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Evaluation of Field Measurements of the American Alligator for Use in Morphometric Studies

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Long-term data typically are collected by different people under varying field conditions, resulting in data sets that are difficult to standardize. Several researchers have examined this problem in varied taxa, such as birds (Arendt and Faaborg 1989; Grant 1979; Yezerinac et al. 1992; Zink 1983), bats (Palmeirim 1998), and snails (Bailey and Byrnes 1990). However, they have used museum specimens or shells. Data for live animals are even more difficult to standardize. The most common data collected on crocodilians are morphometric measurements (e.g., head length, snout–vent length, total length, and mass). These measurements are used in a wide range of analyses, from ecological to taxonomic to evolutionary (Chabreck and Joanen 1979; Hall 1991; Hutton 1986). However, these analyses are only as accurate as the data from which they are derived.

We performed morphometric measurement trials on the American alligator, *Alligator mississippiensis*, to quantify inter-measurer error and determine which morphometric measurement had the least measurer error associated with it. This is necessary to increase confidence levels in future analyses.

Two trials were performed: 1) measurers were inexperienced volunteers; 2) measurers were experienced alligator biologists. The inexperienced trial was performed in the fall of 2000 using ten alligators captured at Arthur R. Marshall Loxahatchee National Wildlife Refuge (Loxahatchee) located in Boynton Beach, Florida (USA), with six groups of volunteers. Alligators were located by observing eye shines from an airboat in the marsh interior and captured using a wire snare. Alligators were secured in the boat and brought back to a covered area for measurement. Alligator size varied from 108 to 248 cm total length. The volunteers consisted of Loxahatchee staff, University of Florida employees, U.S. Geological Survey employees, and students from Palm Beach Atlantic Community College. Each group consisted of 4–6 people who were given both verbal and written measurement instructions. Each group measured every alligator. Different individuals within the group took measurements of each alligator, but measurements were agreed upon within the group before being recorded. Participants were allowed to collaborate within but not between groups. The following were measured by each group on every alligator: head length (HL), snout–vent length (SVL), total length (TL), right hind foot length (HFL), neck girth (NG), tail girth (TG), chest girth (CG), and mass. HL was measured dorsally, while SVL and TL were measured ventrally. A measurement kit was provided with every alligator that contained the following: a clipboard, pencil, string for measuring tail girth between scutes, a Pesola scale, and a flexible centimeter sewing tape. These kits stayed with the alligator so that the same equipment was used. Measurements were made with the flexible sewing tape to the nearest 0.1 cm. Mass was measured with 10–50 kg Pesola scales to the nearest 0.1 kg. The scales were calibrated before use using a weight of known mass. Before release, alligators were marked with individually numbered size 3 Monel tags in the webbing of the back left foot, and scute clipped for permanent identification.

The second trial was performed in fall 2001 with experienced alligator biologists. Nine alligators ranging from 156 to 255 cm TL were captured at Loxahatchee and used for the trial. Ten biologists measured each alligator using the same procedures and instructions as in the previous experiment with three exceptions: 1) each individual measured every alligator and was not allowed to discuss their findings; 2) the participants worked in groups of two to facilitate measuring; and 3) each person recorded their own measurements to reduce bias in and among groups.

Data were analyzed to determine which measurements were most reliable, or contained the least percent measurement error (%ME). Differences in reliability between experienced and inexperienced groups were evaluated using coefficient of variation. Standard deviation for each measurement was calculated and divided by the mean of that measurement for that alligator. A T-test was performed on the coefficients of variation to compare the reliability of experienced and inexperienced measurers. Six of the experienced measurers were randomly chosen so that the N in the T-test would be equal to the six groups of inexperienced volunteers.

The results of the T-test (Table 1) suggest that experienced indi-

Table 1. T-test results for coefficient of variation of experienced individuals versus inexperienced groups of volunteers. * Denotes significant value ($p < 0.05$).

