SWOT
The State of the World's Sea Turtles

THE STATE OF THE WORLD'S SEA TURTLES (SWOT) MINIMUM DATA STANDARDS FOR NESTING BEACH MONITORING

TECHNICAL REPORT

PREPARED BY SWOT SCIENTIFIC ADVISORY BOARD

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

As of 2011, the SWOT (*State of the World's Sea Turtles*) database has expanded to include more than 5,700 individual data records contributed by more than 550 data providers (and literature sources) from more than 2,800 distinct nesting beaches. As such, it is currently the most comprehensive global sea turtle nesting database in existence, and is well positioned to serve as the world's premier data clearinghouse and monitoring system for sea turtles. With this in mind, the SWOT Scientific Advisory Board (SAB) recognized the need to establish minimum data standards (MDS) for data provided to the database 1) to identify datasets that could be included in future analyses of abundance and long-term trends, and 2) to provide SWOT Team members (i.e. data providers) with guidelines for improving their existing monitoring schemes to enhance effectiveness of documenting local temporal sea turtle nesting abundance patterns.

First, the SAB emphasized that the 'gold standard' for sea turtle population monitoring programs are long-term capture-mark-recapture (CMR) studies on nesting beaches as well as foraging areas for populations. Comprehensive CMR studies facilitate robust abundance assessments and diagnoses of population trends, which, in turn, inform effective conservation management efforts. Second, because nesting beach abundance data is an essential component to population assessments, and is the data type contributed to the SWOT database, the SAB defined MDS for nesting beach monitoring programs, which included the following: 1) the unit for reporting sea turtle nesting beach count data and conversions among units; 2) the allowable level of error in seasonal nest abundance estimates (i.e. ≤ 20%); 3) minimum standards for monitoring effort to generate abundance estimates with acceptable levels of variation (i.e. to meet item 2); 4) modeling software that generates total seasonal abundance estimates from partial counts, which will both assist data providers as well as populate the SWOT database; and 5) a classification system to flag individual data records based on whether the monitoring schemes associated with each count reported to SWOT meets the minimum standards. To ensure a smooth transition to the next generation of the SWOT database, relevant resources – including reports, papers, species identification guides, and modeling software – will be available for SWOT Team members on the SWOT website. The SAB will continue to work on refinements to the MDS in the future via further testing of acceptable sampling error and monitoring schemes.

Taken together, the SWOT Minimum Data Standards initiative provides SWOT Team members with guidelines and resources for improving existing sea turtle nesting beach monitoring schemes, makes the SWOT database more sophisticated with respect to dealing with the wide variation in quality of provided data, and lays the groundwork for analyses of sea turtle abundance and population trends in the future. Achieving these goals will allow SWOT to play a critical role in network-building and conservation status assessments for years to come.

1. INTRODUCTION

1.1 SWOT-vision, history, future

The vision statement of the State of the World's Sea Turtles (SWOT) is "a permanent global network of specialists working to accelerate the conservation of sea turtles and their habitats, pooling and synthesizing data, and openly sharing the information to audiences who can make a difference." Thus, ***SWOT's vision is reflected in its three pillars: the Database, the Network, and Outreach***.

At its core, SWOT is a status report; the annual SWOT Report has displayed annual nest counts for individual species reported by SWOT Team members around the world. This information has been very useful in putting individual nesting beaches and projects in a global context, reinforcing the idea of a world full of people dedicated to sea turtle conservation. So far, SWOT has presented maps of global nesting for leatherbacks (Volume I), loggerheads (Volume II), hawksbills (Volume III; also in Spanish and French), flatbacks (Volume IV), and olive and Kemp's ridleys (Volume V). In its upcoming volume, SWOT Report will focus on green turtles (Volume VI, 2011). In recent volumes, genetic stocks and satellite telemetry data have also been displayed along with nesting sites and count data. After all species have been covered, SWOT will continue to collate global nesting data for all species to solidify the database as the premier global clearinghouse for sea turtle data.

Until now, SWOT Report has displayed data reported by providers without any method for standardization, thereby confounding comparisons across reported abundance values presented in SWOT Report maps and SWOT's online application on OBIS-SEAMAP (Ocean Biogeographical Information System – Spatial Ecological Assessment of Megavertebrate Populations; http://seamap.env.duke.edu/swot).

To address this issue, the SWOT Scientific Advisory Board (SAB) has developed a process by which data that are contributed to the SWOT database will conform to certain collection standards. Creating minimum data standards will have three main outcomes: 1) to establish a minimum threshold for data quality to provide guidance for improved field survey methods among the projects that contribute data to SWOT; 2) to facilitate site to site comparisons in nesting abundance and 3) to enhance the SWOT database's role as a global clearinghouse for sea turtle data.

In this report, we describe the process the SAB has performed to derive minimum data standards (MDS) for SWOT data. We also describe our recommended guidelines for nesting data collection efforts, introduce a classification system for data contributed to the SWOT database, and outline the plan for implementation of MDS in the SWOT database and data collection efforts. **ALL DATA contributed to SWOT will be accepted into and maintained in the SWOT database**, but this MDS system will be important for database maintenance, display in maps (printed and online), and supply of data to external requests for analysis. The SAB will continue to refine the MDS through further testing in years to come.

1.2. The 'Gold Standard' for sea turtle population monitoring programs

Successful conservation strategies are built upon foundations of solid science. In particular, to effectively inform conservation management strategies, it is important to report robust estimates of population abundances and trends that utilize the best available data. The first step in assessing the conservation status of a population or species of organisms is determining how many individuals exist in a population or species, and what the trend in those numbers has been, is currently, and might be in the future.

