive effort is known and can be described as either a typical bell-shaped curve or as year-around nesting with no discernible peak –*** In this case, adapted from Russo and Girondot (2009), the simplest methodology is to monitor the nesting population (either in its entirety or at one or more index sites) by counting activities, nests or females a minimum of three times per week throughout the full nesting season (diagram on next page). Importantly, increasing the number of surveys each week reduces error (improves accuracy and, therefore, confidence) in the analytical results.[9]

[8] CV = Coefficient of Variation, reported as the ratio of the standard deviation to the mean.

[9] Diagrams on pages 24-26 are excerpted from "Minimum Data Standards for Sea Turtle Nesting Beach Monitoring, ver. 1.0" (SWOT Scientific Advisory Board, 2011) and are used with permission.



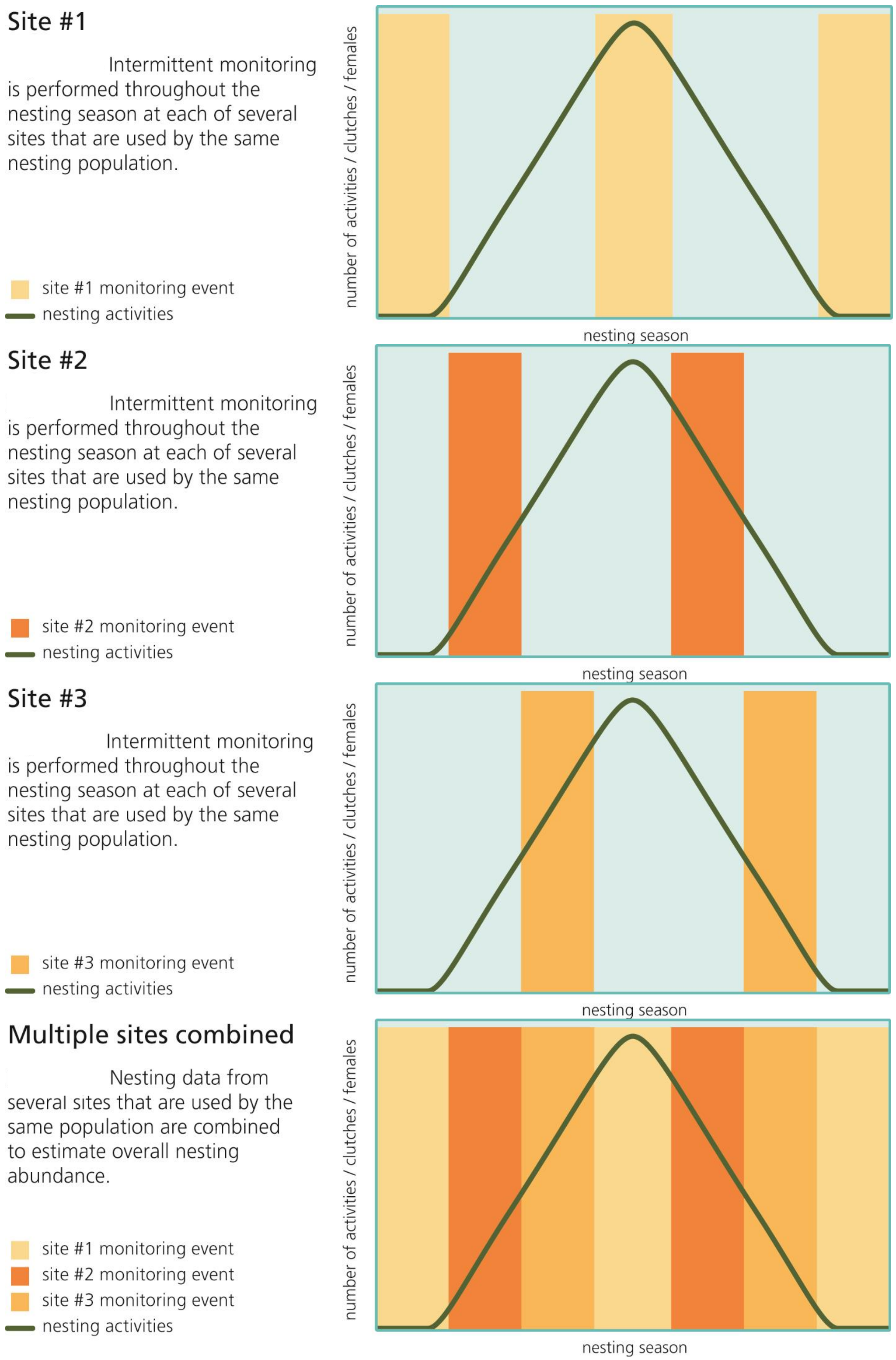

***Protocol C: The nesting season is known to exhibit a discernible and predictable peak –*** In this case (below), adapted from Russo and Girondot (2009), the heterogeneous monitoring scheme is more complex than Protocol B, but the advantage is that it may reduce the number of surveys days required to generate nesting abundance estimates with acceptable error. In this protocol, monitoring is conducted one out of every 15 days *outside* of the known nesting season; three times per week during the first month of the nesting season; once per week during the middle of the nesting season (i.e., when peak nesting occurs); three times per week during the last month of the nesting season; and, finally, one count per 15 days thereafter.



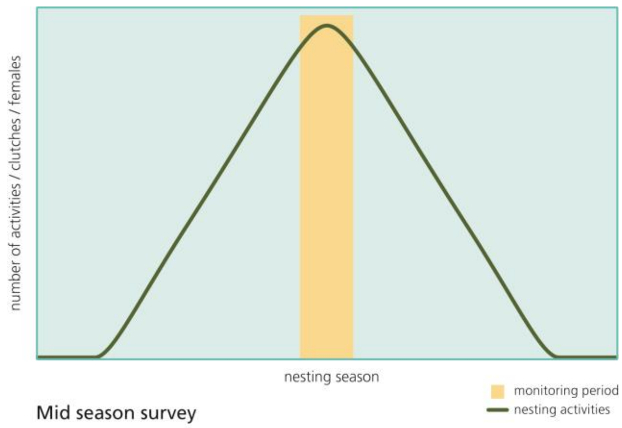

***Protocol D: Numerous, separated nesting beaches are used by the same nesting population and it is not possible to monitor all sites at all times –*** In this case, 100% monitoring of an index beach or the use of a standardized subsampling regime is advised.

The index beach approach, by definition, assumes that annual abundance patterns observed by comprehensive monitoring at the index site closely reflect a broader pattern that occurs at all other beaches used by the same nesting population (see *Survey Data Analysis, Validate Your "Index" Selection*; see also Limpus, 2008). In contrast, more diffuse coverage across multiple sites, followed by aggregate analysis of abundance and trends, can be more useful in situations where natural processes of erosion and accretion eliminate nesting grounds on the scale of years (i.e., shorter than the decadal timeframe needed to establish nesting population trends); where nesting turtles show lower fidelity to particular nesting sites; or where several dispersed sites host nesting, but none at sufficiently high levels to warrant designation as an index beach.

Under these scenarios, “a more favorable protocol would consist of monitoring many sites at low levels of survey effort and then analyzing abundance estimates across sites” (SWOT Scientific Advisory Board, 2011), as illustrated below:



***Protocol E: Where access and/or other logistical challenges make prolonged monitoring events impractical or impossible, intensive monitoring is conducted during the period of highest nesting density –*** To implement this protocol, a mid-season survey resulting in a complete count of nesting females during a (minimum) two-week period (longer, if possible) can be used to calculate a mean value (± standard deviation) for the number of females per night to provide an index for each nesting season. This protocol, while potentially the easiest to implement, is also the least robust, especially if the survey is restricted to the minimum two-week period. Longer survey periods (e.g., see Limpus et al., 2003; Jackson et al., 2008; Sims et al., 2008) can strengthen the analytical result, but without previously established information on nesting phenology at the index site, error will be high using this method (Gratiot et al., 2006).




