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The relationship between nesting habitat and hatching success in *Caiman latirostris* (Crocodylia, Alligatoridae)

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Abstract

The relationship between nesting habitat and hatching success in *Caiman latirostris* (Crocodylia, Alligatoridae). The Broad-snouted Caiman uses different habitats for nesting; it has temperature-dependent sex determination (TSD) and nesting habitat selection by females could affect sex and other hatchlings characteristics. Here we evaluated reproductive parameters in three nesting habitats: forest, savanna, and floating vegetation. We collected 154 caiman nests during the summer of 2001–2002. Since natural incubation could mask possible clutch-effects, eggs were collected soon after oviposition and artificially incubated. We found that eggs laid in the forest were wider than those laid in savanna, hatching success varied, decreasing from floating vegetation to forest. As egg width is positively correlated to female body size, the present results suggest that female body size could be related to nesting habitat use in *Caiman latirostris*. However, there were no differences in hatchling size among nesting habitats.

Keywords: Crocodylia, Alligatoridae, *Caiman latirostris*, reproduction, habitat use.

Introduction

Survivorship of crocodilian hatchlings is not only related to body-size but also to nesting habitat quality (Abercrombie 1989). *Caiman latirostris* (Broad-snouted Caiman) uses different habitats for nesting in the wild (Larriera 1995). Since the Broad-snouted Caiman has temperature-dependent sex determination (TSD) (Piña *et al.* 2003), nesting habitat selection by females could affect the sex ratio of embryos (Piña 2002), as found for *Caiman yacare* (Campos 1993). However, to date, there is no information about nesting site selection by female *Caiman latirostris*.

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Nesting habitat selection could be related to female size. Clutch size is related to female size, as is hatchling size (Larriera *et al*. 2004). Thus, sizes of eggs, clutches and hatchlings from different nesting habitats may be used to infer the size of female selecting these habitats. In rainy years flooding may affect the availability of *C. latirostris* nesting sites (Larriera 1995). Also, during dry incubation seasons, nest depredation increases, possibly due to an increase in nest access by predators. In such conditions, floating vegetation provides more protection against nest predators (Messel *et al*. 1995, Larriera and Piña 2000), and especially more experienced (bigger) females may choose to nest in floating vegetation.

In this study, we evaluated reproductive parameters related to clutch size, egg size, hatching success, and hatchling body-size in three nesting habitats in Santa Fe, Argentina (forest, savanna, and floating vegetation). Nests were transferred to artificial incubators to control the incubation process and to eliminate any effect of differences in habitat on incubation.

Materials and Methods

We collected 5140 eggs from 154 nests during the summer of 2001–2002 in San Javier (30°03'S, 59°58'W) and San Cristóbal (29°59'S, 60°49'W), Santa Fe province, Argentina, from three different nesting habitats. This study area has been surveyed for caiman nests since 1990 (Larriera 1990). Nests found by local people during the first few days after oviposition were transferred to artificial incubators at Proyecto Yacaré in Santa Fe city (Larriera *et al.* 1996), where they were incubated until hatching. Incubation temperature was kept at 31 to 32°C with a relative humidity of approximately 95%.

According to Larriera (1995), the nesting habitats of *C. latirostris* near Santa Fe can be described as follows: (a) savanna - places with low slope that flood in periods of heavy rain; nests are frequently found on the levee near the water bodies; most of the nests are built with grass; (b) floating vegetation - located in heavily vegetated water bodies; nests are built with grass and float on the vegetation surface as the water level varies; (c) forest - located on higher plateaus occasionally flooded in years of heavy rain; nests are found up to 2000 m from water bodies, generally built with mud, small stumps, and little grass.

These three habitats can be found over the whole distribution area of *C. latirostris* in Santa Fe Province, avoiding possibly confounding effects caused by region of origin. For each nest we recorded nesting habitat (forest, savanna, and floating vegetation, as described above), clutch size, and hatching success. For the analysis of clutch size (number of eggs / nest) and hatching success (number of hatchlings / number of eggs) we considered only nests that showed no signals of depredation. In depredated nests some eggs may be exposed to direct sun or rotated, possibly damaging the embryo and consequently reducing hatching success (Donayo *et al*. 2002). We also measured the length (longer axis), and width (smaller axis) of 15 random eggs per clutch with a Vernier caliper to the nearest 0.1 mm.

