Temperature variation in nests of *Caiman crocodilus* (Crocodylia: Alligatoridae)

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Abstract. *Caiman crocodilus* is a widely distributed species in the Neotropics; however, studies of incubation temperatures in wildlife are uncommon. Incubation temperatures in four nests of *Caiman crocodilus* were measured with a digital thermometer, in the National Wildlife Refuge Caño Negro, Costa Rica. Average temperatures in these four nests (no. 1-4) were 32.13 ± 0.92 °C (no. 1), 32.46 ± 0.77 °C (no. 2), 33.60 ± 0.95 °C (no. 3), and 31.78 ± 2.30 °C (no. 4). Temperature variations recorded showed higher temperatures than those reported from other studies in Caño Negro. The temperatures registered in this study will lead to a higher proportion of males within the caiman population, reducing the number of future reproducing females and, therefore, in the population viability.

Keywords: *Caiman crocodilus*, nest temperatures, Costa Rica.

Reptiles have a wide range of sex-determination systems, including genotypic and environmental sex determination. In crocodilians, sex is only determined by incubation temperature (Bull and Charnov, 1989; Thorbjarnarson, 1997), a kind of environmental sex determination. Most studies relating incubation with temperature have been carried out in laboratory conditions, because they permit knowledge of the sex ratios under different incubation temperatures (Aguilar-Miguel et al., 1998). However, these treatments do not necessarily encompass temperature variations that occur in the natural environment.

Incubation temperature affects the sex ratio of crocodilian species differently. Studies of the effect of incubation temperature in crocodilians have been done with *Alligator mississippiensis* (Ferguson and Joanen, 1982), *Caiman yacare* (Campos, 1993; Miranda et al., 2002), *C. latirostris* (Piña et al., 2003), *Crocodylus porosus* (Magnusson, 1979), *C. acutus* and *C. moreletii* (Aguilar, 1995). Even though *Caiman crocodilus* is a widely distributed species in the Neotropics (Ross, 1998), studies of incubation temperatures in their natural environment are uncommon (Allsteadt, 1994). The most common treatment that has been done *in situ* in order to measure temperature variations within the nest used mercury thermometers inside the egg cavities. This method only registered temperatures during a limited period of time (hours along some days or weeks) (Magnusson et al., 1990; Allsteadt, 1994; Miranda et al., 2002; Casas-Andreu, 2003) and, it did not evaluate the thermal gradient present inside the egg cavities.

Due to the lack of information about the variations of temperatures within *C. crocodilus* nests, the objective of this note is to analyze the daily variations of temperatures within nests of *C. crocodilus* located in the northern part of Costa Rica and compare our results with the others existing studies (Allsteadt, 1994; Junier, 2000).

The study was conducted on the National Wildlife Refuge Caño Negro, on the Frio River, at the northern part of Costa Rica (10°54'N, 84°47'W). This protected area extends 9,969 ha and is one of the most important wetlands in northern of Costa Rica. Largest population density of *C. crocodilus* (74.36 ind/km) registered up to now has been reported at this location (Cabrera et al., 2003).

The nests were located by walking transects in the sites where people had seen caiman nests in previous years. Caimans construct mounds of vegetation with leaves, grass, branches and earth in forested areas; mostly in the root area at the base of trees and near water bodies (Cintra, 1988; Álvarez del Toro and Sigler, 2001). When nest was discovered, it was opened to determine the presence of the eggs, because in some cases female caimans build up a nest without laying the eggs (Álvarez del Toro and Sigler, 2001). Once the eggs were observed at the egg cavity, a digital thermometer (StowAway TidbiT Temp Logger) was placed to register the temperature inside the egg cavity every 10 min, until the eggs hatched. The temperature was registered in four nests; no. 1, no. 2, no. 3 and no. 4 during 32, 31, 20 and, 69 days, respectively. The data were averaged daily, for interpretation.

The Kruskal-Wallis test suggests differences between incubation temperature of the nests ($H = 787.266$; $P < 0.01$), with the highest mean temperature being in nest no. 3 (33.60 ± 0.95 °C), followed by nest no. 2 (32.46 ± 0.77 °C), nest no. 1 (32.13 ± 0.92 °C) and nest no. 4 (31.78 ± 2.30 °C) (Table 1). Only one nest (no. 3) indicates significant difference in temperatures between day and night, being higher during the night (Student t-test, $P < 0.05$).

Temperature variations can be correlated with climatic phenomena. Magnusson (1979) observed that the presence of hurricanes affected the temperature within the nests. Location of the nests at the refuge can significantly alter temperatures. Cintra (1988) mentions that in some cases the nests are not placed at the best sites, because of intraspecific pressure or anthropogenic effects. Campos (1993) also observed that the nests that were built on top of organic matter showed higher temperatures than those that were built on top of floating grass. She concluded that nest temperature is determined by nesting habitat but that the effect of habitat depends on weather conditions.

Table 1. Incubation temperature of four nests with mean, standard deviation, minimum and maximum, registered with a digital thermometer in degrees Celsius.

Nest	N°	Mean	SD	Minimum	Maximum
no.1	757	32.13	0.92	25.57	33.39
no.2	735	32.46	0.76	29.11	33.73
no.3	468	33.60	0.95	29.73	35.03
no.4	1654	31.78	2.30	24.82	38.01

Allsteadt (1994) and Junier (2000) registered a mean of 31.8 °C and 31.6 °C, respectively in *C. crocodilus* nests in Caño Negro. Even though, there was not a statiscally significant difference between those studies and this research (Chi-square test, P > 0.05); there is an increase, in average, of 0.53 °C in incubation temperatures. Sometimes crocodilian females built nests on top of old nests, which allows for higher temperatures and also insulates the eggs from low ground temperatures (Magnusson et al., 1990). This fact could explain the higher recorded temperatures at the nests in this research.

Temperature variations registered showed higher variations than those reported in other studies of crocodilians (Chabreck, 1973; Magnusson, 1979; Magnusson et al., 1985; Campos, 1993; Allsteadt, 1994).

The higher temperatures of the nests implicate less reproductive success and decreased numbers of developed embryos but at the same time, hatchlings can be favored by a better growth in length and by a better increase in weight (Piña et al., 1997). Miranda et al. (2001) observed that hatchlings of caiman nests of temperatures higher than 31 °C presented a better absorption of the yolk and, a faster feeding after hatching.

In nest no. 1 there were five post-hatching dead newborns, and no eggs hatched from nest no. 4. We suggest that phenomenon is due to the high and low temperatures registered at those nests, in accordance with the observations of Ferguson and Joanen (1982).

Campos (1993) determined that temperatures higher than 31.5 °C within the nest produce a higher number of males. Assuming that the critical temperature for the production of clutches with 1:1 sex ratios is about 31.5 °C, the proportion of sexes in the observed nests could be higher than 75% male. This could have repercussions on the number of future reproducing females and, therefore, in the viability of the population.

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