The accuracy of these estimates depends on the degree of rigor employed in collection of abundance data. For species like sea turtles that are long-lived and have overlapping generations, population monitoring must persist for several years, sometimes decades, to detect population trends with high confidence. For example, Chaloupka et al. (2008a) defined 'long-term' nesting datasets to be those including annual nesting abundance estimates for 25 yr or more. Analyses of shorter periods can lead to spurious conclusions and fail to detect the true 'background' population trend over a longer period (Chaloupka et al. 2008a,b). Long-term sea turtle nesting abundance trends across species and regions have been published using a variety of statistical methods (e.g. Bjorndal et al. 1999; Balazs and Chaloupka 2004; Laurent-Stepler et al. 2007; Marcovaldi and Chaloupka 2007; Chaloupka et al. 2008a,b; Witherington et al. 2009), and have been fundamental to guiding conservation efforts around the world.

However, a recent report issued by the National Research Council Committee on the Review of Sea Turtle Population Assessment Methods (hereafter NRC) concluded that while abundance assessments are essential, abundance of nesting females and/or their nesting activities alone is insufficient for understanding the underlying, complex processes that truly drive population status and trends (NRC 2010). The reasons for this are clear considering that nesting females account for only a portion of overall population structure and for probably no more than 1% of the total population abundance (e.g. Chaloupka 2002; Heppell et al. 2003). A clear example of this is with loggerheads (*Caretta caretta*) nesting along the eastern coast of the USA, whose nesting abundance has declined substantially in recent years (Witherington et al. 2009). Despite nesting sea turtles in this area being among the most well studied in the world, the drivers of this observed decline are unclear because only nesting females and their activities have been intensively studied (Witherington et al. 2009).

Furthermore, although trends can be detected from counts of tracks, clutches, or nesting females, an understanding of what proportion of the true abundance these counts represent is necessary to more accurately assess nesting abundance and trends. Specifically, an estimate of 'detection probability,' i.e. the proportion of tracks/clutches/females during that season that were recorded, is a key parameter for assessing status and trend of a nesting population. Without an estimate of detection probability, a simple count of tracks or clutches per season is not as reliable an index of population status or trends (Royle and Dorazio 2008).

To accurately assess sea turtle population abundances and trends, as well as permit identification of drivers of observed patterns, the best and therefore preferred approach is long-term capture-mark-recapture (CMR) programs on nesting beaches as well as in-water feeding/aggregation areas (NRC 2010). Comprehensive CMR programs can generate vital demographic data, such as survivorship of different life stages (e.g. adults, sub-adults, juveniles of both sexes), age/size at sexual maturity, breeding conditions of males and females, reproductive output and breeding probabilities for adult females, all of which help to decipher patterns observed on nesting beaches (Limpus and Limpus 2003; NRC 2010). CMR programs also allow for detection of abundance trends in nesting colonies as well as foraging area populations that belong to the same population (Chaloupka and Limpus 2001; Limpus and Limpus 2003; Limpus et al. 1994, 2003; NRC 2010). Additionally, CMR studies permit estimation of detection probabilities, which is key to drawing conclusions about simple count measures like tracks and clutches on a beach during a nesting season (Royle and Dorazio 2008; NRC 2010). Importantly, CMR studies should be conducted strategically within sea turtle Regional Management Units (Wallace et al., in press) or other defined population boundaries, to enhance assessments of biologically and functionally independent population segments that can be targets for management.

For all of these reasons, SWOT recommends that the overarching goal for monitoring programs worldwide should be to develop and maintain long-term CMR studies on nesting beaches and in foraging areas for sea turtle populations. However, we recognize that not all projects can meet the significant logistical demands required by comprehensive CMR studies. Nevertheless, such studies should be undertaken in as many cases as possible to ensure that valuable abundance and demographic data is being generated to inform conservation management strategies. Furthermore, in those cases where CMR studies are not possible, nesting beach monitoring projects should adopt alternative census protocols to optimize the quality of abundance data generated by their efforts, with knowledge of the limitations on interpretation of this information mentioned previously (Royle and Dorazio 2008).

With this in mind, and considering that the vast majority of the world’s sea turtle monitoring projects – including those that contribute data to the SWOT database – are collecting abundance data on nesting beaches, developing guidelines for nesting beach monitoring efforts is an important first step toward improving population status assessments and trend detections. Due to the SWOT database’s global nature, with more than 500 data providers from nearly 100 countries, it has the potential to become an enormously important tool for sea turtle conservation by making nesting abundance data available for status assessments and trend analyses of populations or entire species on relevant geographic scales.

2. METHODOLOGY: DEVELOPING MINIMUM DATA STANDARDS

The SAB convened two workshops (17-19 January 2008, in Loreto, Baja California Sur, Mexico, and 2-4 June 2008 in Shepherdstown, West Virginia, USA) and had several further discussions remotely to discuss and work toward establishing minimum data standards for SWOT data providers. Here we summarize major points discussed, analyses performed, and recommendations for the SWOT minimum data standards (MDS). Specific topics and recommendations include: 1) count types for nesting data; 2) detection of long-term population trends in relation to inter-annual variation and intra-annual error in abundance estimates; 3) model estimates of seasonal nesting abundance and different monitoring schemes that allow for accurate estimates or counts of seasonal nesting abundance; 4) SWOT’s recommendations for monitoring efforts based on 2), and 3); 5) modeling software available to SWOT Team data providers to generate annual nest estimates; and 6) the data classification system SWOT will employ to organize data according to whether they meet MDS.

2.1. Nesting data count types and conversions among count types

There are several different types of counts that can be reported by a project monitoring sea turtle nesting. (Please see **Appendix A – Glossary of terms**, for definitions of terms used in this report.) All count types can be considered proxies for total population abundance, and there are advantages and disadvantages to each, depending on the goals of the monitoring effort. Those count types include (in increasing order of resolution): number of activities (i.e., number of tracks, crawls, or body pits), number of eggs, number of clutches, and number of nesting females.