# VI. SURVEY DATA ANALYSIS

## CALCULATE CONVERSION FACTORS

The conversion of raw data to an estimate of sea turtle abundance often requires conversions that depend on the type of data collected (Table 1). Among the most common conversions are those associated with estimating nest counts from total activity counts and/or estimating the number of individual females from nest counts.

To convert total activity counts to nest counts, a reliable estimate of the ratio of successful to unsuccessful nestings must be available. To convert nest counts to individual turtle counts, the average number of nests per turtle per year, termed "clutch frequency," must be known or accurately estimated. For example, applying a known average nest to false crawl ratio of 4:1 to 200 documented nesting activities estimates 160 nests and 40 false crawls. Further applying a clutch frequency of four nests per turtle per year suggests that only 40 individual turtles were responsible for the 200 activities (Alvarado and Murphy, 1999).

Optimally, the nest to false crawl ratio and the clutch frequency are calculated annually for each nesting population; however, it is not uncommon to calculate these parameters over a period of years and then, especially if the ratio shows little variability among years, to apply an average value to subsequent years. In the absence of site-specific values, average ratios and clutch frequencies calculated from intensive surveys at nearby nesting colonies (for the same species and in similar habitats; e.g., developed mainland coast, undeveloped offshore cay, etc.) are acceptable. When reporting results, always be explicit about how and where the conversion factors were obtained.

***Convert Activity Counts to Nest Counts –*** The most basic sea turtle nesting survey consists of regular morning beach patrols to document the number of nesting crawls (tracks) visible in the sand. However, not all nesting attempts result in the deposition of eggs. When the turtle returns to the sea without laying eggs, the event is often referred to as a "false crawl." Direct calibration of the nest to false crawl ratio can be accomplished in several ways:

*Examination* – Interpret field signs surrounding the nesting crawl to determine the likelihood and probable location of an egg chamber.[10] This method requires experience and does not work equally well for all species. See Schroeder and Murphy (1999) and FFWCC (2007).

*Confirmation* – Carefully remove an amount of sand sufficient to reveal the crown of the uppermost egg in the chamber, then immediately replace the sand in reverse sequence to ensure that the sand closest to the eggs remains the same. Beggs et al. (2007) describe the process as follows: "Any indication of turtle activity (i.e., tracks, sand disturbed in a way that was characteristic of nesting) was documented and the presence of eggs confirmed through careful digging by hand." The disadvantage of this technique is that it can require a significant amount of effort, especially with large numbers of nesting crawls and especially with leatherback and green turtles, which dig the deepest chambers. Locating hawksbill nests, often laid deep in the shelter of beach vegetation, presents its own set of challenges. Finally, if eggs are not located there is no assurance that eggs were not laid – only that you could not locate them. This technique requires skilled personnel able to "read" the covering and camouflaging signs left by the female as she completes the nesting process and exits the body pit, and extreme care must be taken not to break any egg(s) while looking for the nest.

*Marking* – Flag, triangulate, document using GPS readings, or otherwise mark potential nest sites for observation. After an expected period of incubation[11], monitor each site for hatchlings or signs of emergence. If no hatchlings emerge (or you never see them because, for example, foot traffic or rain obliterated the little crawls), you are still left with the task of excavation, but at a reduced scale since some potential nest sites will have been confirmed by a successful hatch. The disadvantages of this technique include excavation effort (see Figure 7), lengthy field seasons (i.e., watching for hatchlings two months or more after the last nesting), inadvertent exposure of a still-incubating clutch (which can harm developing embryos) if you dig into a nest prematurely, and the fact that a most likely unknowable percentage of potential nests will be lost to routine cycles of coastal erosion, poaching, and so on prior to clutch confirmation.

*Subsampling* – Conduct all-night patrols of an index beach on a sampling schedule that should be determined in consultation with a statistician. All-night patrols must be conducted frequently enough so that turtles completing a nest in the fastest known "turn-around-time" are intercepted (generally this means leaving no area unpatrolled for more than 45-60 minutes), and the number of successful vs. unsuccessful nesting crawls directly recorded. The number of patrol nights necessary to provide a statistically viable result will depend on the density of nesting and the probability of encountering a turtle, among other factors.

*Inference* – Take advantage of existing information on species-specific nest to false crawl ratios from previous research conducted at the index site, or at a nearby beach (including a beach with similar characteristics in a neighboring range State). Because of natural variability

[10] If the turtle clearly crawled onto the beach and then returned to the sea without making any attempt to create a body-pit or to excavate a chamber, the activity can be recorded as a "false crawl" without further investigation.

[11] This might typically range from 50 to 70 days depending on species, sand temperature (related to nest depth, vegetation/shade), sand compaction, rain, etc. and the mean incubation period may vary between years.

in the ratio within and between sites and years, the disadvantage here is that there is no way to know how close the borrowed estimate is to the true value. Notwithstanding, it can be a place to start, with the recognition that determining an accurate *in situ* value will be a priority.

***Convert Nest Counts to Turtle Counts –*** When calculating clutch frequency, remember that the average number of observed nestings is rarely equivalent to the true measure of biological clutch frequency. Even when index sites are intensely monitored on a nightly basis, some percentage of nesting is likely to take place before the first day or after the last day of monitoring, outside the boundaries of the index beach(es), during daylight hours, and so on (although in the latter case the nests is likely to be discovered during the next patrol cycle).

Reported values of clutch frequency will vary according to the thoroughness of detection capabilities of a given monitoring program. Observed Clutch Frequency (OCF), defined as the number of observed, confirmed nesting events for an individual turtle, will be an underestimate of the true value if the probability of a nesting turtle escaping detection is high. To address this bias, techniques are available to determine Estimated Clutch Frequency (ECF).

For example, knowing the mean internesting period for loggerhead turtles on Little Cumberland Island, Georgia, to be 13 days (and the minimum observed interval to be eight days), Frazer and Richardson (1985) added an extra nest to the OCF of any turtle missing from the beach for more than 21 days (i.e., 13 + 8 = 21). Knowing, as well, that a turtle seen crawling but not nesting on a given evening would likely return to nest during the next few evenings, one clutch was also added to the OCF of any turtle seen crawling on the beach but not observed to nest that night or during the following eight nights. Bias is still possible, however, because ECF is unable to account for nests that occurred before the first day or after the last day of monitoring (Briane et al., 2007; but see the subsampling method of Reina et al., 2002).

