IUCN-SSC Crocodile Specialist Group (CSG)

Final Report

Project title: Evaluation of reproductive *trade-offs* as a survival factor in the Morelet's crocodile (*Crocodylus moreletii*).

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Introduction

Studies on evolutionary ecology, focused on reproduction or also known as behavioral ecology, are necessary to understand how natural selection shapes the characteristics of the life histories of organisms, given that life histories can be affected if the selection pressures to which a population is subjected change. These studies seek to understand how the characteristics of species vary, improving strategies that optimize reproductive success and thus their survival. The study of the evolution of life histories in vertebrates has helped to identify adaptive and non-adaptive traits focused on reproductive trade-offs, which have been models applicable to any organism that presents this type of trade-offs; however, Congdon and Gibbons (1985) suggested that optimal egg size is more evident in organisms that produce a greater number of offspring per reproductive event and that do not have parental care, because the allocation of energetic resources is limited, and by not presenting these characteristics they can invest more energy in the direct production of offspring. Therefore, reptiles have been taken as an excellent study model to understand the evolution of life histories through reproductive trade-offs between clutch size and offspring size.

Objectives:

1. Evaluate the reproductive exchanges between the clutch size and the egg size in *Crocodylus moreletii.*
2. Quantify the maternal reproductive effort by means of differences or similarities of the characteristics of the clutch (number and volume of the eggs, mass of the clutch).
3. Evaluate whether egg size has an influence on the quality of the offspring.
4. Evaluate if the size or mass of the female has any effect on the size of the offspring.

Goals:

1. Determine how natural selection shapes life histories to favor parental and hatchling fitness.
2. Determine maternal energy investment in their offspring.
3. Determine whether the reproductive strategies evaluated in this study are a factor in survival.

Methods

Data collection was carried out at the Wildlife Conservation Management Unit (Unidad de Manejo para la Conservación de la Vida Silvestre, UMA) Cocodrilia, Quintana Roo Mexico, from May to November 2019, and consisted of three phases: **Phase 1**. Obtaining weight and morphological measurements (total length and snout-vent length) of each post-ovoposition female. **Phase 2.** Measurement of the clutches, eggs were collected within the first 24 hrs post-oviposition, obtaining mass and morphometric measurements (width, length and G point) of each egg, these measurements were used to obtain the real egg volume with the formula of Maritz and Douglas (1994) for ellipsoid eggs. The eggs were then placed in artificial incubators, where they were kept under constant conditions until hatching. **Phase 3.** Sampling of hatchlings, weight and

morphological measurements were obtained at the moment of hatching and for three continuous months, once a month. With the data obtained from the sampling of hatchlings, body growth rates (BGR) were obtained using the formula of Zamora-Abrego *et al*. (2012).

For the analysis of the data, the mean, variance, standard deviation (SD) and coefficient of variation (CV) of the total data obtained corresponding to each trait were obtained, to know the variability of the data, the homogeneity of the variance of the data and normality were determined with Shapiro-Wilk, subsequently, Pearson correlations (r) were performed, using an α of 0.05, to determine the relationship between clutch characteristics, to evaluate the effect of female size on egg size and volume, and on hatchling size and mass, as well as to evaluate egg size and volume on hatchling size and mass. Finally, the coefficient of determination (r^2) was obtained to know the proportion of variation and the *P* value was obtained, using an α of 0.05, to know the level of statistical significance of the association between the variables.

Results

Characteristics of the females

A total of 13 females were sampled, each with its corresponding nest. The 13 females had a LT range from 1925 to 2420 mm and a LHC range from 965 to 1165 mm. The most variable characteristic was LT (CV = 0.08), while LHC had the lowest CV (CV = 0.06).

Nest characteristics

A total of 13 nests were collected (which had oviposition date between 14 May and 4 June 2019), a total of 434 eggs were collected, of which 67% hatching success was obtained, volume (CV = 0.11) and mass (CV = 0.11) were identified as the most variable features, while width (CV = 0.03) and length (CV = 0.07) presented lower CV.

Hatchling characteristics

A total of 292 hatchlings were hatched (66% hatching success), which ranged from 192 to 282 mm LT, 94 to 132 mm LHC and 36 to 63.5 g in weight. The most variable characteristic was weight (CV = 0.11), while LT (CV = 0.05) and LHC (CV = 0.05) had a lower CV.