2.1a. Number of tracks/crawls:
advantage: no confusion about what is included in the count; less effort needed to perform surveys
disadvantage: does not account for variation in nesting success or clutch frequency; tracks from different nights must be distinguished by crossing off old/counted tracks

2.1b. Number of eggs:
advantage: can use eggs harvested or collected regularly to monitor relative abundance
disadvantage: does not account for variation in clutch size or clutch frequency

2.1c. Number of clutches:
advantage: only includes successful nesting attempts; more accurate than all activities to describe patterns in reproductive output
disadvantage: does not account for variation in clutch frequency; higher effort required than for counting tracks

2.1d. Number of females (i.e., uniquely identified individuals):
advantage: best metric for population abundance and trends, patterns in reproductive output and other biological factors
disadvantage: very high effort and large amount of resources required; information gathered only on females that nest in a given season, not on those skipping reproduction

Ultimately, the best count unit for determination of population abundance and trend is the actual number of individuals in the population being surveyed. Therefore, in the case of nesting populations of sea turtles, the number of nesting females is the preferred unit for survey efforts to count. However, logistical and financial constraints on most nesting beach projects preclude accurate, complete counts of uniquely identified nesting females. Therefore, in order to estimate number of nesting females from a different survey count unit, conversion factors are necessary.

For example, if a project reports total number of activities in a nesting season, one needs to have an estimate of the proportion of trawls/counts that resulted in successful nests, and then the clutch frequency per female to convert the original count to an estimate of the number of nesting females. The following schematic formulas demonstrate the conversion factors necessary to convert one count type to another, and we have compiled conversion factors for all species and for the different count types in **Appendix B - Conversion factors for different count types**. It is important to point out that conversion factors introduce additional error to abundance estimates, so SWOT requests that the original unit be reported along with any converted values.

2.1.1. Conversion factors among count types

2.1.1a. Number of clutches = total activities - failed nesting attempts

Required conversion factor: nesting success, i.e., the number of activities that result in oviposition.
This can be confirmed by the following methods: 1) directly observe oviposition (preferred method), 2) excavate fresh nest site to confirm eggs, 3) confirmed egg collection of a nest site, 4) observe hatchling emergence at a specific nest site (not recommended: inaccurate unless nesting sites known and protected completely).

2.1.1b. Number of clutches = total number of eggs / number of eggs per clutch

(this example is relevant for cases of comprehensive egg harvest)
Required conversion factor: number of eggs per clutch.
This can be confirmed by the following methods: 1) direct counts of eggs upon relocation of eggs to a new nest site (preferred method), 2) direct count of eggs during oviposition (not recommended: inaccurate counts).

2.1.1c. Number of females = number of clutches / number of clutches per female

Required conversion factor: number of clutches per female
This can be confirmed by the following methods: 1) identification via tagging of individual females and direct observation of clutches laid by individual females (preferred), 2) estimates of clutch frequency (inaccurate due to variation among females, not recommended unless estimates of clutch frequency are associated with high confidence and encompass inter-annual and inter-individual variation).

SWOT RECOMMENDATION: Whenever possible, conversion factors should be used on a site-specific basis. Researchers should obtain site-specific conversion factors, especially on nesting success (i.e. tracks/crawls to clutches) and report these with data provided to SWOT. However, when a conversion factor is unavailable for a study site, we recommend the use of the best estimate derived from a long-term study site within the same geographic region. If a regionally relevant conversion factor is unavailable, use the best species-specific estimate.

To show, compare, and analyze all contributed data together, SWOT will convert data in different count types to a standard unit (i.e. tracks/crawls), with the understanding that such conversions are oversimplifications and might not account for all biological variation. However, SWOT will accept data reported using any of the above units, along with information about monitoring effort and temporal description of the nesting season.

2.2. Detection of long-term population trends, inter-annual and intra-annual variation in abundance estimates

The ability to detect a trend from a time-series of count data depends on several factors, including (a) the number of years (i.e., nesting seasons) surveyed, (b) rate of change desired for detection (e.g. 1% 5%, 10%), (c) the coefficient of variation, or CV (i.e., technically is the standard deviation divided by the mean), which is a measure of the variability in the count data, for both inter-annual (CV_A) and intra-annual sampling error (CV_E), (d) power, and (e) confidence (Gerrodette, 1993).

As confidence in annual nesting abundance estimates increases (i.e. decreased sampling error associated with increased sampling), the number of years necessary to detect a given trend with the same power and confidence decreases (Jackson et al. 2008; Sims et al. 2008). Alternatively, in cases where there is high variability from year-to-year in nesting abundance (e.g. Australian green turtles; Limpus et al. 2003), more years of survey effort and/or more efficient survey effort are necessary to detect trends (Jackson et al. 2008; Sims et al. 2008). However, for trend estimates of sea turtle nesting abundances in general, several years, if not decades, of survey effort are necessary due to the sea turtle life history traits, e.g., long lifespan, non-annual reproduction, delayed sexual maturity (Chaloupka et al. 2008a).

Marc Girondot and Mathilde Russo conducted modeling that built upon previous work (e.g. Gerrodette 1993) to determine relationships among precision of trend detection, CV_E and CV_A for nesting data, and the required monitoring durations for different sea turtle species (Russo and Girondot (2009a); download the report: INSERT LINK). The report included inter-annual variations CV_As within and among sea turtle species (Broderick et al. 2001) to be able to provide recommendations for minimum thresholds of accuracy of nesting abundance each season for all species.

Table 1 below (from Russo and Girondot, 2009a) shows the number of years of monitoring required to detect trends with confidence ± 0.05 and power of 0.95 (Table 1a) and 0.80 (Table 1b) at three different levels of population trends (±0.01, ±0.05, ±0.10) for all sea turtle species. The report concluded that a minimum of 20 years of monitoring (at annual nesting abundance estimate CV= 0.2) is generally necessary to detect a trend of ±5% in a population of any species with a power of 0.8 to 0.95. This varies according to species, with detectable ±5% trends in roughly 20 years for loggerheads, which show the lowest amount of inter-annual variation, to more than 30 years in green turtles and olive ridleys, which typically show very high inter-annual variation. The report also concluded that detection of a slight trend (i.e. ± 1%) with high probability is extremely unlikely for any sea turtle species, and requires a minimum of 30 years of intensive (i.e. saturation) monitoring (Jackson et al. 2008).