Field directors at Babunsanti, a remote and highly dynamic 6-km nesting beach in the Marowijne Estuary, Suriname, used a slightly different approach. Leatherback nesting peaks during the rainy season, and the beach is monitored from a field camp in the Galibi Nature Reserve. Hilterman and Goverse (2005) reported a mean observed internesting period (OIP) of 9.6±1.0 days (*n*=181), a mean OCF of 1.6±1.0 nests (range 1-7, *n*=645 females), and they observed that 63.6% (*n*=410) of females were seen nesting only once (Figure 10). Applying the techniques of Reina et al. (2002), they calculated an ECF of 4.1±1.8 nests (*n*=140) for turtles observed nesting twice or more "by dividing the number of days in between the first and last nesting dates for an individual by the mean OIP of 9.6, and adding one for the first [nest]." At more intensely monitored Western Atlantic leatherback nesting sites, OCF ranges from 5-7 (Boulon et al., 1996; Tucker, 1988), which both highlights the importance of converting to an

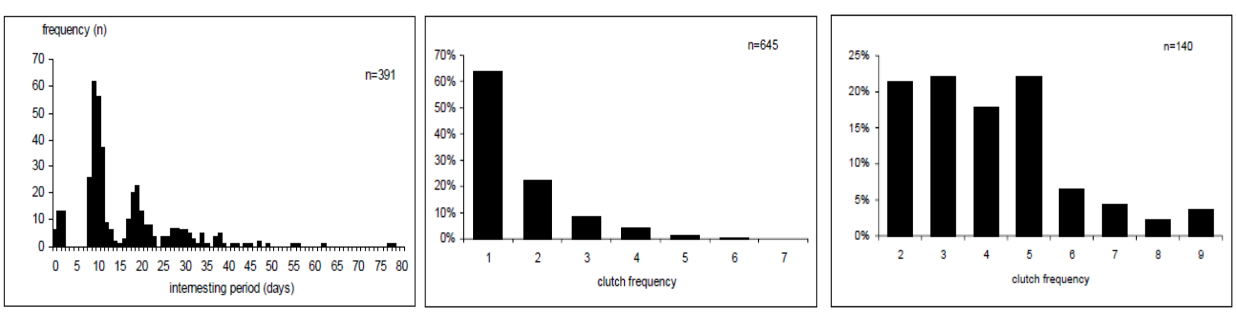



**FIGURE 10.** From left to right: observed internesting periods (OIP), observed clutch frequency (OCF), and estimated clutch frequency (ECF) for leatherbacks nesting at Babunsanti, Suriname, in 2004 (Hilterman and Goverse, 2005).

ECF when data are incomplete and illustrates how easy it is, even using an ECF, to significantly over-estimate population size when individual reproductive histories cannot be known.

In situations where direct counts are impossible, Rivalan et al. (2006) computed Total Clutch Frequency (TCF) by adapting the 'stop-over duration' method used in studies of population density of migratory birds (Schaub et al., 2001). This method relies on parameter estimates of capture probabilities, survival probabilities, and duration of residence of individuals prior to first detection that are derived from Capture-Mark-Recapture (CMR) models. Briane et al. (2007) developed a further method for computing the distribution of TCF by combining information on OCF and monitoring effort with estimates of capture probability to estimate TCF and nesting female population sizes. They also evaluated the effect of including one-time nesters on population estimates of TCF. Fossette et al. (2008) expanded this method to address situations where two distinct categories of females (faithful and erratic) use the same nesting beach; such a situation is observed for leatherback turtles nesting in French Guiana (see Russo, 2008-2009).

Tucker (2010) demonstrated the usefulness of satellite telemetry data in estimating clutch frequency for loggerhead turtles nesting in Florida, emphasizing that "the revised estimates of clutch frequency can enable refined estimates of population size in management and recovery plans."

Whatever approach you take, you must be able to describe and defend your conversion and a measure of the accuracy of the conversion value should always accompany your estimate.

## VALIDATE YOUR "INDEX" SELECTION

Because it is unlikely that your index beach supports all nesting by the target population each year, an index assessment is a type of subsampling in which you estimate nesting population size and/or trend at a particular location (the index beach) and then assume, with verification, that the rest of the population or stock follows the same trend. As described earlier, subsampling can be based on geography, timing, or both, but it can be particularly challenging to provide quantitative support for the assumption that the estimates within the index area are predictably linked to overall population trends. *As a rule, you must prove these assumptions each year for each species.*

Consider that you have been given the responsibility to monitor a nesting population where gravid females distribute their nests along 30 km of coastline. The 30 km distance is too great to be patrolled intensively, so you decide to subsample using all-night foot patrol of a fixed 3 km of high-density nesting habitat every night, operating under the assumption that these 3 km are an index (a direct reflection) of overall nesting trends.

One way to test this assumption is to schedule an annual comprehensive "snapshot" survey of the entire 30 km at some point well after the period of peak nesting activity (but before nesting ends). We will refer to this as a "wide area survey." The wide area survey can provide valuable information about the proportion of nesting that occurs outside the regularly patrolled 3 km index area, as well as some perspective on how closely the index data reflect overall nesting trends.

*Note*: Because turtles do not typically distribute their nests uniformly along the coast, it would not be accurate to multiply the number of turtles nesting (or the number of nesting activities observed) in the 3 km index by 10 in order to estimate the number of turtles nesting in 30 km.

***Methodology –*** To utilize the wide area survey to evaluate population size, recognize that there are a number of variables that can affect the accuracy of your estimate. These include: (i) whether or not the wide area survey encompasses the full range of nesting habitat for the nesting population of interest, (ii) the nature of the survey method selected (e.g., flying at 200 m elevation at 100 knots may yield different values than a careful foot patrol), and (iii) the extent to which field signs are equally observable at every location. If you can calibrate and compensate for these errors in your methodology and analysis, your ability to provide an accurate appraisal of total nesting based on at least one well-surveyed index area and at least one (annual) wide area survey will improve.

*Be Efficient* – The annual survey should be as large as practicable, and the entire wide area survey (30 km in our example) must take place on the same day.

*Be Consistent* – The survey method must be uniform throughout; e.g., you cannot survey one section by vehicle, another section on foot, and another section by boat or from the air. Reliance on multiple survey methods introduces error that is difficult to counteract. A complete foot survey, if practicable, is likely to be the most accurate.

*Be Aware* – Ideally, all nesting activities should be equally observable throughout the survey area. In other words, on the day of the wide area survey there should be an equal chance that field signs can be seen and counted at all locations. If one section of beach receives high levels of visitation (where heavy foot traffic tends to erase evidence of a nesting crawl, cf. Figure 11) or more extreme wave wash than another section of beach, you cannot assume that an observer will be able to document with equal accuracy in both sections the field signs associated with a nesting activity that occurred one week earlier. One approach to reducing this error is to characterize beach sections by their capacity to retain field signs. Such characterization can be as simple as Low, Medium or High, but effort should be expended to measure what each level means and to ensure that the intensively patrolled index area includes each of these areas in roughly the same proportion that they occur throughout the entire 30 km.

**FIGURE 11.** Sea turtle species and beach characteristics affect field signs, crawl longevity, and detection probability. Shown here is a leatherback sea turtle crawl clearly visible on a wide sandy beach in Aruba and a loggerhead sea turtle crawl less visible on a rocky, footprint-strewn beach in Bonaire. Photos: (left) Turtugaruba Foundation; (right) Sea Turtle Conservation Bonaire.

***Analysis –*** To use your index area dataset in combination with the annual wide area survey to estimate total nesting population size (TNPS), every effort must be made to minimize the number of activities missed because they were not observable (e.g., field signs lost to wind, surf or heavy rain; no track visible on a rocky beach; nesting deep within beach forest).

$$TNPS = [A * C/B] * (D/C)$$

Where:

- ***A*** = Total count of all activities visible[12] on the day of the annual wide area survey (30 km in our example);
- ***B*** = Total count of all activities visible within the index area (3 km in our example) on the day of the wide area survey, using the same method as the wide area survey;
- ***C*** = Total count of all activities visible within the index area based on a careful foot-patrol on the day of the annual wide area survey[13]; and
- ***D*** = Total count of all activities within the index area for the entire nesting season

***Validation –*** By undertaking the annual wide area survey, you are better able to validate – or least critically evaluate – the usefulness of relying on your index area as representative of population trends in a larger context. In addition, data will be available to you regarding the proportion of nesting occurring outside the index area, threats present in these areas, and other details useful to management.

