Research and Management Techniques for the Conservation of Sea Turtles
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Techniques for Measuring Sea Turtles

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Sea turtles are measured to accomplish a number of objectives, and there are many technique and equipment options. The objectives may dictate different levels of accuracy and precision (see below) as well as the appropriate methods and equipment to be used. Sea turtles are measured on nesting beaches to relate body size to reproductive output, to determine minimum size at sexual maturity, and to monitor nesting female size for a particular rookery. Sea turtles are measured on foraging grounds to determine frequency of size classes of turtles present as well as to monitor growth rates. The size frequency of a population is an important parameter of that population's demographic structure. Analyses of growth rates can indicate habitat quality and physiological status.

Accuracy and Precision

Project objectives will determine the levels of accuracy and precision necessary to accomplish the project and thus the equipment to be used. "Accuracy is the nearness of a measurement to the actual value of the variable being measured. Precision is not a synonymous term, but refers to the closeness to each other of repeated measurements of the same quantity" (Zar, 1984).

There are few studies of precision in sea turtle measurements (Bjorndal and Bolten, 1988, 1989; Frazier, 1998; Shoop and Ruckdeschel, 1986; van Dam and Diez, 1994). In all reports and publications, measurement precision should be included. One method of reporting measurement precision is to present the mean, standard deviation and/or standard error, and range of the absolute difference between pairs of repeated measures on a series of turtles (sample size should be reported) that span the size range of turtles in the study population (Bjorndal and Bolten, 1988, 1989; van Dam and Diez, 1994). Precision may vary for each type of measurement (Bjorndal and Bolten, 1988, 1989; Shoop and Ruckdeschel, 1986). Precision can be increased by having one individual take all measurements. If that is not practical, the precision of members of the research team should be compared over time (Bjorndal and Bolten, 1988, 1989; Shoop and Ruckdeschel, 1986).

Measurements should be made in metric units; conversion to metric units (necessary for publications) from other systems results in misrepresentation of degrees of accuracy and precision. For example, converting measurements taken to the nearest eighth of an inch to millimeters does not correctly represent the level of accuracy of the measurements. Calipers, tape measures, and scales should be calibrated frequently.

Scute Nomenclature

There is inconsistency in the nomenclature used to describe the elements of the carapace (for a discussion see Pritchard and Trebbau, 1984). The nomenclature suggested by Pritchard and Trebbau (1984) is recommended and can be summarized as follows. Scutes are cornified plates forming the surface of the shell. Vertebral scutes are the large scutes along the midline of the carapace. Costal scutes are the large scutes forming a longitudinal series on each side of the vertebrals. Marginal scutes are the numerous small scutes around the edge of the shell, except the median scute on the midline anterior to the vertebrals (which is the nuchal scute) and the paired posterior marginals (which are the supracaudal scutes).

Measurement Procedures: Linear Measurements

Linear measurements can either be taken with calipers (straight-line measurements) or with a flexible tape measure (curved measurements). The decision is one of accuracy, precision, cost, and convenience. Curved measures tend to be less accurate and less precise (Bjorndal and Bolten, 1989; Frazier, 1998; Pritchard *et al.*, 1983; Shoop and Ruckdeschel, 1986) because of irregularities and epibionts on the surface of the turtle's shell. Also, in the juveniles of some species, the vertebrals are keeled, and the posterior carapace in some species has a steep change in slope which make curved carapace length difficult to measure with accuracy and precision. However, flexible tape measures are significantly less expensive than calipers and are significantly more convenient to carry and maintain.

There are great differences in the quality of calipers, not only in the mechanism and fit of the arms sliding on the main rail, but also in the calibration and scale of measurements *(e.g.*, centimeters versus millimeters). Tree calipers that have very long arms should be modified so that the arms are only as long as necessary. Excess arm length makes calipers more cumbersome to use and reduces both accuracy and precision. Both arms of the calipers must be of equal length so that when measurements are taken, the measurement endpoints on the turtle are at the same distance from the main rail of the calipers. Calipers should be selected for appropriate accuracy and precision and should have metric units.

Flexible, fiberglass tape measures are better than metal tape measures for curved measurements because they more closely conform to the shape of the shell and do not corrode. Cotton tape measures should be avoided because they stretch easily. Tape measures should have metric units.

To ensure accuracy and precision, length of the calipers or the tape measure should exceed the maximum expected length of the turtles in the study population so that reported lengths are the result of a single measurement rather than sums of partial measurements. Epibionts interfering with measurements should be removed when the accuracy of the measurements is important. If measurements are affected by injuries or deformities these irregularities should be noted, and perhaps the measurements should not be included in analyses, depending on the project's objectives.

Five standard linear measurements are presented: carapace length (Figures 1 and 3), carapace width, tail length (Figure 2), head width, and plastron length. For many studies, carapace length may be the only measurement needed.

Linear Measurements of Hard-shelled Turtles

Straight Carapace Length

At least three different straight carapace lengths have been used by sea turtle researchers (Pritchard *et al.*, 1983).