Table 1 (*Table 2 in Russo and Girondot, 2009a*). The number of years of monitoring required to enable detection of trends of 10%, 5%, and 1% with confidence of ±0.05 and power of 0.95 (**1a**) and 0.80 (**1b**) of various precision levels (r). CV_E is the intra-annual variation in nesting abundance based on beach monitoring; CV_A is the inter-annual variation in nesting abundance for each species.

1a		Number of years of monitoring required to detect a trend with a power of 0.95		
Species	CV_E	r=±0.1	r=±0.05	r=±0.01
Some loggerheads	0.1	<10	<20	30
$CV_A=0.1$	0.2	10	20	>30
Loggerheads	0.1	10	20	>30
$CV_A=0.2$	0.2	<10	30	>30
Leatherbacks, Kemps, Flatbacks	0.1	>20	>30	>30
$CV_A=0.4$	0.2	>20	>30	>30
Olive ridleys, greens	0.1	30	>30	>30
$CV_A=1$	0.2	30	>30	>30

1b		Number of years of monitoring required to detect a trend with a power of 0.80		
Species	CV_E	r=±0.1	r=±0.05	r=±0.01
Some loggerheads	0.1	<10	<20	30
$CV_A=0.1$	0.2	<10	20	>30
Loggerheads	0.1	<10	30	>30
$CV_A=0.2$	0.2	10	20	>30
Leatherbacks, Kemps, Flatbacks	0.1	20	30	>30
$CV_A=0.4$	0.2	20	>30	>30
Olive ridleys, greens	0.1	20	30	>30
$CV_A=1$	0.2	20	>30	>30

SWOT’S RECOMMENDED VARIATION/ERROR IN ANNUAL NESTING ABUNDANCE ESTIMATES

To detect a ±5% trend in *ca*. 30 years (for all species; shorter period for species with lower CV), SWOT recommends that monitoring projects aim for **an annual abundance estimate of CV ≤ 0.2 (or 20% sampling error)** over a long period (i.e. decades, depending on the species, see above) in order to allow for robust estimates of abundance and trends.

3. ESTIMATES OF SEASONAL NESTING ABUNDANCE AND MONITORING SCHEMES THAT ALLOW FOR ACCURATE SEASONAL ABUNDANCE ESTIMATES

Prior to discussing acceptable monitoring protocols for nesting counts, it is important to reiterate that SWOT maintains the ‘gold standard’ for monitoring sea turtle nesting populations to be CMR studies in which every adult female turtle is tagged during the nesting season. However, keeping in mind that this is not possible at most sites, we have generated the following schemes as acceptable monitoring protocols for sea turtle nesting. Furthermore, the subsequent analyses and conclusions apply to several species and nesting phenologies (described below). However, there are some species, nesting beach types, or nesting patterns that these analyses do not include. We list alternative monitoring protocols for those particular examples in the next section (3.2. Alternative monitoring schemes for other scenarios).

Generally, any monitoring protocol that limits error in nesting abundance estimates within a season to < 20% will generate data of acceptable quality for SWOT. Below we describe several potential protocols for different types of nesting seasons and different species that, when applied appropriately, will yield estimates with acceptable error. Regardless of the monitoring protocol employed, the first factors that must be ascertained for a nesting site are 1) the species present (See **Appendix C** for species identification information) and 2) the temporal distribution of nesting activities, i.e. the 'shape' or phenology of the nesting season (e.g. typical bell-shape with low levels at the beginning and end of the season with a pronounced increase to peak levels roughly in the middle, year-round nesting without an identifiable peak, etc.). While bell-shaped nesting phenologies are most typical, identifying the beginning, peak, and end dates is critical for designing an efficient monitoring schedule. Thus, preliminary, year-round surveys of relatively low effort are a key first step in establishing nesting phenology at a site, upon which more sophisticated surveys can be based.

3.1. Determination of acceptable monitoring schemes for typical bell-shaped temporal nesting distributions

Russo and Girondot developed a second report (Russo and Girondot, 2009b; download report: http://seaturtlestatus.org/data/standards), which used a modeling exercise to determine different monitoring schemes that allowed for estimates with $CV_E \leq 0.2$. In this analysis, Russo and Girondot used datasets from projects with saturation coverage (i.e. essentially no nesting activities/females were missed in a nesting season) and that included different levels of absolute nesting abundance (i.e. high and low density nesting). Thus, we compared observed abundance values (actual number of activities/turtles in a season) to estimated abundance values based on various patterns of diminished coverage to see which scenarios did and did not meet the minimum threshold for error. Datasets were provided from Brazil, Costa Rica (Pacific Ocean), Suriname, and French Guiana.

The different scenarios were (a) random reduction of days of monitoring, with a probability of reduction between 0 and 0.95 at increments of 0.05; (b) random reduction of consecutive days of monitoring (a stretch of 1 to N-1 days), where N was 7 days, 10 days, or 15 days; and (c) 'heterogeneous' reduction of monitoring during the beginning and end of the season with maintained coverage during the period of peak nesting, or vice versa.

The report concluded that for scenarios (a) and (b), all time series tested allowed for removal probabilities in monitoring effort of up to 0.8 to achieve $CV_E \leq 0.2$. In other words, for all species and all nesting densities, **total seasonal nesting abundance estimates had $CV_E \leq 0.2$ when monitoring occurred *3 or more times per week* throughout the season**. The results did not change depending on when during a seven-day period the two or three days/nights of monitoring occurred, i.e. any combination of three days during a week provided estimates with sufficient confidence. These conclusions apply to typical bell-curve temporal nesting distributions as well as year-round nesting. However, comprehensive mid-season monitoring can also yield estimates with acceptable error (see below; Limpus et al. 2003; Jackson et al. 2008; Pendoley et al., in press). Obviously, the more frequently monitoring occurs, the less error will be associated with the abundance estimates.

