

Population Surveys on Mass Nesting Beaches

Roldán A. Valverde

Department of Biology; University of Michigan; Ann Arbor, Michigan 48109-1048 USA;

Tel: (734) 647-2604; Fax: 647-0884; email: roldan@umich.edu

Charles E. Gates

Professor Emeritus

Texas A&M University, 1002 Pershing, College Station; Texas 77840 USA; Tel: (409) 696-4327;

email: gates@stat.tamu.edu

Overview

The olive ridley turtle (*Lepidochelys olivacea*) is considered the most abundant sea turtle in the world (Limpus, 1995). This is due largely to a circumglobal distribution and the fact that this species nests in larger numbers than any other species of sea turtle. Mass nestings are observed in the Eastern Pacific, Indian Ocean and South Atlantic, where olive ridleys have been estimated to lay from 5,000 to as many as 150,000 clutches of eggs over the course of just a few nights (reviewed by Cornelius et al., 1991). This mass nesting behavior (also called *arribada* after its name in Spanish) is characterized by large numbers of nesting females, as well as by high nesting density and the, as yet unexplained, nesting synchrony of participating individuals.

In spite of the relative abundance of olive ridleys with respect to other sea turtles, historical population ranges have been severely reduced in some areas by over-exploitation, poor hatching success, and the incidental capture of adults in shrimp nets (Cornelius et al., 1991; Valverde et al., 1998). Long term conservation efforts focused on ridley mass nesting populations may have been successful in some cases (Márquez. et al., 1996), but the current status and recovery potential of these species can only be assessed using the long term monitoring of demographic variables, and by employing robust and reliable statistical methods for data analysis (e.g., see Carr, 1980; NRC, 1990; Meylan, 1982). The use of short term survey records to evaluate the status of a population is inadequate and ill-advised because of the natural variability of inter-annual nesting numbers (NRC, 1990; Limpus, 1995).

The survey of olive ridley populations is complicated by the fact that standard ground and aerial survey techniques (see Schroeder and Murphy, this volume) are ineffective when faced with overwhelmingly high *arribada* densities. While surveys of nesting females have been conducted at all known *arribada* beaches, providing at least rough estimates of demographic parameters for the most important olive ridley populations in the world, population estimates are largely based on biased or inadequate methodology (see Valverde et al., 1998, for a discussion).

A general criticism of all previous estimation methods is that they fail to provide a measure of variability in the parameters estimated, including their associated confidence intervals. This constraint makes it impossible to determine the reliability of the resulting estimates. Further, because the mathematical relationship among the estimates obtained by the different methods is unknown, direct comparison of data from the different rookeries is difficult at best. Finally, these various methods have never been validated against *arribadas* of known size. Until this is done, the accuracy of the estimates will remain uncertain.

The objective of this chapter is to describe a universal method designed specifically to estimate in the field the number of nesting females that participate in individual *arribada* events. Because this method is unbiased and has a minimal number of assumptions, it is expected to yield reliable and comparable estimates among different *arribada* rookeries. The technique has been fully described in a recent paper (Gates et al., 1996), to which the reader is referred for a more technical and detailed description.

Methodology

The technique described here is referred to as the “Strip Transect in Time Method”. Although other approaches are available (see Gates et al., 1996), this method appears to be the easiest to implement. For simplicity, we will refer to the strip transects as, simply, “transects”.

At least two transects, but no more than five, should be established per 100 m stretch of beach. At Gahirmatha, India transects are set up above the high tide mark (and are thus unaffected by tidal changes) by burying 1 m of a 2.5 m long, thick (~10 cm in diameter) stick. Three sticks are established along the longitudinal limits of the transects, one set per side, every 5-10 m between sticks depending on the extent of the available nesting area. A thread is tied on the sticks waist-high so as to join the three sticks along one side of the transect (contributed by Bivash Pandav, Wildlife Institute of India). The width of the transect can be fixed as desired. We suggest a transect width of 2 m. Because turtles may obliterate the high tide mark when crawling *en masse* up the beach, the approximate distance between this point and the closest transect stick can be noted prior to the *arribada*. This will allow surveying the same transect length every time.

We estimate that an observer should not survey more than 20 transects (at a rate of 2 transects/100 m) during one *arribada*, particularly on beaches exceeding 2 km in length. We recommend that the survey of all 20 transects/km take no longer than 45 minutes. On long beaches where turtles are known to shift laterally from *arribada* to *arribada*, transects should be established to include the entire stretch of beach known to accommodate nesting. Although surveys must be conducted regularly in the area of higher utilization during a given *arribada*, quick inspection of the transects outside the main area should be performed to ensure that no turtles are nesting there.