- Minimum straight carapace length (SCLmin; Figure 1a) is measured from the anterior point at mid-

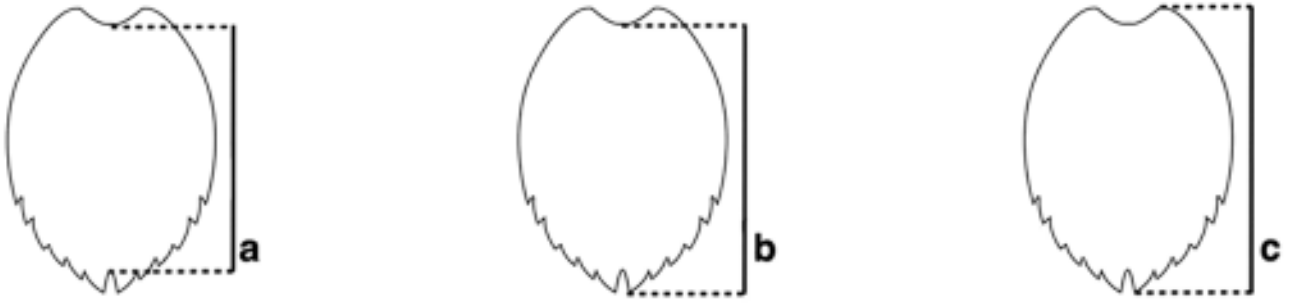

Figure 1. The anterior and posterior pairs of anatomical points for three carapace length measurements. (a) Minimum straight carapace length (SCLmin) and minimum curved carapace length (CCLmin) are measured from the anterior point at midline (nuchal scute) to the posterior notch at midline between the supracaudals. (b) Straight carapace length notch to tip (SCLn-t) and curved carapace length notch to tip (CCLn-t) are measured from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudals. (c) Maximum straight carapace length (SCLmax) is measured from the anterior edge of the carapace to the posterior tip of the supracaudals. Anterior and posterior locations must be on the same side of the carapace.

line (nuchal scute) to the posterior notch at midline between the supracaudals.

- Straight carapace length notch to tip (SCLn-t; Figure 1b) is measured from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudals. Often the tips of the supracaudals are not symmetrical; for consistency, the supracaudal that yields the longer SCLn-t should be used.
- Maximum straight carapace length (SCLmax; Figure 1c) is measured from the anterior edge of the carapace to the posterior tip of the supracaudals. Anterior and posterior locations must be on the same side of the carapace. For consistency, the side that yields the longer SCLmax should be used.

The recommended straight carapace length measurement is SCLmin (Bjorndal and Bolten, 1989; Gerosa, 1995). SCLmin is a better measurement because the posterior tips of the supracaudals are frequently broken in juveniles or worn away in adults. If time permits, both SCLmin and SCLn-t can be measured so that comparisons with other data sets can be made. To avoid confusion, measurements should always be clearly defined on data sheets and in publications.

Curved Carapace Length

The lack of clearly defined starting and ending points may contribute to the variance in precision of curved carapace lengths (Shoop and Ruckdeschel, 1986). Because of the curvature (and thickness) of the nuchal scute, the junction of skin and scute should be used as the anterior point. The posterior point should be the posterior tip of the dorsal surface. Two different curved carapace lengths have been used.

- Minimum curved carapace length (CCLmin; Figure 1a) is measured from the anterior point at midline (nuchal scute) to the posterior notch at midline between the supracaudals.
- Curved carapace length notch to tip (CCLn-t; Figure 1b) is measured from the anterior point at midline (nuchal scute) to the posterior tip of the supracaudals. Often the tips of the supracaudals are not symmetrical; for consistency, the supracaudal that yields the longer CCLn-t should be used.

The recommended curved carapace length measurement is CCLmin (Bjorndal and Bolten, 1989; Shoop and Ruckdeschel, 1986). There is greater variability in CCLn-t because of the unpredictable way that the tape measure deviates from the midline.

Carapace Width

Carapace width is measured at the widest point; there are no anatomical reference points. Straight carapace width (SCW) is measured with calipers; curved carapace width (CCW) is measured with a flexible tape measure. For each turtle, the anatomical location on the carapace where SCW and CCW are measured may not be the same. There must be consistency in the orientation of the turtle when SCW is measured, particularly with juvenile turtles, to avoid an additional source of variation. If the turtle is lying on its carapace (plastron up), the mass of the turtle tends to spread the carapace thus increasing the width of the carapace. Also, carapace width changes as the turtle inhales and exhales. For consistency, because CCW must be measured with the turtle lying on its plastron, SCW should be measured with the turtle also in this orientation.

Tail Length

Figure 2 shows two tail measurements. Total tail length (TTL) is the distance from the midline of the posterior margin of the plastron to the end of the tail following the curvature of the tail. Postcloacal tail length (PTL) is the distance from midcloacal opening to the end of the tail following the curvature of the tail. For both TTL and PTL, the turtle is positioned on its carapace, and a flexible tape measure is used to obtain the measurements. In sea turtles, tail length is a secondary sex characteristic; mature males develop long tails and females have short tails. In mature male turtles, the ratio of TTL to PTL is greater than in mature females. In juvenile sea turtles, tail length does not indicate an individual's sex.