For scenario (c), high reduction rates during the beginning and end of a nesting season – even if monitoring is still high during the peak – resulted in unacceptable error ($CV_E \geq 0.2$) using this modeling technique. The ideal scenario – i.e. compromise between highest precision (lowest CV_E) and least amount of monitoring – is where at least one night out of 10 is monitored during 2 months around the peak but at least 8 out of 10 nights are monitored during the beginning and end of the season (see **Appendix A** for a glossary of terms). Thus, **another acceptable monitoring scheme would be a heterogenous pattern of effort in which one count is obtained every 15 days outside of the known nesting season, 3 counts per week during the first month of the nesting season, one count per week during the middle of the nesting season (when peak nesting occurs, 8 weeks), 3 counts per week during the last month of the season, and finally one count per 15 days thereafter (Figure 1)**. Clearly, this method only applies to bell-shaped nesting seasons.

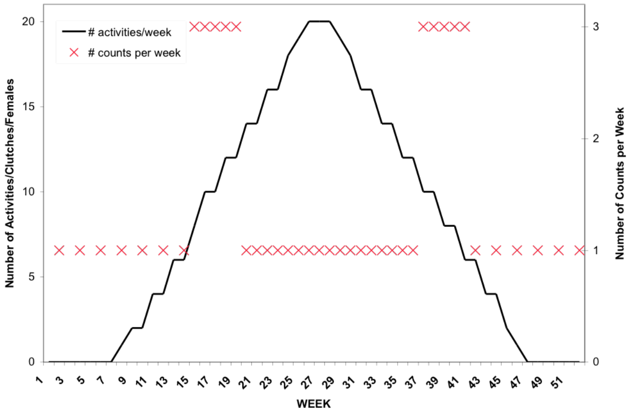

Figure 1. 'Heterogeneous' monitoring scheme described above wherein the number of counts per week varies with the temporal pattern of a nesting season.

3.2. Alternative monitoring schemes for other scenarios

The modeling approach above included high and low density nesting abundance data that were temporally distributed according to the bell-curve typical of many sea turtle nesting phenologies (Girondot 2010). However, it did not include examples from other nesting scenarios, such numerous sites used by the same nesting population, remote sites, and mass nesting sites. Here, we present alternative monitoring schemes for season types/species not included above.

1) ***Numerous sites used by the same nesting population.*** In situations where numerous, non-contiguous nesting beaches are used by the same population of nesting females, it is usually not possible to distribute resources to all sites to ensure maximum coverage. In these situations, *SWOT recommends either of two different protocols, depending on the situation: a) comprehensive monitoring of an index beach or beaches within each*

population/management unit (e.g. Limpus 2008) or b) diffuse coverage across multiple sites, followed by aggregate analysis of abundance and trends (Delcroix et al., in review).

The index beach approach assumes that annual abundance patterns observed via comprehensive monitoring of an index beach reflect a broader pattern that occurs at all other beaches used by the same nesting population of that species. An index beach might be selected because it hosts a significant proportion of the overall nesting population within a region or other defined unit. A key to selecting an appropriate index beach(es) is understanding the geographic boundaries around sites used by a nesting population, which can also be distinguished genetically from other nesting populations (Management Units, Limpus 2008). Index beaches can then be selected among the nesting sites within population boundaries to provide a basis for monitoring a widespread nesting population. Using this approach, monitoring of six sea turtle species has occurred over four decades in eastern Australia, allowing for robust estimates of seasonal and inter-annual abundance patterns.

However, in cases where the lifetime of beaches due to ephemeral coastal erosion and sand transport patterns is shorter than the time necessary to detect population trends, or nesting turtles show lower fidelity to particular nesting sites, or where several, dispersed sites host nesting, but none at significantly high levels to be index beaches, the index beach approach might not be appropriate (Girondot et al. 2007; Delcroix et al., in review). In such cases, a more favorable protocol would consist of monitoring many sites at low levels of survey effort, and then analyzing abundance estimates across sites. Delcroix et al. (in review) described such a method used to assess nesting of three species in the Guadeloupe archipelago, which includes over 150 known nesting beaches. In this case, researchers monitored roughly 40% of sites during a nesting season, with frequency of monitoring days increasing from early in the season through the peak, and then decreasing again to pre-peak levels toward the end of the season. This approach meant that personnel could obtain track counts from numerous beaches at the same point during the season by continually rotating the monitoring efforts from beach to beach. At the end of the season, track counts from different beaches were analyzed together to generate a total abundance for a species, and these estimates were used to estimate abundance trends over multiple seasons (Delcroix et al., in review). If a very remote site is of interest among the beaches, this site can be monitored for 10 days around the peak of nesting (i.e. a mid-season survey, see below) and analyzed with the other sites. When a common analysis is performed, the information about the shape of nesting season will come from the beaches monitored at low levels during the entire nesting season, complimenting the information from the remote site, resulting in a complete estimate of seasonal abundance.

2) ***Mid-season surveys and remote sites.*** Some situations (e.g. enormous populations, remote sites) preclude comprehensive censuses, and require sub-sampling that maximizes probability of encountering nesting females to enhance total abundance estimates. For such nesting sites where access and prolonged monitoring events are not possible due to logistical challenges, *SWOT recommends that projects follow methods described in Limpus et al. (2003) for mid-season counts*, briefly described here (see also Jackson et al. 2008; Sims et al. 2008). First, sporadic counts throughout a calendar year are necessary to establish

when the period of highest nesting density (i.e. the nesting season) occurs. If nesting occurs regularly year-round or nearly so, periodic counts outside of the period of highest density are also necessary. Next, once the temporal nesting pattern is known (i.e. months during which nesting occurs, including the period of highest density), a census should consist of complete counts of nesting females during a roughly two-week period (or longer, if possible) during the period of highest density nesting (Jackson et al. 2008; Sims et al. 2008). A mean value (± standard deviation) can then be calculated for number of females per night to provide an index for each nesting season (Limpus et al. 2003; Limpus 2008). This protocol is also applicable to mass nesting sites (see below). If intensive survey efforts are well-timed, i.e. coincide with the period of highest abundance of nesting females, sighting probability increases, thereby improving abundance estimates and shortening the required number of years for trend detection (Jackson et al. 2008; Sims et al. 2008).