## ESTIMATE ABUNDANCE

Having made the decision, based on stated goals and objectives, to monitor sea turtle nesting at index site(s) (or to monitor an entire nesting colony, as practicable), the timing and "shape" of the nesting season are known (that is, you know when nesting starts and ends and whether the season is "bell-shaped" with a defined seasonal peak or continues year-around with no peak in activity), and the methodology best suited to facilitate an estimate of population size and trend has been selected and implemented, the next step is to interpret the collected data.[14]

To build capacity for monitoring sea turtle populations, promote best practices with regard to tagging and record-keeping, and facilitate collaboration among range States with regard to data sharing, documenting international movements, and assessing population status and trend, WIDECAST maintains a regional Marine Turtle Tagging Centre in Barbados (Horrocks et al., 2011). A variety of online tools are available, including standard guidelines for sea turtle tagging (Eckert and Beggs, 2006) and database management software to help standardize data collection, archival, and analysis (Eckert and Sammy, 2008). The software was developed using Microsoft Access™, but users need not be proficient in Access™ in order to utilize it. Visit http://www.widecast.org/management/regional-tagging-centre/ to download the software, which includes standard data forms, as well as data analysis modules that generate summary reports and allow the export of data into other analysis formats (e.g., spreadsheets and statistical programs).

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[12] "All activities visible" means *any* body-pit still visible in the sand, not just the activities of the previous night.

[13] "C" is meant to represent a known and accurate count of all field signs visible in the census area. If your annual wide area census of the entire 30 km is done on foot, "B" and "C" will be the same. However, if the annual wide area census is done by another method (e.g., aerial, boat, vehicle), the objective here is to calibrate the accuracy of the wide area census methodology against the known "C."

[14] For background on basic statistical concepts, including interpreting sampling data, websites such as "Stat Trek" http://stattrek.com/estimation/estimation-in-statistics.aspx?Tutorial=AP can be very useful.

Once nesting data have been collected, assembled and checked for completeness and accuracy, analytical software developed by Prof. Marc Girondot for the State of the World's Sea Turtles (SWOT) "Minimum Data Standards for Sea Turtle Nesting Beach Monitoring" initiative can be downloaded for PC and Mac computers from http://seaturtlestatus.org/data/standards. Data providers can download the software directly to their personal computers to run the analyses and generate outputs, including seasonal abundance estimates. To run the program, users are directed to drop in a *.txt file of nest counts by date counted, and the software provides estimates of total (annual) abundance with confidence intervals. Results can be emailed directly to the SWOT Database Manager for inclusion into the global SWOT database, if desired.

Generally speaking, analytical results are more reliable and therefore more useful as more data are incorporated. Therefore, historical information should also be examined for the degree to which it "fits" the scenarios described above. Whether you select a model supported by the SWOT "Minimum Data Standards for Sea Turtle Nesting Beach Monitoring" initiative, or any number of other potentially useful models, data collection methods that do not conform to the requirements of the model should be excluded from the analysis. For example, you might focus on a particular species, or make use of data collected only during certain periods or at certain sites where data collection methods were standardized over time and reporting was reliable.

To illustrate this point, consider the work of del Monte-Luna et al. (2011). The authors note that direct surveys of hawksbill turtles has been carried out along more than 200 km of the Campeche, Mexico, coast since 1977; however, they restrict their analysis to data collected during 1980-2010 at Isla Aguada, Sabancuy, Chencán and Punta Xen (Figure 12) because these sites (i) are spatially and temporally continuous, (ii) use standardized working methodology (starting in 1980), and (iii) account for 80% of all recorded nesting hawksbills in Campeche and 50% of the total sightings of nesting females in the Yucatán Peninsula. The authors also had the

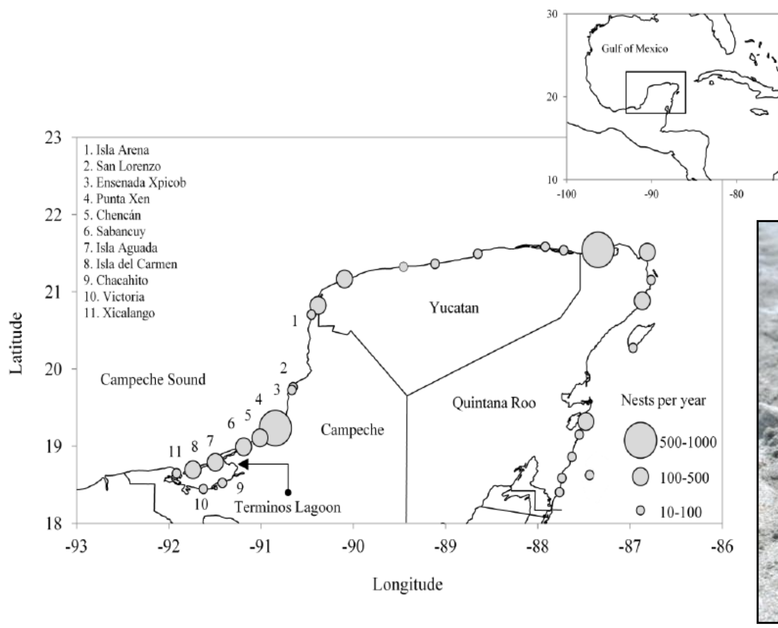



**FIGURE 12.** Mean annual nest density of hawksbill turtles along the Southern Gulf of Mexico (taken from Dow et al., 2007). The primary sea turtle camps in Campeche are indicated numerically. Source: del Monte-Luna et al. (2011).

benefit of previous research showing that the number of nesting females in Campeche, Yucatán and Quintana Roo showed strong synchrony over time, and therefore the number of nesting females along the Campeche coast could reasonably be considered as representative of the entire nesting population of the Southern Gulf of Mexico; had access to existing estimates of clutch frequency, internesting interval, and other biological parameters; and were aware of certain fundamental operational statistics, such as more than 90% of all nesting individuals had been observed by trained field teams. In this example, long-term data collection was able to provide reliable estimates of population trends, as well as support a contemporary review relating those trends to interannual variations in oceanographic conditions at the turtles' developmental habitats, including how those conditions might be affected by climate change scenarios.

# VII. CONCLUSIONS

Sea turtles have complicated life histories embracing delayed sexual maturity, long life spans, and non-annual reproduction. Individuals move through a number of developmental life stages and habitats, for which the duration spent in each stage may vary in unpredictable ways. Accounting for the number of turtles within (and passage rates through) each stage is problematic, and a general dearth of population monitoring beyond the nesting beach continues to complicate efforts at population-level trend assessments (NRC, 2010).

Complexities notwithstanding, assessing population status is a priority recommendation of WCR sea turtle recovery plans (http://www.widecast.org/widecast-publications/national-recovery-plans/). That data were lacking to support such assessments was lamented during the First (Bacon et al., 1984) and Second (Ogren et al., 1989) Western Atlantic Turtle Symposiums. At a regional meeting in 1999, governments echoed their concern that "there is insufficient scientific information available for management purposes, especially from long-term monitoring of marine turtles and their habitats in the WCR", and recommended that index sites be selected and monitored to "determine demographic trends for each population using statistically robust procedures over ecologically relevant time frames" (*Santo Domingo Declaration:* Eckert and Abreu Grobois, 2001). Monitoring also has value to regional entities; for example, Parties to the IAC are obliged to submit an Annual Report[15] to the Secretariat detailing activities taken on behalf of the "protection, conservation and recovery of sea turtle populations and their habitats" (Art. 4), reporting which relies, in part, on standardized data collected at index sites.

