

## Editorial: The Zero Counts

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For several years, I have been developing methods to analyze the seasonality of nests or tracks of marine turtles during the nesting season (Girondot & Fretey 1996; Girondot et al. 2007; Girondot et al. 2006; Godgenger et al. 2009). As part of this, I have been in contact with many groups that shared their data for analysis. Often, a similar problem emerged in which the data collectors did not distinguish between a record of zero tracks (or nests) counted and a night (or day) in which no monitoring was conducted. In this paper, I will demonstrate that this lack of precision can create a strong bias as a result of time-series analysis. A methodology is proposed to use nevertheless such a data but with loss of precision.

Calculating the size of a marine turtle population is an essential step toward assessing population status and trends. There are various challenges associated with directly counting the total number of individuals in a marine turtle population, including cryptic life history stages, trans-oceanic dispersal, and non-sequential annual reproduction (Meylan & Meylan 1999). As a result, researchers have traditionally relied on enumerating numbers of nests laid by a population as an index of population size (Gerrodette & Taylor 1999). Because the adult females leave wide deep tracks on the beach after nesting, it is a relatively easy task to identify a sea turtle nesting crawl (Schroeder & Murphy 1999). A challenge in counting sea turtle nests for field workers is that nesting seasons usually span several months and turtles can lay their eggs on remote beaches that are difficult to access. As a result, for many programs engaged in sea turtle nest monitoring, there are often temporal and/or spatial gaps in monitoring effort that must be corrected for, particularly when comparing datasets from different years or populations.

Recently, several methods have been developed to fill spatial or temporal gaps. The general idea is to build a mathematical function that fits the known point and is used to estimate the missing points. The mathematical function can be parametric or obtained nonparametrically by local fitting. During the fit, a measure of distance (least-square or maximum-likelihood) is used to compare each known count with estimated one. During this fit, a zero count value is used exactly in the same way as any other count value and is informative. However, based on my personal experience with various databases from around the world, zero counts are often not reported and thus are potentially confounded with no monitoring for that day (or night). In cases where a zero and a lack of monitoring are not differentiated, the use of statistical methods to fill this gap in nest counts will produce a strong bias.

To demonstrate this effect, I will use a published complete time-series of leatherback nest counts obtained in 2001 in eastern French Guiana (Gratiot et al. 2006). A total of 2762 nests were recorded during daily patrols for the entire year (Figure 1A). For demonstration purposes, I removed all zero counts from this time series and then re-analyzed the revised data with gaps, to get an estimate of the total number of nests during this season (see annex and Girondot 2010). The resulting value was 3295 nests, with a

95% confidence interval between 3262 and 3328 nests (Figure 1B), which is nearly a 20% overestimate. This bias is a direct result of the algorithm, which replaced the missing data (i.e. nights originally with 0 counts) with values derived from the mathematical function.

To better deal with this situation, conditional probabilities must be used. First, recall that likelihood is proportional to the hypothetical probability that an event that has already occurred would yield a specific outcome. Given outcome  $A$ , use the likelihood function:

$$L(B|A)$$

to reason about parameters  $B$  ( $B$  refers to a multidimensional set of parameters and  $b$  to one particular set of values for  $B$ ). The likelihood of  $N_i$  nests observed the night  $i$  is then:

$$L(B|N_i) = \alpha P(N_i|B=b)$$

with  $\alpha$  being a proportionality constant.

From the previous situation, we know that among the events that have already occurred, those with 0 counts are discarded. When the  $N_i=0$  are discarded, a new likelihood function will be used:

$$L(B|N_i \neq 0) = \alpha \frac{P(N_i|B=b)}{1 - P(0|B=b)}$$

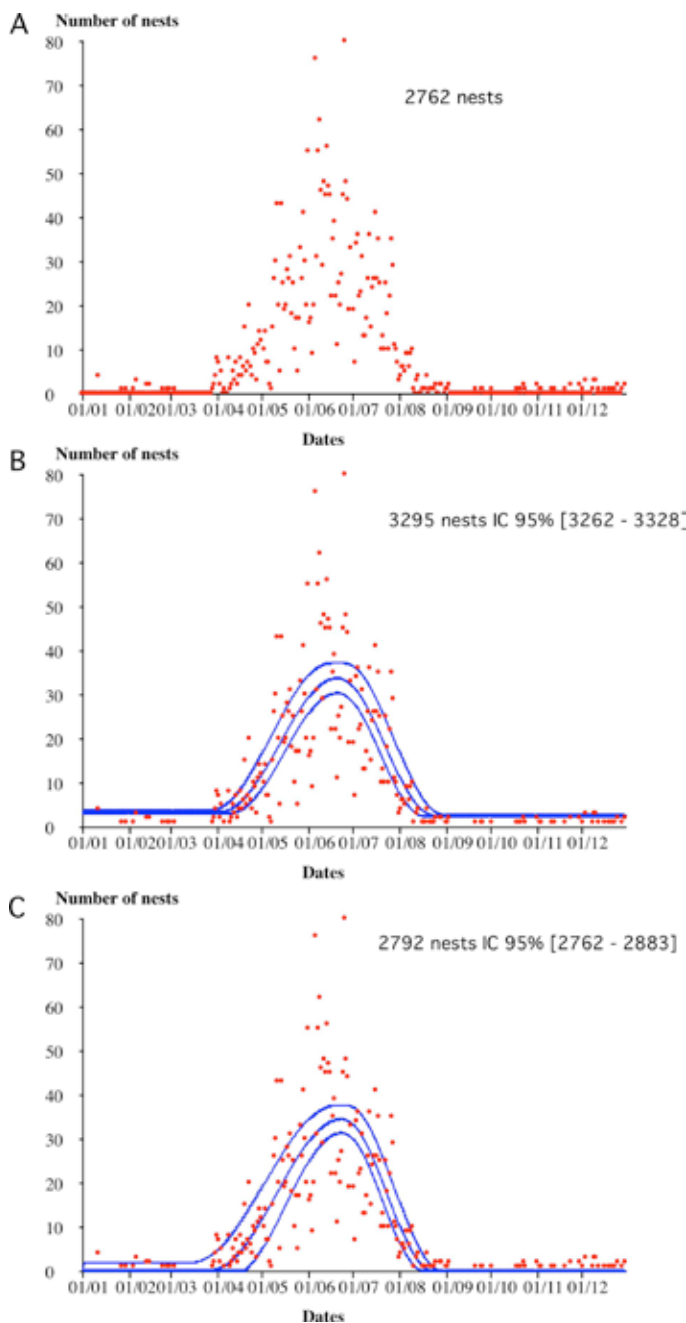
The set of parameters  $B$  maximizing this likelihood is then searched for. With this set of parameters, the final estimate for the total number of nests was 2792 nests, 95% confidence interval between 2762 and 2883 nests (Figure 1C); which is a better approximation of the true total (2762 in Figure 1A).

The new likelihood function allows one to circumvent the lack of information about nights monitored vs. zero nest (or track) counts. However, this estimation is done at the cost of precision of the estimate. The use of this likelihood function implies that all the nights with 0 counts are discarded.

Based on the various statistical tools available, it is not necessary to monitor marine turtle nests or tracks during the entire season in order to generate a good estimate of the nesting effort. However, information concerning the quality of the numbers produced during the monitored night is important. Quality of information is related to:

- Which nights were monitored?
- Does the final count represent all the nests or tracks of the entire night or could have some tracks been missed (e.g. they were erased by high tide)?
- Does the count total reflect the entire beach or only a portion?
- Are there other factors that affect the uncertainty of the final count (species misidentification, confusing true nests with false nests, counting tracks from previous nights)?

Perhaps in the future we may be able to manage all these uncertainties using adequate statistical tools, but for now they should be reported



**Figure 1.** Leatherback nest counts in 2001 in eastern French Guiana, from Gratiot et al. (2006). The blue curves represent the best-fit model with its 95% confidence interval, generated by bootstrapping 1000 times.

by field workers and not hidden.

Finally, there is a similar situation in which nesting effort is reported at the scale of an entire season. A beach that is monitored and zero nests are recorded is not the same as a non-monitored beach. It may seem ridiculous to report a zero nest count for Greenland beaches, as it was to report zero nests along beaches in continental France, before a loggerhead nest was found in 2006 (Sénégas et al. 2009). In the context of global climate change and possible establishment of new sea turtle nesting areas, it may be increasingly challenging to interpret maps where only beaches with >0 nests are reported. Such a situation can be seen in the wonderful maps produced by SWOT (<http://seaturtlestatus.org/learn/maps/all>).

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#### **Annex: Model for marine turtle nesting season analysis (Girondot 2010)**

Let  $t$  being a day, the number of nests deposited per night is modeled using system of equations:

The model requires at most 7 parameters that have a direct biological interpretation:  $MinB$  is the mean nightly nest number before the beginning of the nesting season;  $MinE$  is the mean nightly nest number after the end of the nesting season;  $Max$  is the mean number of nests at the peak of the nesting season;  $P$  is the date of the peak of the nesting season;  $F$  is the number of days being flat around the date  $P$ ;  $B$  is the date of the beginning of the nesting season;  $E$  is the date of the end of the nesting season

Likelihood function used here is a negative binomial distribution, which can be described as a combination of various Poisson distributions with different  $l$  values (Lawless 1987). The negative binomial distribution has broad applications as a model for count data, particularly those exhibiting overdispersion; i.e. with sample variance exceeding the mean (Lloyd-Smith

2007). In the biological literature, classic uses of the negative binomial distribution include analysis of parasite loads, species occurrence, parasitoid attacks, abundance samples and spatial clustering of populations.