3) ***Mass nesting sites.*** Several species (e.g. *Lepidochelys* spp., green turtles, flatbacks) have sites that host extremely high-density nesting. Because a complete census is impossible at these sites, alternative methods are necessary. The synchronous mass nesting behavior (i.e. *arribadas*) exhibited by the *Lepidochelys* spp., olive ridleys and Kemp's ridleys is such an example. *SWOT recommends that projects monitoring abundance and trends of these ridley arribada populations implement the 'strip transect in time' method described by Valverde and Gates (1999) (download here).* This method estimates the number of effective nesting females during a mass nesting event, and therefore avoids overestimates caused by more simplified counting procedures.

For mass nesting sites of other species (e.g. green turtles, flatbacks), *SWOT recommends that a census should consist of complete counts of nesting females during a two-week period during the period of highest density nesting* (Limpus et al. 2003; Jackson et al. 2008; Sims et al. 2008). A mean value (± standard deviation) can then be calculated for number of females per night to provide an index for each nesting season (Limpus et al. 2003; Limpus 2008).

It should be noted that **selection of monitoring protocol from the variety of protocols available must be based on the pre-defined goals of a monitoring project.** Delcroix et al. (in review) counted tracks and clutches, but did not attempt total tagging censuses because of logistical constraints and because they wanted to improve estimates of total nesting abundance and overall trend among several sites. In contrast, Pendoley et al. (in press) performed comprehensive tagging of nesting flatback females to determine survivorship and reproductive output of individual nesting females. Additionally, Whiting et al. (2008) employed a combination of track counts as well as tagging of nesting flatback females to identify temporal patterns in nesting as well as intra-individual female reproductive outputs. These examples and others presented in this section illustrate the importance of identifying the goals of a monitoring study prior to designing a nesting survey.

4. MODELING SOFTWARE AVAILABLE TO SWOT DATA PROVIDERS TO ESTIMATE ANNUAL ABUNDANCE

In most cases, complete or saturation coverage of sea turtle nesting activities during an entire season is not possible. Thus, partial counts are the most commonly reported raw survey data with respect to seasonal abundance patterns. However, while some partial counts are generated by sufficient monitoring effort from which to derive estimates of total seasonal abundance, other such counts are produced by insufficient monitoring effort from which to derive acceptable seasonal abundance estimates. Girondot (2010) reviewed published modeling approaches to generate seasonal abundance estimates from partial counts and developed a new statistical framework improving on previous models. In short, the Girondot (2010) approach is a parametric, asymmetric sinusoidal model that essentially fits a curve to sea turtle nesting data to generate estimated values from missing monitoring days (i.e. when no count was obtained due to no monitoring), thereby generating an estimate of total abundance for the duration of a season. This model also produces confidence intervals around the total abundance estimates to allow for evaluation of the uncertainty associated with the abundance estimates. For a detailed description of this modeling approach, please see Girondot (2010).

Because many data records provided to SWOT are partial counts, SWOT – thanks to Professor Marc Girondot – is making this abundance estimate model available to data providers via the SWOT website. Specifically, the model is available as a intuitive, user-friendly software interface that data providers can download to their own computers, enter a *.txt file of their count data (i.e. simply two columns: date and count), and the model will produce a figure with the total estimate (with 95% confidence intervals). These results will automatically be sent to the SWOT database manager to be included with all other data entered by that provider in the SWOT datasheets. In this way, SWOT data providers can obtain total seasonal abundance estimates for their beach or beaches that they can use in reports and other applications as well as confidence estimates to show the degree of uncertainty associated with these estimates due to the current monitoring scheme – and SWOT will also obtain total abundance estimates for the global database.

While this modeling software and its products will be available to all SWOT Team members, **SWOT specifically recommends that data providers with partial count data utilize the model to generate total abundance estimates**; section 6 below outlines specific recommendations about which projects must use the model. A 'user manual' or FAQ document is available with the model software to help with necessary clarifications, and the SWOT database manager will also be available to help data providers use the software effectively. **If data providers choose to use another modeling approach to generate abundance estimates, SWOT requires that it be a reputable method published in the scientific literature (e.g. Generalized Additive Models: Chaloupka et al. 2008a, Whiting et al. 2008; Horvitz-Thompson type estimates: Chaloupka and Limpus 2001, Pendoley et al., in press; linear regression: Chaloupka and Limpus 2001; Chaloupka et al. 2008a), and that it be reported and cited with the data contribution.**

5. SWOT'S RECOMMENDATIONS FOR MONITORING EFFORTS

Based on the discussions during the SAB meetings and the two reports described above, we are able to make the following sequence of recommendations for establishing a monitoring regime for sea turtle nesting beaches that do not currently meet the minimum threshold of $CV_E \leq 0.2$.

It is important to point out that we are aware that there are several sites where adequate nesting beach monitoring regimes are already in place, and already successfully characterize the nesting activity that occurs at those sites. In these cases, where variation in abundance estimates meets the threshold of $CV_E \leq 0.2$, *we are NOT recommending that those projects change protocols to conform to SWOT recommendations*.

