

Research and Management Techniques for the Conservation of Sea Turtles

Prepared by IUCN/SSC Marine Turtle Specialist Group

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Preface

In 1995 the IUCN/SSC Marine Turtle Specialist Group (MTSG) published *A Global Strategy for the Conservation of Marine Turtles* to provide a blueprint for efforts to conserve and recover declining and depleted sea turtle populations around the world. As unique components of complex ecosystems, sea turtles serve important roles in coastal and marine habitats by contributing to the health and maintenance of coral reefs, seagrass meadows, estuaries, and sandy beaches. The *Strategy* supports integrated and focused programs to prevent the extinction of these species and promotes the restoration and survival of healthy sea turtle populations that fulfill their ecological roles.

Sea turtles and humans have been linked for as long as people have settled the coasts and plied the oceans. Coastal communities have depended upon sea turtles and their eggs for protein and other products for countless generations and, in many areas, continue to do so today. However, increased commercialization of sea turtle products over the course of the 20th century has decimated many populations. Because sea turtles have complex life cycles during which individuals move among many habitats and travel across ocean basins, conservation requires a cooperative, international approach to management planning that recognizes inter-connections among habitats, sea turtle populations, and human populations, while applying the best available scientific knowledge.

To date our success in achieving both of these tasks has been minimal. Sea turtle species are recognized as “Critically Endangered,” “Endangered” or “Vulnerable” by the World Conservation Union (IUCN). Most populations are depleted as a result of unsustainable harvest for meat, shell, oil, skins, and eggs. Tens of thousands of turtles die every year after

being accidentally captured in active or abandoned fishing gear. Oil spills, chemical waste, persistent plastic and other debris, high density coastal development, and an increase in ocean-based tourism have damaged or eliminated important nesting beaches and feeding areas.

To ensure the survival of sea turtles, it is important that standard and appropriate guidelines and criteria be employed by field workers in all range states. Standardized conservation and management techniques encourage the collection of comparable data and enable the sharing of results among nations and regions. This manual seeks to address the need for standard guidelines and criteria, while at the same time acknowledging a growing constituency of field workers and policy-makers seeking guidance with regard to when and why to invoke one management option over another, how to effectively implement the chosen option, and how to evaluate success.

The IUCN Marine Turtle Specialist Group believes that proper management cannot occur in the absence of supporting and high quality research, and that scientific research should focus, whenever possible, on critical conservation issues. We intend for this manual to serve a global audience involved in the protection and management of sea turtle resources. Recognizing that the most successful sea turtle protection and management programs combine traditional census techniques with computerized databases, genetic analyses and satellite-based telemetry techniques that practitioners a generation ago could only dream about, we dedicate this manual to the resource managers of the 21st century who will be facing increasingly complex resource management challenges, and for whom we hope this manual will provide both training and counsel.

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Estimating Population Size

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Introduction

Estimating population size is important for several reasons. An estimate of population size is critical for science, conservation, and management. Many threats to turtle populations cannot be evaluated unless we have an estimate of population size. For example, if we know that 100 turtles per year die in fishing nets, is this a serious threat? If population size is 1,000 turtles, the deaths of 100 turtles per year is indeed a very serious and immediate threat, but if population size is 1,000,000 turtles, the threat is much less serious. Estimating population size is also important for assessing the risk of extinction or extirpation. Small populations are more likely to become extinct than large ones.

Because of sea turtle life history characteristics, it is nearly impossible to estimate total population size directly for any sea turtle population. Instead, we estimate the size of only one part of the population, such as adults (typically, adult females). Because juvenile turtles are pelagic, dispersed over a wide area, and difficult to detect in the water, it is extremely difficult to estimate the size of this part of the population. Therefore, when discussing population size, it is important to be clear about which part of the total population is being estimated and the assumptions underlying any extrapolation to the total population (*e.g.*, 1:1 sex ratio among adults).