Head Width and Plastron Length

Head width (HW) and plastron length (PL) are less frequently measured in sea turtles than are carapace length and width. HW is measured at the widest point with calipers. PL should be measured with calipers along the midline. Some variation in measurement is introduced because frequently the anterior and/or posterior edges of the plastral scutes do not completely overlay the anterior and/or posterior edges of the underlying bone. PL should be measured along the midline from the anterior edge to the posterior edge of the underlying bone when it extends beyond the scutes. PL measurements are less precise than SCLmin and SCLn-t (Bjorndal and Bolten, 1988).

Figure 2. Two tail length measurements: (a) total tail length (TTL) is the distance from the midline of the posterior margin of the plastron to the end of the tail following the curvature of the tail; (b) post-cloacal tail length (PTL) is the distance from mid-cloacal opening to the end of the tail following the curvature of the tail.

Linear Measurements of Leatherback Turtles

Carapace Length

Both straight carapace length (SCL) and curved carapace length (CCL) are measured from the nuchal notch (anterior edge of the carapace at the midline) to the posterior tip of the caudal peduncle (Figure 3). If the caudal peduncle is asymmetric, for consistency, measurements should be made to the longest point. Straight measures are recorded using calipers. Curved measures are made alongside the midline (vertebral) ridge. Curved length is not measured along the crest of the ridge because of irregularities in the ridge and the difficulty of keeping the tape on the ridge. The end of the tape measure should be securely positioned at the junction of skin and carapace at the midline ridge, and the tape pulled taut to the caudal peduncle, allowing the tape to follow a "natural" position alongside the ridge.

Carapace Width

Carapace width is measured at the widest point; there are no anatomical reference points. Straight carapace width (SCW) is measured with calipers. Curved carapace width (CCW) is measured with a flexible tape measure; the tape measure does not follow the curvature of the ridges, but rather spans from ridge crest to ridge crest. For each turtle, the anatomical location on the carapace where SCW and CCW are measured may not be the same.

Tail Length, Head Width, and Plastron Length

Head width is measured at the widest point with calipers. Turning an adult leatherback onto its carapace for the purpose of measuring tail and plastron length is not desirable. If juveniles are encountered, tail length should be measured as described for hard-shelled turtles and plastron length should be measured with calipers along the midline from the anterior edge to the posterior edge.

Linear Measurements of Hatchling Turtles

Hatchlings should be measured with small calipers following procedures for straight-line measurements described above. Because the shells of hatchlings are very flexible, care should be taken not to distort the shape of the shell when taking measurements.

Measurement Procedures: Mass Measurements

Body mass is a more biologically significant measure of body size than are linear measurements because physiological parameters scale to mass. However, body mass is more difficult to measure and is more variable because of reproductive state and nutritional status *(e.g.*, extent of gut fill). After a series of mass measurements and linear measurements have been collected for a population, a regression equation

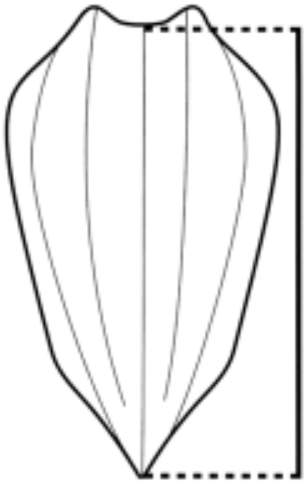

Figure 3. The anterior and posterior anatomical points for straight carapace length (SCL) and curved carapace length (CCL) in leatherback turtles. In both cases, length is measured from the nuchal notch (anterior edge of the carapace at the midline) to the posterior tip of the caudal peduncle.

can be used to estimate body mass from carapace length (Bjorndal and Bolten, 1988; Boulon *et al.*, 1996). However, over time the relationship of mass to length can change with changes in habitat quality and density-dependent effects (Bjorndal *et al.,* in press).

Sea turtles can be weighed using a spring scale. The appropriate scale for the size range of turtles should be selected. In general, the absolute accuracy of a spring scale decreases with increasing total capacity. To reduce trauma when weighing sea turtles, a net or mesh support should be used to cradle the turtle. A portable tripod with a pulley system can be constructed to lift the turtle. Hatchlings can be placed in a small clean bag (obtain tare first) and weighed on a spring scale. Greater accuracy can be achieved by weighing hatchlings on a triple-beam balance or electronic balance.

Sources of Supplies

Supplies for measuring turtles *(e.g.,* tree calipers, tape measures, spring scales, and waterproof notebooks) are available from forestry supply companies. Anthropometer calipers (available from scientific or medical suppliers) are very accurate but are expensive.

Conclusions

There are a number of ways to measure turtles. Methods appropriate for the study should be selected and used consistently. Recommended methods for measuring sea turtles have been described in this chapter. However, whatever measurements are used, the specific measurements should be clearly defined. The precision of the measurements should be determined and included in any project report and publication.

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