$$\begin{cases} \text{if } t < B \rightarrow \text{Min}B \\ \text{if } t \in [B, P - F/2] \rightarrow \left( \left( 1 + \cos\left( \pi(P - F/2 - t) / (P - F/2 - B) \right) \right) / 2 \right) (Max - \text{Min}B) + \text{Min}B \\ \text{if } t \in [P - F/2, P + F/2] \rightarrow \text{Max} \\ \text{if } t \in [P + F/2, E] \rightarrow \left( \left( 1 + \cos\left( \pi(t - P + F/2) / (E - P + F/2) \right) \right) / 2 \right) (Max - \text{Min}E) + \text{Min}E \\ \text{if } t > E \rightarrow \text{Min}E \end{cases}$$

## Radar Beacon Balls as a Recovery Aid in Field Studies

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Field biologists that follow nest fates face a multifold challenge in repeated visits to the nesting beaches situated in zones of environmental flux or within obvious public domains. A need often arises for cryptic marking methods that do not clue predators or human vandals to an exact nest location (Bowen et al. 1976; Nilson 1985; Vacca and Handel 1988; Tuberville and Burke 1994; Burke et al. 2005). Furthermore, nest locations marked on dynamic beach environments are merely hopeful that storm events do not remodel the beach fore-slopes and dune terraces. Nevertheless, recording the distances and location of nests from multiple physical landmarks remains a standard procedure to document the final outcomes of nest site selection, nest fates, and hatching percentages.

Thus, a general problem statement is a search for technological solutions in fine scale geolocation, especially if involving the recovery of valuable research samples or data loggers. Redundant modes of nest relocation are also desirable for the standard triangulation methods or GPS locations. We report herein on relocation and detection trials for radar beacon balls buried in the sand to test a novel tool for effective recovery of sea turtle nests or data loggers.

Radar beacon balls enable fine-scale detections at 10-33 m distances under open range conditions, but were never intended for underground use or underwater detection. Therefore, field testing was required to specifically evaluate the detection performance at different distances, depths, and substrates (including wet vs. dry seasons and nourished vs. non-nourished substrates) that were challenges represented by sea turtle nesting beaches. Furthermore, the results should be relevant to other field studies seeking a cryptic marking method or tool for fine-scale geolocation.

We evaluated the RadarGolf™ balls and hand-held detectors (Radar Corporation, www.radargolf.com), which are directionally sensitive with a visual bar indicator for signal reception strength, accompanied by an audible pulse that increases as a detector approaches a target ball. The golf balls were regulation size (i.e. 4.2 cm diameter) and not significantly different than the average egg diameter of loggerhead turtle eggs (mean = 4.1 cm, s.d. = 0.1 cm, n = 10, for *Caretta caretta* eggs in Sarasota County, Florida). Balls were not modified except to write an institutional name and contact phone number on the surface. Nests or data loggers were triangulated

in a standard manner with a tape measure and marked each with a Radargolf ball located 1 ft landward from the nest chamber. Golf balls were presumed inert but we evaluated an equal number of nests with and without golf balls to evaluate any possible negative effects of inclusion of a ball on nest hatch rates.

At recovery 2-3 months later, the signal strength indicator and a changing rate of audible pulses pinpointed the vicinity of a buried golf ball. Searches approached from seaward to landward to maximize the sensitivity. Detection units were held perpendicular to the ground and at arm's reach, adjusting the angle slightly as needed when signal sensing to move toward the strongest signal alarm and indication. Distance and signal strengths were recorded as the number of indicator bars at 1 m steps while approaching the nest site.

We evaluated variation in detection distances and burial depths to simulate species ranging from shallow *Lepidochelys* nests to deeper *Dermochelys* nests. In a first experiment, beacon balls were tested on loggerhead nesting beaches of Dauphin Island, Alabama on 9/5/07 at varied depths (5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70, 80 cm depth) and for three zones used by turtles: upper, middle, and lower zones of the beach width to evaluate nests deposited in those areas or that might later represent a washed out nest scenario.

Distance	Upper Beach				Middle Beach				Lower Beach			
	Depth (cm)				Depth (cm)				Depth (cm)			
	20	40	60	80	20	40	60	80	20	40	60	80
0	9	9	7	4	9	9	5	5	9	9	7	7
1	7	7	3	2	8	4	3	3	8	6	4	2
2	5	4	2	0	5	2	2	2	5	5	2	0
3	4	1	0	0	3	1	0	0	3	3	1	0
4	2	0	0	0	1	0	0	0	2	1	0	0
5	0	7	0	0	0	0	0	0	0	0	0	0

**Table 1.** Comparisons of depth (20, 40, 60, 80 cm depth) and position along the beach (upper, middle, lower sections of a cross beach profile) on signal detection strength (number of signal bars from 0=low to 9=high) of a buried radar golf ball. Data collected on Dauphin Island, AL, distance in meters.