While most projects cannot expect to count 100% of the target nesting population each year, this does not mean that a quantitatively accurate appraisal of abundance and trend cannot be made. The intent of this handbook is to provide managers with a practical understanding of (and caveats associated with) the design and implementation of long-term surveys of abundance at sea turtle nesting beaches, including selecting the areas to be monitored, survey timing and duration, what (and how often) to count, measuring and reporting data accuracy, and, finally, estimating abundance in such a way as to allow trend analysis over time.

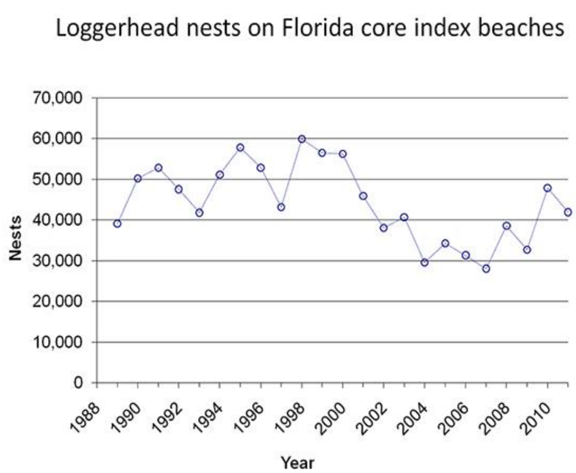
As confidence in annual nesting abundance estimates increases (e.g., decreased sampling error associated with increased sampling), the number of years necessary to detect a given trend with the same power and confidence decreases (Chaloupka et al., 2008; Jackson et al., 2008; Sims et al., 2008). For most sea turtle populations, at least 20 years of monitoring with

[15] Article XI(1). Each Party shall prepare an annual report, in accordance with Annex IV, on the programs it has adopted to protect and conserve sea turtles and their habitats, as well as any program it may have adopted relating to the utilization of these species in accordance with Article IV(3). Source: http://www.iacseaturtle.org/texto-eng.htm

low levels of error (CV≤0.2) are necessary to detect a population trend of ±5% (SWOT Scientific Advisory Board, 2011), so it is essential that standardized population monitoring be maintained over decadal scales.[16] Equally important is that monitoring locations and methodologies are selected to "fit" local staff, financial, and logistic constraints and realities, as well as address stated management goals and objectives.

Creative partnerships and collaborations (with volunteers, community and youth groups; rangers and police; beachfront residents, including hoteliers and their staff; researchers, fishers, divers or tour guides that regularly visit remote areas, and so on) should be nurtured to help ensure the long-term viability and cost-effectiveness of the monitoring program. Where practical, and without diverting resources from core monitoring efforts, full advantage of visits to index sites should be taken for related research and/or conservation action (e.g., nest protection, habitat restoration, anti-poaching patrols, data collection related to habitat use, hatch success, nesting behavior).

Florida's Index Nesting Beach Survey is an example of how long-term collaboration between state and federal governments and an extensive network of trained volunteers (including members of conservation organizations, university researchers, and private citizens) can implement a detailed monitoring program able to identify trends in sea turtle nesting over a large geographic area (Figure 13). Since 1989, "the index survey has used standardized data collection criteria to measure seasonal nesting and to allow accurate comparisons between beaches and between years. Consistent effort by location and date and specialized annual training of beach surveyors make the index program suited to these trend assessments. Approximately 30% of Florida's beach length is surveyed under index-survey criteria. At a core set of index beaches ... trained surveyors monitor 320 km of nesting beach (nearly 200 miles) divided into zones that average 0.8 km (about 0.5 mile) in length. Beach surveyors monitor core index zones daily during a 109-day sea turtle index-nesting season (May 15-August 31). Researchers record nests and nesting attempts by species, nest location, and date. Index nest counts represent ap-



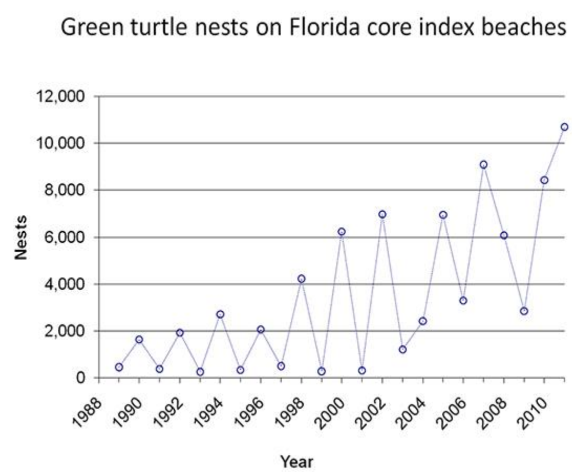




**FIGURE 13.** Florida's Index Nesting Beach Survey data allows managers to identify trends in sea turtle nesting statewide. For example, loggerhead nesting at index beaches has declined from a peak of nearly 60,000 in 1998 and now appears to be stabilizing (see also Witherington et al., 2009). In contrast, green turtle nest counts have increased about tenfold since 1989. Source: http://myfwc.com/research/wildlife/sea-turtles/nesting/beach-survey-totals

[16] Do not be discouraged by this, every journey starts with the first step!

proximately 69% of known loggerhead nesting in Florida, 74% of known green turtle nesting, and 34% of known leatherback nesting."[17]

Whether sea turtle nesting population monitoring is just getting started or has been ongoing for a decade or more, such as in Florida and at other WCR sites where data have been published (e.g., Antigua and Barbuda: Richardson et al., 2006; Barbados: Beggs et al., 2007; Costa Rica: Troëng and Rankin, 2005; Chacón and Eckert, 2007; Cuba: Moncada et al., 2010; Guianas: Girondot et al., 2007; Mexico: Márquez et al., 2005 Garduño-Andrade et al., 1996; del Monte-Luna et al., 2011; Nicaragua: Campbell et al., 2012; Puerto Rico: Joglar et al., 2007; Diez et al., 2010; US Virgin Islands: Boulon et al., 1996; Garner and Garner, 2010), there is always an opportunity for improvement in methodology, training and evaluation, reporting, and/or analysis.

Too often, Caribbean managers find that even after several years of monitoring, the accumulated data are inadequate to estimate population distribution, size, or trend with sufficient rigor to meet basic management goals and objectives. We hope that this manual – with its many local examples, diagrams, checklists, and cited resources – will encourage an improved understanding of how to plan, conduct, and analyze surveys of abundance and that, as a result, Caribbean managers will more commonly find that they are able – regardless of staffing, funding or logistical constraints – to design a monitoring program based on best practices that fits their situation and can be relied upon to provide credible information on the status of sea turtle nesting populations in the 21st century.