Within 48 hours after hatching, we measured 15 randomly chosen hatchlings per nest in tail length (TL), snout vent length (SVL) and body mass (BM). Length measurements were taken to the nearest 0.5 cm, whereas BM was taken with 0.5 g precision.

We analyzed the relationship between clutch size and hatching success, egg size and hatchling size (BM, SVL and TL) with simple Model I regressions. We also compared hatching success, clutch size, egg size (egg length and egg width), hatchlings TL, SVL and BM, among nesting habitats with a One Way ANOVA, but if regression was significant, we included clutch size in the ANOVA model as a covariate.

Results

Only egg width was related to clutch size ($y = 37.67 + 0.11$ clutch size; $F_{152} = 26.59$;

Table 1 - Clutch size, hatching success, and egg measurements by nesting habitat (mean ± SD). In egg width and hatching success, habitats sharing similar letters presented no significant difference in mean values at a = 0.05 using the Fisher (LSD) multiple range test.

	Savanna	Floating vegetation	Forest
Clutch size	34.45 ± 5.03 (n = 106)	36.08 ± 6.75 (n = 14)	34.36 ± 6.38 (n = 34)
Hatching Success	0.65 ± 0.26^{AB} (n = 103)	0.75 ± 0.18^{A} (n = 12)	0.56 ± 0.24^{B} (n = 34)
Egg length (mm)	65.8 ± 3.1 (n = 106)	66.1 ± 2.2 (n = 14)	66.2 ± 2.6 (n = 34)
Egg width (mm)	41.2 ± 1.6^{A} (n = 106)	41.8 ± 1.4^{AB} (n = 14)	42 ± 1.5^{B} (n = 34)

$p < 0.001$; $R^2_{Adj.} = 14\%$; Figure 1). We found no relationship between egg length ($p = 0.1186$) and clutch size. We also failed to detect any difference in clutch size ($F_{2, 152} = 0.02$; $p = 0.9802$) and egg length ($F_{2, 153} = 0.20$; $p = 0.8195$) among the different nesting habitats; on the other hand egg width was larger in forest than in savanna (ANCOVA $F_{2, 152} = 4.08$; $p = 0.0189$; Table 1).

Average hatching success was 62 ± 27% (Mean ± SD; 3180 hatchlings in 5140 eggs). Hatching success was higher in floating vegetation than in forest nests ($F_{2, 148} = 3.25$; $p = 0.0417$; Table 1), and was not related to clutch size ($p = 0.7635$).

Hatchling length [SVL ($p = 0.0617$) and TL ($p = 0.4509$)] were not related to clutch size, but hatchling body mass was positively related to clutch size ($y = 30.16 + 0.28$ clutch size; $F_{152} = 12.76$; $p = 0.0005$; $R^2_{Adj.} = 7\%$). We did not find differences in hatchling size among habitats (SVL, $p = 0.0714$; TL, $p = 0.7753$; BM, $p = 0.3454$). There was a positive relationship between egg width (x) and hatchling SVL ($p < 0.0001$, $y = 5.88 + 0.13x$, $R^2_{Adj.} = 17\%$), TL ($p = 0.0004$, $y = 6.36 + 0.14x$, $R^2_{Adj.} = 9\%$), and BM ($p < 0.0001$, $y = -66.29 + 2.56x$, $R^2_{Adj.} = 56\%$; Figure 2).

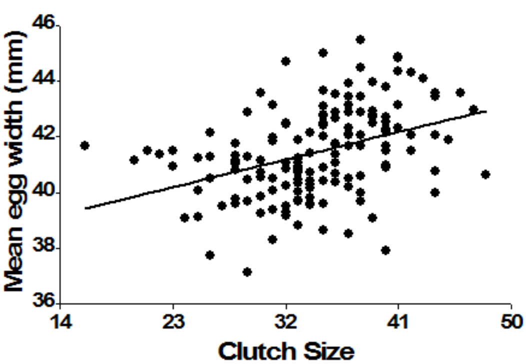

Figure 1 - Linear regression of mean egg width and clutch size. Regression equation: Mean egg width = 37.67 + 0.11 clutch size; $p < 0.001$.