It is absolutely essential that only egg-laying females be counted during the transect surveys. To satisfy this condition for every female participating in the survey, egg deposition must be verified (such as by carefully excavating into the nest chamber). If no eggs are present, the animal should not be included in the tally. Only egg laying animals whose carapace centers are within the borders of the transects can be counted. The average time required for egg-laying (i.e., the elapsed time between the release of the first and the last eggs of a single clutch) must also be determined. At Nancite Beach the value is approximately 15 minutes. It is important that this parameter be de-

termined for each *arribada* until no significant variability is observed among *arribadas*. At this point, the same value can be used for future mass nesting events. An initial sample of some 30 individuals may suffice to accomplish the task.

Counts within the transects should begin at the onset of the *arribada*. The purpose of defining the beginning of the *arribada* is to avoid initiating the surveys on a night of heavy solitary nesting. There appears to be considerable variability among biologists as to when the onset of the *arribada* occurs. For the purpose of standardization, we suggest that the onset of the *arribada* be defined when 100 or more turtles are estimated to be on the beach simultaneously (Cornelius et al., 1991). It is unnecessary to predefine the end of the *arribada*.

Counts should always be initiated at one extreme of the nesting area and finished at the opposite end. Before initiating the surveys, a fixed time interval between counts must be established. This interval should remain constant throughout the duration of the *arribada*. If no nesting occurs within the transects, zeroes must be recorded. We suggest surveying the transects every two hours to allow surveyors time to examine all the transects and still have time to carry out other chores. The interval between surveys cannot be shorter than the effective time of nesting to avoid counting the same turtle more than once. An important modification from the original method we proposed (Gates et al., 1996) is that transect surveys need not be conducted during non-nesting hours (usually daylight hours). The reason for this is that zeroes are ignored when computations are done.

The available nesting area on the beach must be calculated; for example, by measuring the length of individual transects and multiplying their average value by the length of the stretch of beach used by the gravid females. Transect sticks can be used as a reference to define the beginning and the end of each transect. This will facilitate the measurement of the transects during or after the *arribada* has concluded.

Information collected during the survey should be organized to facilitate data processing. We recommend that a table including at least the parameters listed in Table I be utilized for recording data. The example given in the table illustrates the use of the formulas for one session of a three session *arribada*. Here, a “session” is defined as the consecutive hours in which turtles emerge synchronously to nest within a 24-hour stretch of an *arribada*. Usually, this period occurs at night as olive ridleys tend to nest during dark hours. With all the necessary information collected, an

estimate of the number of nesting turtles and various parameters can be obtained using the following equations (again, for details see Gates et al., 1996):

$$\hat{M} = \frac{AH}{2wtl} \cdot \frac{n..}{h}$$

with a variance of the estimated number of nesting turtles in the *arribada*:

$$\hat{v}(\hat{M}) \approx \hat{M}^2 \left[\frac{\hat{v}(n..)}{n..^2} \right]$$

If transects are approximately of equal length:

$$\hat{v}(n..) = \frac{m \sum \sum_{i=1,t} n_{ij}^2 \sum n_i^2}{m-1}$$

If transects are not of equal length:

$$\hat{v}(n..) = \frac{m^2 \sum_{i=1,t} \left[L \sum_{j=1,m} l_j n_{ij}^2 - \left(\sum_{j=1,m} l_j n_{ij} \right)^2 \right]}{L^2 (m-1)}$$

The associated 95% confidence interval is given by the approximation:

$$\hat{M} \pm \hat{M} \sqrt{\frac{\hat{v}(n..)}{n..^2}}$$

The coefficient of variation is given by:

$$CV(n..) = \sqrt{\frac{\hat{v}(n..)}{n..^2}}$$

The length of the session can be calculated using the simple equation:

$$k = t * r$$

Where:

\hat{M} = estimated number of nesting females;

A = total available nesting area (m²);

H = duration of the *arribada* (min);

w = half-width of transect (m);

t = number of sampling periods;

$\sum l_j = l = L$ = sum of the lengths of all transects (m);

$n..$ = sum total of egg laying turtles counted;

\bar{h} = average time spent by turtles laying eggs (min);

$\hat{v}(\hat{M})$ = estimated variance of estimate;

$\hat{v}(n..)$ = estimated variance of the total number of egg-laying females;

m = number of transects;

n_{ij} = number of egg laying turtles in the i^{th} period and the j^{th} transect;

n_i = sum total of turtles in all transects in the i^{th} period;

k = length of session (min);

r = inter-sampling interval (min).

When analyzing the *arribada*, the statistics must be calculated independently on each individual session of continuous monitoring as variances and other parameters are not directly additive. Nonetheless, the estimates of number of females can be summed to provide a global estimate of number of nestings.

We recommend that standard errors and confidence intervals be reported, rather than the variances, which tend to be large. In addition, the units of the different variables included herein are different from those of our previous publication (Gates et al., 1996). This modification is intended to facilitate manual calculations in the field. Alternatively, a computer program has been written and transformation of the units may be necessary. Copies of the program, as well as complementary information on its use, are freely available and may be obtained from the author (CEG). The program includes a simulation option that permits a comparison of standard errors obtained from real data with those of an idealized population.

