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Size Estimates of Crocodilians

WILLIAM E. MAGNUSSON, *Departamento de Ecologia, Instituto Nacional de Pesquisas da Amazônia (INPA), Caixa Postal 478, 69.000 Manaus—Amazonas, Brasil.*

Where the relationship between age and size is known, size estimates of crocodilians made during spotlight surveys can be used to give a broad picture of the age-structure of populations, particularly the juvenile segment. This is important in studies aimed at determining the conservation status (see for example Messel et al., in press) or the effect of hunting (see for example Palmisano et al., 1973) on crocodilians. For an animal whose fecundity and reproductive success is probably strongly size/age dependent slight differences in the allocation of animals to size classes can significantly alter the interpretation of the resulting life-table. Accurate estimates of total numbers present are of limited use without some idea of the accuracy of the size estimates. It is appropriate then that some thought be given to how size estimates are made and the factors that effect them.

One method frequently suggested when only the head is visible is to use the relationship between length of head and total length. For example, Chabreck (1966, 1976) suggested that the distance between the eye and the tip of the snout in inches is approximately equivalent to the total length of *Alligator mississippiensis* in feet. Other studies have not attempted to explain the way estimates of size were made but used observers experienced in the capture of crocodilians who had the opportunity to adjust their estimates with experience (for example, Messel et al., in press). Webb and Messel (1978*a*) suggested that photographs of the head of crocodiles could be used to objectively calculate lengths. I know of no studies where the relationship between actual and estimated lengths has been presented.

This note reports on the relationship between actual and estimated sizes of four species of Amazonian crocodilians, *Melanosuchus niger*, *Caiman crocodilus*, *Paleosuchus palpebrosus*, and *P. trigonatus* when estimated by a researcher experienced at estimating sizes of *Crocodylus porosus* in Australia. The results are subjective in that the exact relationships are observer specific. However, the factors that lead to differences between species are likely to operate for all species and influence all observers to a greater or lesser extent. The results therefore illustrate a number of concepts which may be of value to others who are surveying populations of crocodilians.

During routine spotlight surveys of crocodilians in the Amazon (Tapajós) National Park and Amanã Lake and its effluents in the central Amazon, estimates of the sizes of the four species of crocodilians present—*Caiman crocodilus*, *Melanosuchus niger*, *Paleosuchus palpebrosus*, and *P. trigonatus*—were made at distances of between two and five meters. Approximately 25% of these animals were subsequently captured and measured with a tape graduated in cm. The size estimates were based on experience with *Crocodylus porosus* and no attempt was made to adjust the method of estimation with respect to the actual sizes measured. In fact, the captured crocodilians were not measured until the following day and the estimates and actual sizes were not tabled together until the end of the surveys.

For reasons that will be detailed in the discussion it is appropriate to regard both actual and estimated lengths as dependent on a third, conceptual, variable—size, rather than regard one as dependent on the other. Therefore geometric mean estimates of the functional (GM) regressions were used to describe all relationships that did not exhibit significant curvature. Ricker (1973) details the theory and calculations involved. GM polynomial regressions are less understood and their calculation more complicated. The one relationship that exhibited curvature was described by a least squares predictive regression with actual size as the dependent variable. This model gives a good approximation to a number of other curves and is a useful description when the precise relationship is not known. It does not however, imply that the data could not be better represented by some other curve or series of curves. Representing all relations by least-squares predictive regressions would not in any way change the biological conclusions.

To determine the ability of observers to discriminate lengths at survey distances, six pieces of cord—two three inches long, two four inches long and two five inches long—where arranged on the ground at random angles and random distances between two and four meters from an observation point. The background contained information on which to base relative sizes as it was covered with fallen leaves. Three observers—a researcher with some experience observing crocodilians under field conditions, a university student, and a laboratory technician—were asked to quickly estimate the sizes of the lengths of cord as they were indicated with a pointer. All observers hesitated a few seconds before making estimates for each piece so it is assumed that they had time to make size comparisons with the background as they would in the field. The observers had an added advantage over field conditions as all of the pieces of cord were visible at the same time, facilitating comparisons.

The sizes of no species in the Amazon were predicted accurately by the raw estimates. However, data are not available to indicate whether this would also apply to *Crocodylus porosus.* There was a linear relationship between the estimated and actual lengths of *Paleosuchus trigonatus* and *Melanosuchus niger.* The regression lines are not significantly different but are presented separately as there is insufficient data to make a fair test for a small underlying difference.

M. niger

$$y = -19.16 + 1.33X$$
$$(N = 10)\ P < 0.05$$

P. trigonatus

$$y = 19.18 + 1.90X$$
$$(N = 13)\ P < 0.05$$

where y = total length in cm and x = estimated length in cm. Lengths of both species could be estimated with reasonable accuracy from the regression lines ($r = 0.94$ and $r = 0.90$ respectively).

The relationship between estimated and actual lengths was curvilinear for *Caiman crocodilus.*

$$y = -65 + 2.8X - 0.01006X^2$$
$$(N = 54)\ P < 0.05$$

x and y as above. The regression line gives reasonable prediction of actual values ($R = 0.92$).