Furthermore, we recognize that there are other published statistical techniques available for estimating sea turtle nesting abundance and trends in addition to the Girondot model (e.g. Generalized Additive Models: Chaloupka et al. 2008a, Whiting et al. 2008; Horvitz-Thompson type estimates: Chaloupka and Limpus 2001, Pendoley et al., in press; linear regression: Chaloupka and Limpus 2001; Chaloupka et al. 2008a). Abundance estimates (based on sufficient monitoring effort) that are generated using one of these other reputable methods also meet SWOT's standards.

One goal of this initiative was to provide recommendations for new or recently started projects and/or projects with limited capacity for monitoring so that their efforts – when undertaken in the long-term – can be compared to other datasets for the purposes of population trend and abundance estimation and conservation priority-setting.

In addition, these recommendations for minimum monitoring effort schemes allow individual projects to identify their resource needs (e.g. volunteers, equipment, money, etc.) to enhance their current efforts and productivity to a shared standard. Lastly, by providing the Girondot statistical modeling software freely to projects for use in analyzing their data, SWOT hopes to help projects with limited statistical capacity to generate total nesting abundance estimates, assess the quality of their monitoring data, and assure that the nesting data that they are collecting provide reasonable accuracy for future trend detection.

*****SWOT RECOMMENDATIONS FOR MONITORING EFFORTS*****

1) For any of the following monitoring recommendations to be implemented, **the species present (see Appendix C for identification information) and the nesting season type(s) (e.g. bell-shaped, year-round, etc.) must be determined**. Thus, if nesting season is unknown, a preliminary census of nesting activity is recommended. This preliminary census should at least consist of regular (e.g. weekly) morning counts of activities from the previous night(s) for a full calendar year (ideal) or at least should encapsulate the entire nesting season.

2) Once nesting phenology is known, **monitoring effort should follow the recommended protocol appropriate for the identified nesting season type; see above for details.** Any protocol that results in $CV_E \leq 0.2$ is acceptable. *Capture-mark-recapture methods on nesting beaches and in foraging areas are the 'gold standard' for estimating vital demographic rates, assessing abundance and diagnosing trends.*

3) All nesting activities should be counted during a monitoring event, and all zero values should be recorded. In other words, if monitoring occurs but no nesting attempts are recorded, a value of zero should be included in the overall season's monitoring report.

4) Because the minimum nesting activity unit is number of tracks/crawls, but count data come in various units, **site-specific conversion factors should be obtained to allow estimations of number of clutches (or females) from number of crawls**.

5) Abundance estimates should be made using a published method and reported with an estimate of the error associated with the value (e.g. Chaloupka and Limpus 2001; Chalopuka et al. 2008a; Whiting et al. 2008; Jackson et al. 2008; Girondot 2010; Pendoley et al. in press).

6) Periodic monitoring of the entire potential nesting area should be conducted roughly every 5 years to account for spatial shift in nesting activities. If spatial shift is apparent, boundaries of the study area should be adjusted to account for this shift.

6. SWOT'S CLASSIFICATION SYSTEM FOR DATA PROVIDED TO THE DATABASE

Because monitoring schemes vary tremendously among sea turtle nesting beach projects worldwide due to myriad factors (e.g. logistical constraints, species behavior, capacity, etc.), and we now have established recommendations for minimum standards for data provided to the SWOT database, we need to create a system to classify data based on these standards. This system will be used to filter data records in the SWOT database itself for future analyses of long-term trends and abundances, as well as for creating biogeography maps in SWOT Report. In addition, this system will provide clear guidance to data providers with respect to need for improvements to their current monitoring schemes. It is important to note that **ALL DATA contributed to SWOT will be accepted into and maintained in the SWOT database**. However, for display in maps (printed and online) as well as supply of data to external requests for analysis, this classification system will allow SWOT to discern data according to whether they meet MDS.

*****The SWOT data classification system*****

Level 1: *These data meet SWOT Minimum Standards, and are of the highest quality in the SWOT database. These data include total abundance counts, total abundance estimates or a reliable index of seasonal abundance. However, SWOT prefers that partial seasonal abundance counts that meet monitoring effort requirements be processed using the Girondot model (or another published modeling approach) to generate estimates of total seasonal abundance with confidence intervals.*

Level 2: *These data do not meet SWOT minimum quality standards, but will be included in the SWOT database. These data must be processed using the Girondot model (or another published modeling approach) to generate estimates of total seasonal abundance with accompanying error, in order to give data providers, and SWOT, a clear assessment of the degree of uncertainty that is associated with their data due to their monitoring effort.*

7. IMPLEMENTATION OF SWOT MINIMUM DATA STANDARDS

Implementation of SWOT-MDS will consist of a) retro-fitting standards to existing data in the SWOT database, and b) applying standards to future rounds of data collection.

To retro-fit the standards to existing data, we will use information about monitoring effort provided with each data record to classify each data record according to the two MDS Levels described above. We will then send the updated, pre-populated data forms to each data provider to have them verify our tentative classification. If they contend that a change in the classification of their data is merited, they must provide a report or other documentation that justifies this contention, i.e. clear description of their monitoring efforts that conforms to the MDS-Level to which the data record would be classified. If a data record is classified as MDS-Level 1, no further action is necessary from data providers, unless data providers download the Girondot model and use it to generate an estimate of total nesting season abundance with confidence intervals (or that they use another reputable method, see above), which will then be included with the updated data record. If a data record is a MDS-Level 2, the data provider will need to download the Girondot model and use it to generate an estimate of total nesting season abundance with confidence intervals (or use another reputable method, see above), which will then be used to gauge the difference between the project's current level of monitoring and the threshold for MDS. Quantifying this gap could help MDS-Level 2 projects decide how to re-allocate existing resources and/or could provide justification for additional fundraising to enhance monitoring protocols to improve to MDS-Level 1.