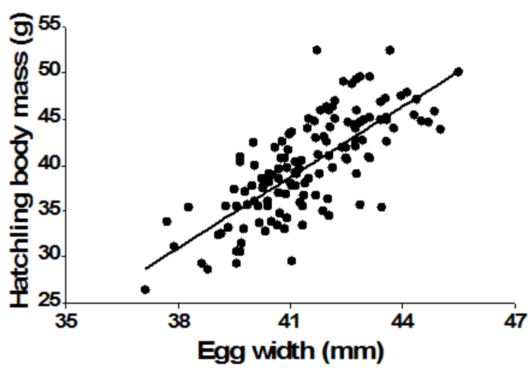

Figure 2 - Hatchling body mass in relation to egg width for the study area. Regression equation: Mean hatchling body mass = -66.29 + 2.56 Mean egg width (mm); $p < 0.001$.

Discussion

Our results show that egg width and hatching success vary among nesting habitats, but egg length, clutch size, and hatchling sizes were similar among habitats. Schulte and Chabreck (1990) found that *Alligator mississippiensis* eggs from low marsh habitat were smaller in volume than those on levees, but bigger than those in high marsh. According to Schulte and Chabreck (1990), low marsh nests are usually more humid than in the other habitats. We found that eggs from forest nests were wider than those from savanna.

We found that egg width and hatchling BM were related to clutch size. Previous studies did not detect this relationship measuring egg volume in *C. latirostris* (Piña *et al.* 2002) and in a related species (*Caiman yacare*; Campos and Magnusson 1995). Larriera *et al.* (2004) did not find a significant relationship between clutch size and egg mass after removing female BM or SVL effects. So female body size may be the factor that connects clutch size and egg width or hatchling BM.

Imhof *et al.* (1996) reported that floating vegetation is the nesting habitat with the lowest hatching success, compared with other habitats. However, their findings may be explained by the late harvest of the eggs, after two thirds of the incubation period. This late harvest seems to be related to a breakdown in hatching success for the species, due to an increased chance of flooding or depredation (Larriera 1995). Our results show that hatching success was related to nesting habitat with floating vegetation having a higher hatching success than forest. It is possible that collection method could influences hatching success, but we carefully collected nests for the experiment in the three different habitats. Because we collected nests at the beginning of the incubation period and artificially incubated all the nests under similar conditions, the differences in hatching success among the nesting habitats under natural conditions were removed, showing only differences on females reproductive quality among the nesting habitats.

Schulte and Chabreck (1990) found that *Alligator mississippiensis* hatchling body size (BM and total length) varied among nesting habitats, with bigger hatchlings in low marsh, a habitat similar to our floating vegetation. Our results show that hatchling body size variation among habitats is due to incubation conditions. As previously reported (Piña *et al.* 1996, In den Bosch and Bout 1998), hatchling BM presents a stronger relationship with egg width than TL, with larger eggs tending to produce bigger hatchlings. TL or SVL might depend on the amount of internalized yolk by the embryo during incubation. If the embryo internalized more yolk, then its BM (including yolk, as we measured in this study) would be similar to the BM of an embryo with less yolk residual, but with more advanced body development (Webb *et al.* 1987), thus producing a longer hatchling with SVL varying more in relation to egg width than BM.

We infer that nesting females use the three nesting habitats according to their body size. Although we did not capture nesting females in this study, egg width is positively related to female body size in *Caiman latirostris* (Larriera *et al.* 2004). Females nesting in the forest are possibly bigger than those nesting in savanna since they produce wider eggs.

Nesting habitat was related to sex ratio of embryos in *Caiman latirostris* (Piña 2002), *C. yacare* (Campos 1993), and *Alligator mississippiensis* (Ferguson and Joanen 1983). The present results suggest that nesting habitat use in *C. latirostris* and hatchling sex ratio could be related to female body size.

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