Analysis of results

The results of the Shapiro-Wilk normality test using an α of 0.05 showed that the clutch data presented a normal distribution, egg width ($P = 0.271$), length ($P = 0.6461$), mass ($P = 0.3433$) and volume ($P = 0.2537$). About Pearson correlations, a positive relationship was found between the egg characteristics, between mass and length ($r = 0.9126$, $r^2 = 0.8328$, $P = 1.36 \times 10^{-5}$), between mass and width ($r = 0.8914$, $r^2 = 0.7946$, $P = 4.29 \times 10^{-5}$), between volume and length ($r = 0.9008$, $r^2 = 0.8115$, $P = 2.65 \times 10^{-5}$) and between volume and width ($r = 0.9230$, $r^2 = 0.8520$, $P = 6.87 \times 10^{-6}$), while between width and length a moderate correlation was found ($r = 0.6662$, $r^2 = 0.4438$, $P = 0.0129$). On the other hand, clutch size (number of eggs per nest) and egg characteristics had no significant correlations, between clutch size and *A* ($r = 0.1641$, $r^2 = 0.0269$, $P = 0.5921$), clutch size and volume ($r = -0.0232$, $r^2 = 0.0005$, $P = 0.9401$) and between clutch size and *L* ($r = -0.2353$, $r^2 = 0.0553$, $P = 0.4391$). No correlation was found between LT of females and egg characteristics, between LT of females and *A* of eggs ($r = 0.5320$, $r^2 = 0.2830$, $P = 0.0613$), between LT of females and egg mass ($r = 0.4935$, $r^2 = 0.2436$, $P = 0.0866$), between LT of females and egg volume ($r = 0.0803$, $r^2 = 0.0064$, $P = 0.5023$), between LT of females and *L* of eggs ($r = 0.3770$, $r^2 = 0.1421$, $P = 0.2041$), and between LT of females and clutch size ($r = 0.2740$, $r^2 = 0.0751$, $P = 0.3649$). A positive correlation was found between egg characteristics and hatchling measurements, a strong correlation was obtained between egg mass and hatchling mass ($r = 0.9688$, $r^2 = 0.9386$, $P = 5.20 \times 10^{-8}$), between egg volume and hatchling mass ($r = 0.9585$, $r^2 = 0.9188$, $P = 2.46 \times 10^{-7}$), between *L* of eggs and hatchling mass ($r = 0.8495$, $r^2 = 0.7217$, $P = 0.00024$), on the other hand, a moderate positive correlation was found between egg mass and hatchling LT ($r = 0.6815$, $r^2 = 0.4645$, $P = 0.0103$), between egg volume and LT of hatchlings ($r = 0.6460$, $r^2 = 0.4174$, *P*

= 0.0171), as well as between *L* of eggs and LT of hatchlings (r = 0.7041, r^2 = 0.4957, P = 0.0072). No correlation was found between females and hatchlings, between LT of females and LT of hatchlings (r = 0.2559, r^2 = 0.0655, P = 3987), and between LT of females and mass of hatchlings (r = 0.4445, r^2 = 0.1976, P = 0.1281). Finally, no significant correlation was found between egg characteristics and hatchling body growth rates (BGR), *L* of eggs and hatchling BGR (r = -0.0098, r^2 = 0. 0001, P = 0.9745), between egg mass and hatchling BGR (r = 0.0699, r^2 = 0.0049, P = 0.8206) and between egg volume and hatchling BGR (r = 0.1160, r^2 = 0.0135, P = 0.7058). Also, no statistically significant correlation was found between LT females and hatchling BGR (r = 0.2863, r^2 = 0.0820, P = 0.343).

Conclusions

In this study we were able to find that the largest eggs tend to be the heaviest, the widest and the ones that obtain the highest energy allocation. It was also found that the heaviest and largest eggs produced the heaviest and largest hatchlings. However, no relationship was obtained between females and clutch characteristics, from which it was expected to find a reproductive trade-off, since due to energetic constraints it would be expected that the female would allocate her energy to either a large clutch size (more number of eggs) with small eggs or, on the contrary, a reduced clutch size (less number of eggs) but with large eggs. It should be noted that there are other factors that may be influencing the clutch size, such as environmental factors, reproductive quality, type of feeding, physical condition of the females and captivity conditions. Also, this lack of trade-offs could be attributed to the fact that females allocate their energy in a way that favors both traits, clutch size and egg size, because it has been shown that in crocodiles the energy available for reproduction increases as females mature, due to a reduction in energy demands for growth and competition for energy resources, so that larger and more dominant females can restrict the access of subdominants to resources through competitive interactions. It would be important to replicate this type of studies in captivity with more than one breeding season and considering a larger LT range of females.