Another important distinction is the difference between relative and absolute population size estimates. Absolute population size is the actual number of animals. Relative population size, also called an index of population size or an index of abundance, is a number proportional to absolute population size. Unless the factor of proportionality is known, there is no way to convert an estimate of relative abundance to an es-

timate of absolute abundance. Nevertheless, estimates of relative abundance can be very useful. The most common example is the use of nest counts as an index of abundance. Such data can be extremely valuable as a way of detecting trends in abundance over long periods of time. Estimates of relative population size are usually simpler and less expensive to obtain than estimates of absolute population size. However, estimates of relative population size also require more assumptions; if these assumptions are violated, the estimates may be biased.

Bias and Precision

The quality of any estimate has two measures: bias and precision. It is important to know the distinction between these terms. Consider an analogy of shooting at a target (Figure 1). When Figures A and B are compared, we see that both are precise (*i.e.*, the shots are not widely scattered), but the shots in B tend to be too low. In statistical terms, the shots in B are (negatively) biased. Consider the challenge of estimating the number of turtle nests when the beach is not walked frequently enough to tally every nest. We may know that a few were missed and that our count is therefore negatively biased, but that our count is still very close to the true number. To improve accuracy, we could adjust the sights of our "estimation gun" by applying a correction factor. Now consider two guns: a pilgrim's musket and a sniper's rifle. The rifle shoots with great precision and is equivalent to an abundance estimate with very low variance, such as a nest count in an intensely surveyed area. Even an expert marksman, however, would be considerably less precise with the musket; repeated attempts with the musket result in a more diffuse pattern than with the rifle (Figures C and D). Statisticians measure the

precision of an estimate by its variance; thus, the shots in C and D have high variance (low precision) relative to A and B. This poor precision is equivalent to abundance estimates made for aerial surveys of turtles at sea where they are rare, hard to see, and some unknown proportion is beneath the surface. If we did not correct for the proportion not visible, the result would be an estimate that was both imprecise and biased (Figure D).

When decisions are made using estimates, we should consider the quality of the estimate. Therefore, each estimate of any quantity, such as population size, should be accompanied by a consideration of its bias and an estimate of its variance. Variance is important because it is a measure of the certainty (precision) of the estimate. If an estimate of population size has high variance, it means that we are not very certain of its value, and any management decisions based on it should be made cautiously. In their seminal paper on management of living resources, Holt and Talbot (1978) advocate that the less precise the data are, the more conservative the management decisions should be. For example, suppose a population of turtles is declining. If our estimates of abundance have high variance, it is likely that we will not be able to detect that decline statistically. Without an estimate of variance, the data could be interpreted as indicating no decline, and consequently no management action would be taken. On the other hand, if we

do have an estimate of variance, we can calculate the probability of being able to detect the decline (Gerrodette, 1987, 1993; Taylor and Gerrodette, 1993).

The importance of bias depends on the question under consideration. For example, if we are interested in trends in the abundance of adult females, a relative index of abundance may suffice (bias is unimportant as long as it is constant). On the other hand, if we want to know if a certain mortality level is too high (*i.e.*, unsustainable at the population level), we would certainly want to remove bias and have an estimate of absolute abundance.

Methods of Estimating Population Size

Estimating Population Size from Beach Counts

From the number of nests, the number of adult turtles (male and female) can be estimated as

$$\hat{N} = \left(\frac{\text{number}}{\text{of nests}} \right) \div \left(\frac{\text{no. nests}}{\text{per female}} \right) \div \left(\frac{\text{proportion of}}{\text{females nesting}} \right) \\ \div \left(\frac{\text{proportion}}{\text{of females}} \right) \div \left(\frac{\text{proportion of}}{\text{beaches covered}} \right).$$

Obviously this involves the estimates of many separate quantities. The estimation of each factor in