Measurement	P-value
HL	0.046*
SVL	0.098
TL	0.129
HFL	0.758
CG	0.010*
NG	0.284
TG	0.015*
Mass	0.010*

viduals measure more accurately for HL, CG, TG, and mass than groups of inexperienced volunteers. There is no statistical difference for SVL, TL, HFL, and NG.

Percent measurement error was calculated for the experienced group to determine which measurements are more reliable for morphometric studies. Bailey and Byrnes (1990) pioneered the use of Model II ANOVA and ANCOVA to estimate within-individual and among-individual components of covariance and variance to predict percent measurement error. A Model II ANOVA and ANCOVA was run as a part of the SAS NESTED procedure (SAS Institute, Inc. 1988), according to the Bailey and Byrnes (1990) procedure. The among-individual variance was calculated by the following equation (Yezerinac et al. 1992):

$$s^2_{among} = (MS_{among} - MS_{within}) / m,$$

where MS is the mean squared deviation and m is the number of repeated measurements. Covariances were calculated as follows:

$$r_{x.y\ among} = (cov_{x.y\ among} / sx_{among}\ sy_{among}).$$

%ME was then determined by:

$$\%ME = 100\%\ (s^2_{within} / s^2_{within} + s^2_{among}).$$

Percent measurement error ranged from 0.50 to 49.53% (Table 2). HFL had the highest %ME because the landmarks used for the measurement are not easily located. TL was also relatively high. TL should be one of the most reliable measurements, as it is the largest and allows for greater margin of error. It is interesting to note the high covariance that NG and CG share with the other volumetric measurements.

This assessment can be used as a guide for future crocodilian studies that use morphometric measurements, such as the analysis of growth rate and condition. If performing morphometric analysis using data obtained by inexperienced groups, it would be more accurate to use TL, SVL, or NG. For experienced individuals, HL, SVL, TG, or mass should be used. For example, condition factor analysis requires a skeletal measurement and a volumetric measurement. SVL would be adequate for the skeletal measurement regardless of who collected the data, but more care should be taken in choosing the volumetric measurement. If these trials were to be replicated, it would be useful to modify the design so that each individual would take three or more measurements of each measurement for each alligator. This would provide data to quantify intra-observer error.

Table 2. Within alligator variance and covariance components for length and volumetric measures. Diagonal elements are variance components represented by percent measurement error (%ME). The off-diagonal elements are covariance components represented by within-gator correlations (rwithin).

	HL	SVL	TL	HFL	NG	CG	TG	Mass
HL	0.79							
SVL	-0.07	1.52						
TL	0.02	0.01	3.88					
HFL	0.09	-0.15	0.01	49.53				
NG	-0.04	0.16	-0.15	0.14	7.64			
CG	-0.03	0.10	0.16	-0.22	0.31	4.89		
TG	-0.06	0.09	0.10	0.10	0.63	0.40	2.93	
Mass	-0.08	-0.08	0.09	0.04	-0.25	-0.10	-0.13	0.50

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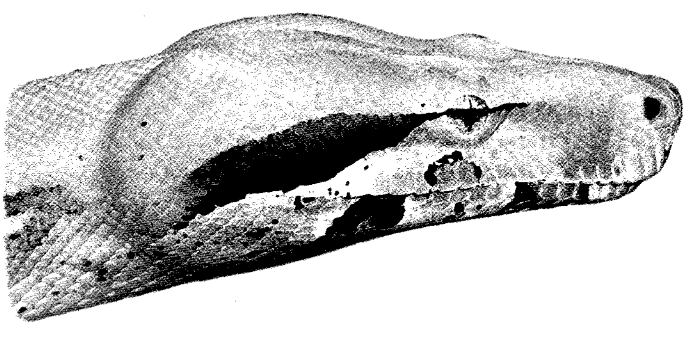

Boa constrictor (Common Boa). Captive specimen derived from Surinam stock. Photolithograph by Will Brown.