To apply the standards to future rounds of data collection, we will direct SWOT Team members to the new standards (described in detail on the SWOT website, and briefly in the call for new data contributions), and provide clear instructions about new steps requested of data providers, including self-classification of data provided (with justifications for classification) and download and use of the Girondot model, if applicable. Updated data forms will be sent to all previous data providers that will include pre-populated fields showing data already provided to SWOT report with new fields in need of completion by data providers. In addition, we have developed an online user interface for data providers to submit data using online forms on the SWOT website. We will incorporate into the user interface for data submission a brief 'survey' about monitoring schemes used by data providers that will allow for determination of MDS-Levels, which will accompany the submitted data into the SWOT database.

All relevant resources – several of which are Appendices to this document – will be available to SWOT Team members via the SWOT website. These resources will include this technical report, a concise version of the MDS for easy field application, the Girondot model, species identification resources, and scientific papers and reports related to the topics described within this document. In addition, SWOT data providers will be able to download data forms and/or submit data directly via a new online user interface, which represent multiple ways for SWOT Team members to provide data.

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9. APPENDICES

Appendix A. Glossary of terms

This glossary includes terms used throughout the manual and in future SWOT publications on minimum data standards. The definitions here are specific to the SWOT minimum data standards protocol.

Aborted Nest Attempt: An emergence onto the beach by a female sea turtle that includes attempted nest construction, but does not result in oviposition.

Beginning of nesting season: date when frequency of nesting activities increase above background levels during a defined nesting season

Body pit: depression made by nesting female sea turtle following emergence from the sea and prior to excavating an egg chamber; also refers to the depression made by a female turtle following oviposition and nest covering; feature used as a proxy activity to represent nesting attempt

Census: coordinated effort to monitor (i.e. count) sea turtle nesting activities during a certain period of time, usually associated during a defined nesting season

Clutches: a count of the number of egg clutches laid by female sea turtle(s) during the monitoring period.

Crawls: a count of observed number of emergences of female sea turtles from the ocean onto the beach during the monitoring period; also referred to as tracks. These counts may include successful oviposition events (egg clutches), aborted nest attempts, or false crawls.

End of nesting season: date when frequency of nesting activities returns to background levels during a defined nesting season.

Estimated number of clutches: An estimate of the number of sea turtle clutches laid in a season. Methods of estimation vary.

False crawl: an emergence onto the beach by a female sea turtle that does not result in any attempt to nest, but is a track/crawl only.

Monitoring effort: The level of effort used to monitor nesting on a given beach.

Nest: The physical structure created by a female sea turtle into which she deposits her eggs.

Nesting activity or attempt: any attempt by a female sea turtle to make a nest into which to lay eggs; if successful, includes a crawl, body pit, nest and eggs, but could be counted during a census even if eggs are not laid if oviposition (or lack thereof) is not directly observed.

Nesting beach: stretch of sandy coastline that supports consistent sea turtle nesting; for purposes of SWOT database and Minimum Data Standards, this refers to the portion of potential nesting habitat monitored for sea turtle nesting activities.

Nesting females: a count of unique observed nesting female flatbacks during the monitoring period.

Nesting population: a common group of nesting female turtles.

Nesting season: period of time during which nesting activities by a colony or population of nesting sea turtles occurs.

Nesting success: the proportion of nesting activities that result in successful oviposition.

Number of observations: count of observed nesting activities, which could include crawls, clutches, or female turtles.

Number of unique observations of turtles: count of distinct nesting females that are usually identified using individually numbered tags (external or internal).

Observation: nesting activity by a female sea turtle documented by a researcher during monitoring efforts

Oviposition: when a nesting female sea turtle deposits a clutch of eggs into a nest she excavated during a nesting attempt.

Peak of nesting season: period during described nesting season when highest frequency of nesting activities occurs

Potential nesting habitat: stretch of coastline that could support sea turtle nesting; in monitoring terms, this could include the study area (i.e. nesting beach) as well as areas outside.

Time series: count of nesting activities collected consecutively over a certain period of time that can be used to estimate a trend

Tracks: see also *crawls.*

Trend: pattern of increase, decrease or stable series of consecutive counts of nesting activities, or other units that represent population abundance.

Appendix B. Conversion factors for different count types

<SWOT_MDS_AppxB_conversion_factors.xls> (all species, by regions where possible)

Appendix C. Species Identification Guides: morphology

Taxonomy, external morphology, and species identification
Peter C.H. Pritchard and Jeanne A. Mortimer
http://mtsg.files.wordpress.com/2010/07/06-taxonomy-external-morphology-and-species-identification.pdf
Detailed descriptions of morphology of all life stages of all sea turtle species.

<SWOT_MDS_AppxC_crawl_IDs.pdf>
Descriptions of sea turtle nesting crawls (leatherbacks, green turtles, and loggerheads) INSERT LINK

Appendix D. Relevant Resources

Russo and Girondot reports: INSERT LINKS
Girondot (2010) Endangered Species Research paper: INSERT LINK

Research and Techniques Manual for the Conservation of Sea Turtles
Prepared by the IUCN Marine Turtle Specialist Group
Edited by Karen L. Eckert, Karen A. Bjorndal, F. Alberto Abreu-Grobois, Marydelle Donnelly

Download entire document:
http://mtsg.files.wordpress.com/2010/11/techniques-manual-full-en.pdf
en Español: http://iucn-mtsg.org/publications/manual-tecnicas/

Selected chapters:
Priorities for studies of reproduction and nest biology
James I. Richardson
http://mtsg.files.wordpress.com/2010/07/03-priorities-for-sutdies-of-reproduction-and-nest-biology.pdf

Population surveys (ground and aerial) on nesting beaches
Barbara Schroeder and Sally Murphy
http://mtsg.files.wordpress.com/2010/07/08-population-surveys-on-nesting-beaches.pdf

Population surveys on mass nesting beaches
Roldán A. Valverde and Charles E. Gates
http://mtsg.files.wordpress.com/2010/07/09-population-surveys-on-mass-nesting-beaches.pdf

Estimating population size
Tim Gerrodette and Barbara L. Taylor
http://mtsg.files.wordpress.com/2010/07/12-estimating-population-size.pdf