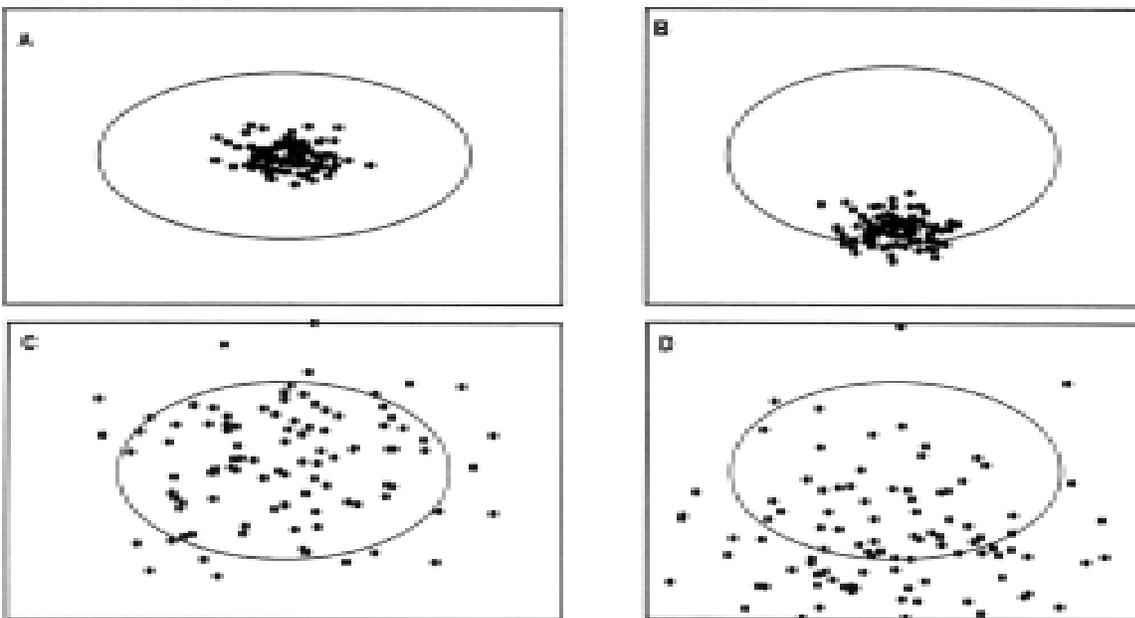


Figure 1. Shot patterns on targets demonstrating (A) precise and accurate (non-biased) shots, (B) precise but inaccurate shots, (C) imprecise but accurate shots, and (D) imprecise and inaccurate shots. (Source: White et al., 1982).

the equation is covered in other sections of this manual. The variance of \hat{N} is a sum of the variance of each factor (assuming independence). The bias in \hat{N} similarly depends on the biases of each of the factors in this equation. However, some are more likely to contribute bias than others. For example, if a complete nest count is attempted, the count is likely to be slightly negatively biased because a few nests will be missed. On the other hand, incorrectly estimating the proportion of beaches covered could contribute large positive or negative biases.

Estimating Population

Size from Transect Surveys

Estimating population size from transects is a widely-used method in wildlife studies. A standard reference is the monograph by Seber (1982). Small aircraft can be used to count nests on beaches (see Schroeder and Murphy, this volume). Sighting surveys from planes or ships can also be used to estimate turtle abundance at sea. Because turtles tend to occur at low density and are hard to see, such surveys will tend to produce few sightings, but they can be conducted in conjunction with surveys for other species such as sea birds or marine mammals. To estimate absolute abundance, such surveys must also correct for turtles which are submerged at the time of the survey and are not available to be seen.

There are two basic types of transect surveys. Strip transects assume that an area of a certain width has been surveyed and that no turtles within a certain distance of the trackline have been missed. This will not be true unless the width of the strip is very narrow, in which case the survey will cover only a small area and not be very efficient. Line transects (Buckland *et al.* 1993), a newer and superior method, have largely replaced strip transects. Line transects make efficient use of all sightings, the statistical models are well developed, and free software is available (see footnote). However, line transects require a minimum of about 30 sightings, and preferably more than 50, to estimate population size. Also, while strip transects simply require the number of turtle sightings that occur along a transect, line transects also require that the distance of each sighting

from the trackline be measured. That is, line transects require extra information, but if this extra information is available, better estimates are possible.

For transect surveys, the number of turtles is estimated by

$$\hat{N} = \frac{n}{2wlg} A,$$

where n = number of turtle sightings, l = length of transects, w = width of transect on one side of trackline, g = fraction of turtles visible, and A = size of the study area. The fundamental difference between line- and strip-transect surveys is that, in a strip transect, the width w is simply chosen, while in a line transect, w is estimated from the data and is called an “effective strip width.” The variance of \hat{N} is estimated from the variance of replicate transect lines, by assuming some distribution for n (usually Poisson), or by a computer intensive technique called bootstrapping (Efron and Tibshirani, 1993).