[17] Source: http://myfwc.com/research/wildlife/sea-turtles/nesting/beach-survey-totals/. For specific training materials, visit http://myfwc.com/research/wildlife/sea-turtles/nesting/training-materials/

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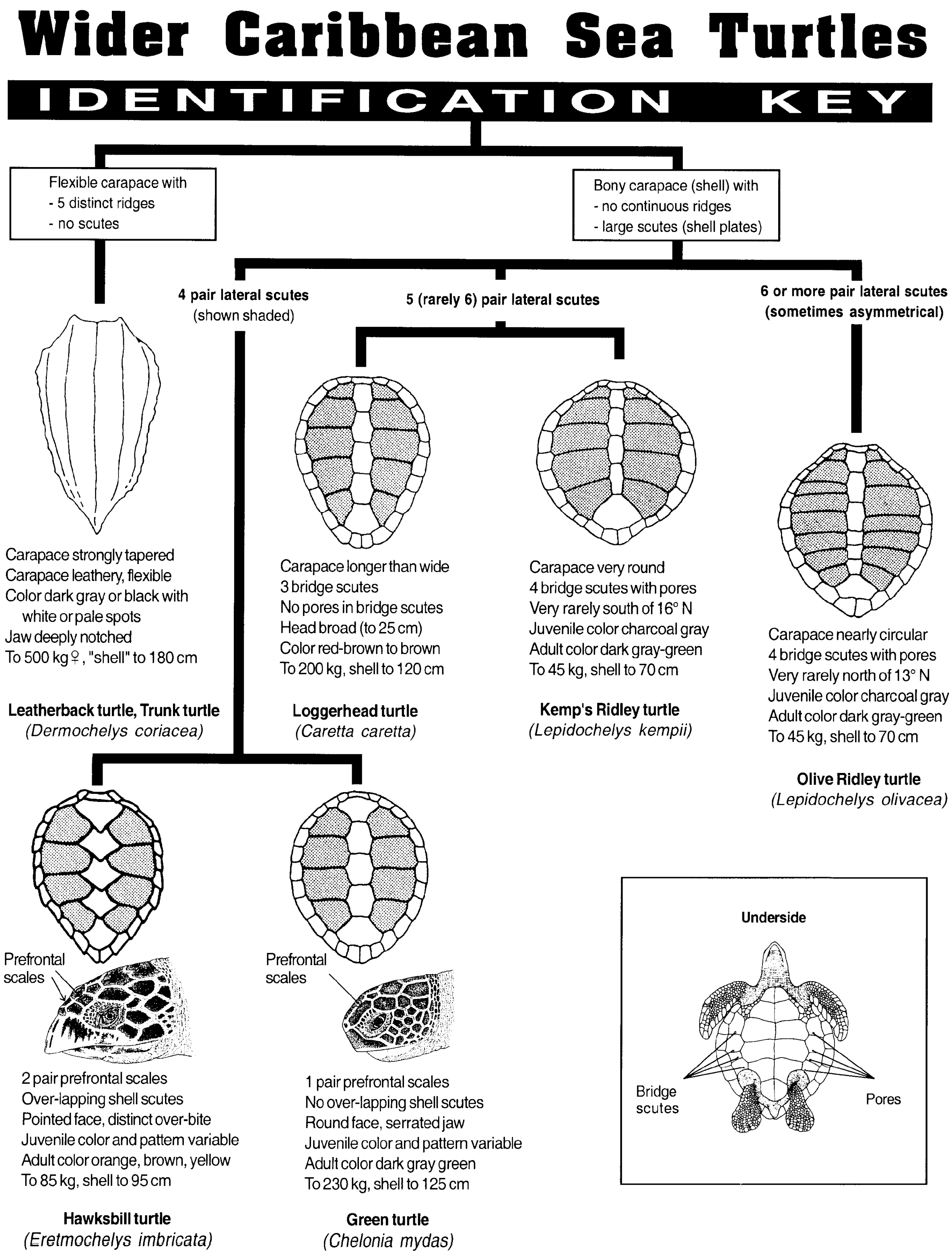
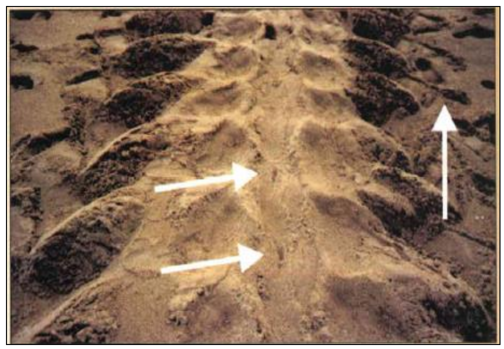
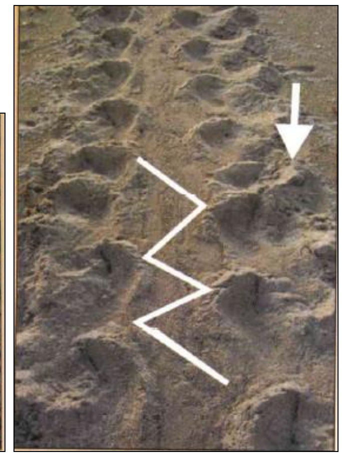
# ANNEX I: Sea Turtle Species Identification



# ANNEX II: Interpreting Crawl Signs

Sea turtles can often be identified based on nesting crawl signs. According to Wood (2004), leatherbacks leave symmetrical (non-alternating) flipper marks in the sand, often with a noticeable tail drag as illustrated in the photo on the left (the turtle is moving toward the top of the picture). Wood (2004) also notes the tail drag and "poke" (arrows) in the center of the symmetrical green turtle crawl (center photo), and the alternating flipper marks of a loggerhead (right photo) where the turtle is moving toward the bottom of the picture. Photos: Wood (2004)





Gait (symmetry), crawl depth and width, and the presence or absence of a body pit and/or tail drag are the most useful characteristics when attempting to identify a sea turtle based on nesting crawl signs (table adapted from Pritchard and Mortimer, 1999).

| SPECIES | GAIT | CRAWL DEPTH | CRAWL WIDTH (cm) | BODY PIT | TAIL DRAG |
|---|---|---|---|---|---|
| Leatherback | symmetrical | deep | 150 – 230 | deep | present, usually deep |
| Green Turtle | symmetrical | deep | 100 – 130 | deep | present, solid or broken line |
| Loggerhead | alternating | moderate | 70 – 90 | moderate | none |
| Hawksbill | alternating | shallow | 70 – 85 | shallow | often present |
| Kemp's Ridley | alternating | very shallow | 70 – 80 | shallow | none or minimal |
| Olive Ridley | alternating | very shallow | 70 – 80 | shallow | none or minimal |

Leatherbacks (left) and green turtles (middle) leave the most obvious field signs, including deep body pits. Hawksbills (right) make shallow crawls and often nest in vegetation; field signs can be cryptic. Photos: Scott Eckert (Mexico), Edith van der Wal (Aruba), Seth Stapleton (Antigua).

# ANNEX III: Sea Turtle Tagging[18]

Tag types most often used on sea turtles are externally placed flipper tags (generally metal or plastic) and internally placed PIT (Passive Integrated Transponder) tags.

## FLIPPER TAGS

Flipper tags are modified livestock tags that must be pierced through the flesh and clamped closed using tag applicators designed for each tag type. Tags are the most commonly used identification marks on sea turtles, and their successful application can facilitate the collection of information on population trends, habitat residency, movement patterns (including international movements and migrations), individual growth rates, reproductive life history (e.g., remigration intervals, nesting frequency, clutch size, and/or hatchlings produced per female), and stranding patterns.

Metal flipper tags,
© National Band & Tag Company

***Tag Size –*** Most flipper tag styles are unsuitable for use on turtles smaller than 25-30 cm straight carapace length (SCL). While very small metal tags are commercially available (e.g., National Band and Tag [NBT] #1005-1), there are few data to evaluate their retention rates or any effect they may have on the movement or survival of very small turtles. In general, turtles larger than 30 cm SCL are tagged with NBT Inconel #1005-681 tags. A larger tag (NBT #1005-49) is better suited for adults of the larger sea turtle species; i.e., green, loggerhead, and leatherback turtles. See https://nationalband.com/wildlife-conservation-tags/ for details.