Limitations

The method described here is easy to implement, involving few logistical hurdles. Nevertheless, the method may not be suitable to estimate number of nesting females under all conditions. For example, low numbers of nesting animals, such as are found on beaches where solitary nesting occurs, reduces the accuracy of estimates. As a general rule, the method is only applicable in circumstances where more than 1,000 turtles nest synchronously. In cases of lower densities, more orthodox surveying approaches (e.g., Schroeder and Murphy, this volume) may be advisable. Our method, however, is self-compensating since very large confidence intervals (probably encompassing zero) will inevitably result when sampling very small populations, thus rendering the estimates highly dubious.

A drawback of carrying out computations per session is that the number of turtles during some sessions may be too low to allow statistically sound

results. Thus, the value of the analysis per session as shown in this paper is to provide an example of the correct use of the formulas and to manually generate estimates in the field with the assistance of a hand calculator where power may not be available.

Sources of Error

Errors result from the erroneous classification of turtles. For example, wrongly presuming a turtle to have nested (laid eggs) or prematurely including turtles engaged in the construction of an egg chamber. These errors are difficult to quantify. The best solution is to insist that surveyors stringently conform to the rule that the presence of eggs must be verified in every case. Errors result from the incorrect measurement of nesting and sampling areas (transects). Because of the expansion factors included in the formulas used (see above), these mistakes may induce significant deviations from accurate population estimates. Again, efforts must be made to ensure proper measurements. It is important that the inter-sampling interval be maintained constant throughout the *arribada* to ensure consistency in the collection and processing of data.

Lastly, determining the exact time of the onset of an *arribada* can be problematic. Large deviations may have significant effects on the estimates obtained. It is advisable that experienced observers determine these times. Nonetheless, under most conditions, a deviation of one or two hours from the true value of this parameter may not have a significant impact on the final estimations.

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Table 1. Strip Transect in Time Method. An analysis of the first session from a hypothetical survey are shown to illustrate method.

Session	Day	Time	Transect Number																			n _{i..}	
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19		20
Observer:			M																			9,652	
Average egg-laying time (min)			13.17																			24,200	
Total duration of arribada (min)			360																			1	
Number of sampling periods			3																			376.96	
Total available nesting area (m ²)			24,200																			9,652	
Half-transect width (m)			1																			2,068	
Total length of transects (m)			376.96																			13,786	
																						5,515	
I	1	12:00 AM	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
		2:00 AM	0	0	0	0	0	0	0	0	0	3	2	3	2	2	2	0	0	2	0	0	2
		4:00 AM	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	1	0	1
		6:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		8:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		10:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		12:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		6:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	8:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
II	2	10:00 PM	0	0	0	0	0	0	1	4	4	1	2	1	0	0	0	0	0	0	0	0	0
		12:00 AM	0	0	0	0	0	0	1	0	2	1	3	2	1	0	0	1	0	0	2	0	1
		2:00 AM	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	1	0
		4:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		6:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		8:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		10:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		12:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
III	3	12:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		6:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		8:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		10:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		12:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4:00 AM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		6:00 PM	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Calculations for Session I data

$$\hat{M} = \frac{AH}{2wtl} * \frac{n_{..}}{h} = \frac{(24,200 \text{ m}^2)(360 \text{ min}) * 33 \text{ turtles}}{2(1 \text{ m})(3)(376.96 \text{ m})} * \frac{13.17 \text{ min}}{13.17 \text{ min}} = 9,651 \text{ turtles}$$

$$\hat{v}(n_{..}) = \frac{m \sum \sum_{f=1}^m n_{fj}^2 - \sum_{f=1}^m n_{f.}^2}{m-1} = \frac{20(1^2 + \dots + 1^2) - (2^2 + 23^2 + 8^2)}{19} = 50$$

$$\hat{v}(\hat{M}) \approx \hat{M}^2 \left[\frac{\hat{v}(n_{..})}{n_{..}^2} \right] \approx (9,651)^2 \left[\frac{50}{(2+23+8)^2} \right] \approx 4,276,483$$

$$S.E. = \sqrt{\hat{v}(\hat{M})} = \sqrt{4,276,483} = 2,068$$

$$U.C.L._{.95\%} = \hat{M} + 2\hat{M} \sqrt{\frac{\hat{v}(n_{..})}{n_{..}^2}} = 9,651 + 2(9,651) \sqrt{\frac{50}{1,089}} = 13,786$$

$$L.C.L._{.95\%} = \hat{M} - 2\hat{M} \sqrt{\frac{\hat{v}(n_{..})}{n_{..}^2}} = 9,651 - 2(9,651) \sqrt{\frac{50}{1,089}} = 5,515$$

$$CV(n_{..}) = \sqrt{\frac{\hat{v}(n_{..})}{n_{..}^2}} * 100 = \sqrt{\frac{50}{1,089}} * 100 = 21.4\%$$