Estimating Population Size by Mark-Recapture

Mark-recapture is another common technique for estimating abundance in wildlife studies. Several comprehensive papers explain mark-recapture theory, discuss assumptions, and demonstrate the technique (Cormack, 1979; Seber, 1982; Pollock *et al.*, 1990). In this context, “marking” or “tagging” means any method of identifying individual turtles and “recapture” means any method of re-identifying a marked individual at a later time. Individual turtles might be “tagged” and “recaptured” photographically, for example, by unique patterns on carapaces or heads. Tagging is widely used in sea turtle studies, mostly to obtain information on growth, movement, and population dynamics (Chaloupka and Musick, 1997).

Mark-recapture models come in a variety of forms. “Closed” models assume that no births, deaths, immigration, or emigration occur during the period of study, and so are applicable only for discrete populations of turtles within a relatively short period of time (within one nesting season, for example). “Open” models, on the other hand, allow populations to change in size during the period of study. Open mark-recap-

Authors' note: Software referred to in this chapter may be obtained at no cost by writing to the Colorado Cooperative Fish and Wildlife Research Unit, Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, CO 80523, USA. Software may also be obtained through the Internet at <http://nmml.afsc.noaa.gov/distance/map.htm> for line-transect analyses and at <http://www.cnr.colostate.edu/~gwhite/software.html> for mark-recapture analyses.

ture models, often referred to as Jolly-Seber-Cormack models after the original developers, estimate survival rates as well as abundance. There may be a single or multiple periods of tagging, and a single or multiple periods of recapture. In general, population size is estimated by assuming that the proportion of marked animals in a sample is the same as the proportion of marked animals in the population. The original simple estimator, proposed by Petersen 100 years ago for a closed population with a single period of tagging and a single period of recapture, is

$$\hat{N} = \frac{nM}{m},$$

where \hat{N} is the number of animals tagged in the first period, and M is the number of animals captured in the second period, of which m are tagged. More complicated models involve the simultaneous estimation of population sizes and survival rates in each year, and no simple equation can be written for the estimator of population size. However, free software is available for carrying out such analyses, including the variances of the estimates (see footnote).

The general assumptions of mark-recapture analysis are: (1) there are no births, deaths, immigration, or emigration during the period of study (although this assumption can be relaxed for open population models, as noted above); (2) all animals have the same probability of being tagged; (3) tagging does not affect the probability of being recaptured; (4) tags are not lost, and tags, when present, are always detected; and (5) recaptured animals are a random sample of the population.

When applying mark-recapture analysis to sea turtle populations, there are several important issues. One is tag loss (assumption #4). Any kind of “tag” may be lost, and estimating rate of tag loss is an important part of a mark-recapture analysis. Of course, it is good if tag loss is low, but it is more important that tag loss be consistent. The interpretation and analysis of mark-recapture data is far more difficult if, over the years, different kinds of tags have been used, tags have been applied in different positions, and tagging has been carried out by different people with varying skill and experience. With long-lived animals such as sea turtles, these kinds of variation are inevitable, but the importance of keeping this variation to a minimum cannot be overemphasized. To interpret mark-recapture data properly, specific studies need to be carried out to estimate tag loss (*e.g.*, McDonald and Dutton, 1996).

Another important issue is the randomness of samples (assumptions #2 and #5). At the beginning of a study, it is important to define the population that is to be estimated, and to take steps to tag and re-sample the population randomly. If turtles are tagged on a certain beach, for example, is the population being estimated restricted to that beach? If turtles are visiting other beaches, and turtles from other beaches are occasionally coming to the beach being studied, then the population being estimated is not for that beach only, but for a larger area. Also, is the beach under study a random sample of the whole population? It is important to consider these questions, and to test them if possible. Unlike transect studies, it is not important that effort in mark-recapture studies be constant. The tag and recapture sample sizes can be different. Methods of capturing turtles during the tagging and recapture phases can be different. In fact, there may be some advantage in having different methods during the two phases because there may be slightly different biases. The most important thing is to obtain a random sample. Simply tagging and recapturing a large number of turtles gives meaningless data (at least for abundance estimation) unless the assumptions of the analysis are fulfilled.

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