Flipper tag through the scale,
© B. Bergwerf, SCA

***Tag Placement –*** Two tags, one in the trailing edge of each front (or rear) flipper, are applied to each turtle. “Double-tagging” increases the likelihood that the turtle retains its unique identification over several years.

Front flipper tags can be applied in one of two ways: either through or between the enlarged fleshy scales on the trailing edge of the flipper. If *through* the scale, we recommend placement in the center of the first or second scale proximal (closest) to the body. If *between* the scales, we recommend placement between the first and second scales. Each tag should be applied with ca. 3-5 mm of open space between the trailing edge of the flipper and the inside curve of the tag.

Rear flipper tag,
© M. Godfrey, NCWRC

Rear flipper tags are placed through (or adjacent to) the first large scale on a hard-shelled species. For leatherbacks, the tag is placed in the “baggy pants area”; that is, in the fold of skin that connects the tail to the rear flipper.

Rear flipper tag,
© P. Dutton, NOAA

[18] Adapted from Eckert and Beggs (2006) and Bluvias and Eckert (2010). For additional detail, see NMFS (2008).

**Concerns and Warnings –** Regardless of whether your tag is placed through or between scales, remember that with increasing distance away from the body, tag retention is compromised. In other words, the further the tag is placed from the body, the more likely it is to be lost due to hydrodynamic forces, biting during courtship (or by predatory or curious fish), entanglement in a fishing net, etc. In the case of rear flipper tagging, placing the tag too close to the tail can be painful for the turtle. Alternatively, placement too far from the tail risks loss by predatory or curious fish, or loss to abrasion during nest excavation, in the case of a female.

***Tag Cleansing* –** During the manufacturing process the tags are covered in a lubricating oil comprised of an animal-based oil and mineral spirits, and therefore the tags must be washed prior to being applied to a turtle. Unwashed tags can quickly cause infection at the point of application. One option is to wash the tags in hot soapy water; another option is to use a biodegradable solvent or cleaning solution, such as Simple Green® or BioChem SolSafe 245®. After cleaning, dry the tags and store them in sealed plastic food storage boxes or Ziploc™ type bags.

***Tag Pliers* –** If you consistently encounter problems with tags that do not fully cinch closed, give extra care to loading each tag correctly with the base plate flush against the pliers. You may also find it useful to adjust or bend the tag to help ensure that the point of the tag enters the hole during the application process. Bend the tag so that the pointed end meets up with the hole, but *be careful not to bend the tag too frequently* as this will affect the integrity of the metal (this is particularly true with the softer Monel tags). Once you have bent the tag to ensure a fit, reopen the tag so that it will be retained snugly in the tag applicator.

Tagging pliers with metal flipper tag, © National Band & Tag Co.

***Examine the Turtle* –** Before applying a tag, feel along the flipper edges and gently squeeze the first and second scales to identify any sores, lumps, or obvious sensitivity. Record the presence of potential tag scars (these may appear as rips in the flipper scales or skin, or lumps of scar tissue in the same location on both front flippers), and avoid placing new tags in these areas.

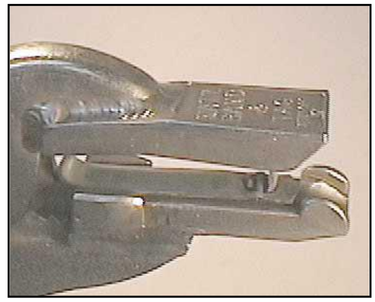
Positioning pliers to tag, © Virginia Aquarium Foundation

### TAG APPLICATION STEPS: A CHECK LIST

- Rinse the tip of the tagging pliers and the tags in alcohol. Clean hands with soap and water or hand sanitizer prior to tagging and between tagging turtles.
- Cleanse tagging site on the turtle with a broad-based topical microbicide, such as a povidine-iodine antiseptic solution (e.g., Betadine®) or rubbing alcohol before tag insertion.
- Pull the tag through the grooved guides in the jaws of the applicator (pliers) until it “snaps” into place. Make sure that the base plate of the tag is flat against the bottom jaw and the “bubble” is seated in the hole. Marking one jaw of the pliers with white paint can assist in loading the tags correctly at night. *Check that the tag is seated securely*.
- Position the tag and pliers so that the tag number is facing upwards, is at the proper location on the flipper, and will result in an appropriate gap between the trailing edge of the flipper and the inside curve of the tag.

- Squeeze the pliers with a firm, smooth action. Squeezing too lightly will not allow the tine to bend and lock in place, while squeezing too hard may cause the tag to flatten and pinch the flipper. *Either mistake will result in tag loss, and the latter (i.e., squeezing too tightly) can cause unnecessary and unacceptable discomfort to the turtle.*

- Confirm that the tag is properly applied and cinched. For Inconel tags, turn the flipper over and examine the bottom of the tag to confirm that the tag has penetrated and that the tip (tine) is completely bent over and secure. An Inconel tag that is not secure can often be re-crimped with the tagging pliers. If this fails, remove the tag carefully and try again with a new tag, using the same puncture hole if possible.



Closed pliers; note the stirrup style, © National Band & Tag Co.

- In the case of a stirrup-style Monel tag (see insert) where the bent tine is not visible, place your thumb and index finger on either side of the tag and gently attempt to wedge your fingers under the tag; if the tag pops open, it is not secure and must be replaced.

- RECORD THE TAG NUMBER. It is only after you have confirmed the proper and secure placement of the tag(s) that the tag numbers are recorded on the datasheet. Record the numbers carefully, and indicate the placement site (e.g., left front flipper) if required by the data form. Check and *double-check* that you have read and recorded the numbers correctly (it is helpful if a second person reads the numbers to the data recorder). Always record zeros.

**Concerns and Warnings –** Practice tagging technique on a sheet of corrugated cardboard. It is important to become comfortable and confident with the quick, decisive action needed to penetrate the flesh and cinch the tag correctly. Slow or imprecise movements can cause discomfort to the turtle. Moreover, if the animal moves (especially in a startle response) during tag placement, the application may be ruined. Two people should be involved in each tagging – one person to hold the flipper and the turtle in case the turtle lurches, and one to do the actual tagging.

### *PIT TAGS*

Passive Integrated Transponder (PIT) tags are cylindrical in shape and about the size of a grain of rice. They are injected under the skin or into muscle. PIT tags are "small inert microprocessors sealed in glass that can transmit a unique identification number to a hand-held reader when the reader briefly activates the tag with a low frequency radio signal at close range" (Balazs, 1999). When a specialized reader is passed over the tag, a number, typically 9-15 digits arranged in a unique and unalterable alphanumeric code (i.e., a combination of numbers and letters), is displayed in the reader's viewing window. The sea turtle feels nothing as the reader (or, scanner) is passed over it.

PIT tags, © Loggerhead MarineLife Center

The use of PIT tags in adult sea turtles is well-tested and offers the advantage of superior tag retention when compared to metal flipper tags. Less information is available on the long-term effects of PIT-tagging juvenile turtles. We do not discourage the PIT tagging of small juveniles, but we encourage you to contact colleagues who are experienced with younger age classes.

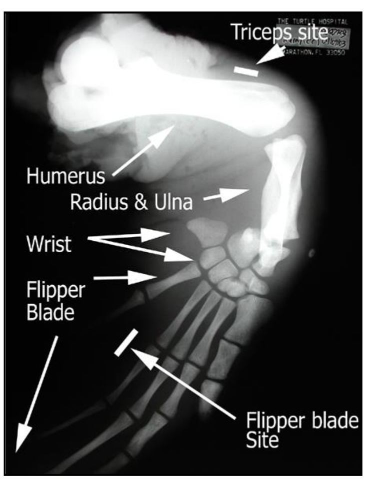
**Concerns and Warnings –** Applying a PIT (Passive Integrated Transponder) tag is more invasive than applying a flipper tag, and should be done only under the guidance of workers experienced with the technique. PIT tagging is not a substitute for flipper tagging, but is best used together with flipper tagging so that at least one external tag is readily visible for the next encounter.