The regression of actual on estimated lengths of *P. palpebrosus* had a very small slope in comparison to those for the other species indicating that I was unable to accurately estimate body length. The line was not significantly different to zero ($F_{1,10} = 2.9$, $0.1 < P < 0.25$) and hence has no value for prediction.

The experiment with the lengths of cord indicated that under the conditions of the experiment it is difficult to accurately estimate lengths in the range of those most commonly encountered as the distance between the eyes and snout of a crocodile. The observers gave only two correct estimates (within 2 cm of actual) of their combined total of 18. The observers ability to rank the lengths may give a better indication of their potential as with experience it is possible to adjust the magnitude of estimates by a constant factor. That is their estimates when ranked should give the three inch pieces a rank of one or two, the four inch pieces a rank of three or four and the five inch pieces a rank of five or six. The estimates of one observer gave correct ranks to three pieces and the others to two each. The expected number of correct ranks if they allocated ranks randomly is two.

The experiment with the lengths of cord indicated that observers cannot estimate lengths of objects at survey distances. This point is critical to an understanding of how size estimates are made. The experiment contained all of the information available to an observer surveying for crocodiles except for the form of the head. If an observer cannot accurately estimate the length of a crocodile's head the fact that there is a relationship between head length and total length (Chabreck, 1966) becomes irrelevant. Unless it can be shown that the observers had special capacity for estimating lengths I suggest that researchers should cease to use Chabreck's observation as justification for their estimates.

Given that observers cannot directly estimate lengths of heads there must be other clues that experienced researchers use. For three of the four species studied the correlation coefficient between my estimates and the actual lengths was better than 0.9. That crocodilians do not grow isometrically is well known (Dodson, 1975; Kramer and Medem, 1955; Mook, 1921; Webb and Messel, 1978*a*, *b*). Associated with changes in the shape of the head is an increase in rugosity and prominence of ridges (Mook, 1921). The development of these features appears not to be linear with age. Hatchling skulls are markedly different to those of adults but this characteristic is largely lost within the first year (Dodson, 1975; Mook, 1921). The skull then changes slowly throughout life but there is evidence for a somewhat dramatic change (associated with faster growth rates and more scarring in *C. porosus* (Webb and Messel, 1978*a*)) at a larger size. These morphological changes have been linked with a change in diet from invertebrate to vertebrate prey for *A. mississippiensis* (Dodson, 1975) and *C. porosus* (Webb and Messel, 1978*a*, *b*). However, they occur at about the size that females of these species enter the breeding population and there may be other changes of life style (see Webb and Messel (1978*a*) for more detailed discussion). *Caiman crocodilus* also exhibits morphological changes (Kramer and Medem, 1955) but its small size precludes a major shift to large vertebrate prey except in very old individuals. Whatever the causes, it is obvious that a crocodile's head offers a large number of clues as to the total length (age?) of its owner even when the absolute length of the head is unknown.

From the foregoing we might predict that if we use the same method of estimation on different species the relation between estimated and actual lengths will differ between species. The prediction is borne out in the results presented here. The relationship between estimated and actual lengths is linear for *M. niger* and *P. trigonatus* and curvilinear for *C. crocodilus*. The difference is not trivial. It indicates that with experience I could use a correction factor or modify my method of estimation to obtain direct estimates of sizes of *P. trigonatus* or *M. niger* up to about 180 cm in length. In contrast, even though my estimates of small *C. crocodilus* were reasonable, above about 120 cm actual length there was no relation between actual and estimated lengths. This casts doubt on the validity of using experienced observers or doing spot checks. Unless a correction curve is given the reader will not know the scatter around the curve, or whether the accuracy of the estimates is the same throughout the size range.

The data for *P. palpebrosus* were limited. The sample size was similar to that for *M. niger* and *P. trigonatus* but the size range was less. None-the-less, the difference between this species and the others is sufficient to warrant at least preliminary discussion. The correlation coefficient between my estimates and actual sizes (0.48) was not statistically significant ($P > 0.1$). That is, my predictions were virtually worthless. *P. palpebrosus* is unique amongst crocodilians in that its head remains high and smooth, and the snout short, throughout life. It appears that in the absence of other clues I was reduced to trying to estimate absolute length and the results bear witness to the accuracy of that approach.

There can be no doubt that any form of size estimate is better than simply reporting total numbers in a survey situation and in many cases crocodilians are not sufficiently numerous or approachable to be caught. However, in long term studies that involve the construction of life tables or comparisons of size classes between years the construction of correction curves for estimates given by observers should be an integral part of the study. The results presented here indicate that as few as 10 animals can suffice to demonstrate the relationship for some species. Also, when broad size/age classes are used, such as hatchling, medium and large (Messel et al., in press), hatchling, small, medium, and large (Pernetta and Burgin, 1980) or young, juvenile and adult (Woodward and Marion, 1979) it would be profitable to look for natural breaks in the developmental pattern such as those suggested by Webb and Messel (1978*a*, *b*) to give more precision to the allocation of boundaries.

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