***Brand Considerations –*** There is little standardization among sea turtle projects with regard to PIT tag brand, frequency, placement (tag site), or record-keeping. The challenge this presents for data collection is that when the reader is not "matched" to the frequency of the tag, the tag cannot be detected. Standardizing brand use across geographic regions would assist in ensuring that turtles PIT-tagged at one site could be detected as tagged at other project sites. In the absence of standardization, we recommend **un**encrypted PIT tags so that they can be read by other scanning technologies (other manufacturers) should your tagged turtle nest or be captured in another location. We also recommend you select a reader capable of detecting PIT tags made by different manufacturers.

Scanning for a PIT tag,
© B. Bergwerf, SCA

***Tag Placement –*** A PIT tag is injected under the skin, generally into muscle, using a sterile needle applicator available from the manufacturer.

Triceps muscle complex
PIT tag injection,
© NOAA/NMFS/SEFSC




© The Turtle Hospital, annotated by J. Wyneken

For sea turtles larger than 30 cm SCL, we suggest tag insertion into the triceps muscle complex on the anterior and dorsal aspect of the upper arm. This muscle mass, located on the humerus, can be pinched up so that the applicator easily enters the muscle. (*Note*: The major joint in the flipper is between the humerus bone and the radius and ulna bones.) An alternative site is adjacent the radius and ulna atop the flipper blade. You can feel the edges of the radius and ulna adjacent to the three largest scales. If this site is used, insert the tag parallel to the radius and ulna on the flipper's trailing edge. In some cases, PIT tags placed at this site may not enter muscle and can migrate and cause irritation.

Whatever location you choose, remember that PIT tags are designed to become encapsulated with fibrous connective tissue in muscle. When the tag is encapsulated, it will not migrate away from the insertion point. Experience has shown that the tags do not encapsulate as reliably in skin, tendon, ligament, connective tissue or fat.

***Tag Sterilization –*** Most PIT tags and applicators are pre-sterilized and packaged for field use, and we strongly recommend these. If the PIT tag style you select is not pre-sterilized, *each tag* must be soaked in non-toxic disinfectants (such as Betadine™, followed by alcohol) prior to use.

***Examine the Turtle –*** Verify that the sea turtle is not already PIT-tagged. As there is no consensus on PIT tag placement, examine foreflippers, shoulder muscles, rear flippers, and neck. Continue scanning even if a tag is found because some turtles may already have more than one PIT tag. To scan for an existing tag: turn the reader ON, place the reader directly on the skin of the turtle to decrease the "read distance", and then press and hold the READ button while moving over the area to be scanned in a circular motion. Use the entire reading surface of the scanner when trying to detect a tag.

After scanning an area, re-scan while tilting the scanner at various angles. PIT tags read best when the tag is pointing with the small end (picture the tip of a grain of rice) pointed directly toward the scanner, but the tag is not always oriented optimally under the skin. By tilting the reading surface at different angles during a sweep, the probability of tag detection is increased.

***Record Existing Tags –*** If a PIT tag is found, enter the number (and any hyphens) on your data form exactly as it appears on the scanner display. The number is usually hexadecimal (digits 0-9 and letters A-F) and 10 (125, 128, or 400 kHz) or 15 (134.2 kHz) bytes long. Double-check to verify that the number is recorded without error, taking extra precaution concerning letters/numbers that can be confused; e.g., letter O and number 0 or Ø. If the display is inconsistent, displays a 16-byte alphanumeric code (0-9 and A-Z), or reads "AVID", you may have found an undecipherable, encrypted AVID tag.

### PIT Tag Application Steps: A Check List

- Scan and record the new tag before insertion to verify that the tag is functional.
- Clean the injection site with a swab saturated in antiseptic solution, such as Betadine®.
- Insert the tagging needle under the skin and depress the syringe plunger to move the tag out of the applicator and into the muscle tissue. To inject using the triceps muscle complex, isolate by pinching the area next to the dorsal humerus, angle the applicator to ensure the tag is inserted into the muscle complex and not too deep into the flipper, and push the plunger to move the tag out of the applicator. If injecting into the flipper blade, identify the bones and inject adjacent to the radius and ulna.
- Watch for bleeding after injection. If blood flows from the wound, apply pressure with swab soaked in antiseptic solution until the flow stops. It may be necessary, especially in small juveniles, to apply a small amount of surgical glue to close the opening.

***Concerns and Warnings –*** If the scanner has a low battery, or finds an unrecognized encrypted tag, the scanner may give bogus or "ghost" numbers; e.g., an excessively long alphanumeric code or nonsense symbols. Turn the scanner OFF, then ON, then re-scan. If bogus readings persist, replace the batteries or try another scanner – or, record the reading for later evaluation and make relevant notes on the data form. If the turtle is resting on anything iron, such as the bed of a truck, lift it up a few inches before scanning. Iron (and certain neon lighting and electrical motors nearby) render the scanner ineffective.

# WIDECAST

*Wider Caribbean Sea Turtle Conservation Network*

***"Working together to build a future where all inhabitants of the Wider Caribbean Region, human and sea turtle alike, can live together in balance."***

The Wider Caribbean Sea Turtle Conservation Network (WIDECAST) is a regional coalition of experts and a Partner Organization to the U.N. Environment Programme's Caribbean Environment Programme. WIDECAST was founded in 1981 in response to a recommendation by the IUCN/CCA *Meeting of Non-Governmental Caribbean Organizations on Living Resources Conservation for Sustainable Development in the Wider Caribbean* (Santo Domingo, 26-29 August 1981) that a "Wider Caribbean Sea Turtle Recovery Action Plan should be prepared ... consistent with the Action Plan for the Caribbean Environment Programme."

WIDECAST's vision for achieving sea turtle recovery on a regional scale has focused on bringing the best available science to bear on sea turtle management and conservation, empowering people to make effective use of that science in the policy-making process, and providing a mechanism and a framework for cooperation within and among nations. By involving stakeholders at all levels and encouraging policy-oriented research, WIDECAST puts science to practical use in conserving biodiversity and advocates for grassroots involvement in decision-making and project leadership.

Emphasizing initiatives that strengthen capacity within participating countries and institutions, the network develops and replicates pilot projects, provides technical assistance, enables coordination in the collection, sharing and use of information and data, and promotes strong linkages between science, policy, and public participation in the design and implementation of conservation actions. Working closely with local communities and resource managers, the network has also developed standard management guidelines and criteria that emphasize best practices and sustainability, ensuring that current utilization practices, whether consumptive or non-consumptive, do not undermine sea turtle survival over the long term.

With Country Coordinators in more than 40 Caribbean nations and territories, WIDECAST is uniquely able to facilitate complementary conservation action across range States, including strengthening legislation, encouraging community involvement, and raising public awareness of the endangered status of the region's six species of migratory sea turtles. As a result, most Caribbean nations have adopted a national sea turtle management plan, poaching and illegal product sales have been dramatically reduced or eliminated at key sites, many of the region's largest breeding colonies are monitored on an annual basis, alternative livelihood models are increasingly available for rural areas, and citizens are mobilized in support of conservation action. You can join us! Visit www.widecast.org for more information.

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