Thermoregulatory behavior of broad-snouted caiman (*Caiman latirostris*) under different thermal regimes[1]

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Abstract

The maintenance of crocodilians in captivity affects their thermoregulatory capacity. Improper husbandry may result in inadequate growth rate and a break down of immunological resistance in captive colonies. We studied the thermoregulatory behavior of hatchlings and young broad-snouted caimans (*Caiman latirostris*) housed in a greenhouse and in a heated shed under regimes of high and low thermal amplitude, during a 48-hour observation period.

Temperatures were recorded hourly in three specific places within the facilities: water-floor, water-border, and dry-floor. At the same time, the locations of the animals in the different zones were recorded. Temperatures varied from 25 to 30 °C in the heated shed, and from 16 to 36 °C in the greenhouse. We designated as "Selected Temperature" (ST) the temperature registered in the zone occupied at a specific moment by a majority of the animals. Hatchlings and young did not differ in terms of thermoregulatory behavior. Animals under the low thermal amplitude regime showed an intermediary ST between maximum and minimum temperatures. Animals under the high thermal amplitude regime showed a more complex thermoregulatory behavior, apparently alternating between hypothermia and thermophily.

[1] Presented in the 3rd Workshop on Conservation and Management of the Broad-snouted Caiman (*Caiman latirostris*). São Paulo, Brasil. 1992.

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Introduction

Reptiles, as ectotherms, depend basically upon external heat sources to control their body temperature, unlike endothermic birds and mammals. Therefore, their energy consumption is relatively shorter and their capacity to transform energy into biomass is relatively higher than those of birds and mammals (Pough, 1980). Reptiles' metabolism is approximately one tenth that of endotherms of similar body size (Benett, 1982), being directly affected by ambient temperature. Oxygen consumption in American alligators (*Alligator mississipiensis*) increases approximately eight times while their body temperature varies from 5 to 30 °C (Coulson & Hernandez, 1983).

Crocodilians are among the largest living reptiles. Their ontogenical development, from hatching to maturity, represents a dramatic increase in their body size. Therefore, individuals suffer considerable changes in their morphology, physiology, and behavior. The amphibious life style of crocodilians results in a distinct thermoregulatory behavior in relation to small lizards and snakes. Their frequent movement from and to water is primary a thermoregulatory function (Lang, 1987).

Crocodilian food consumption is also dependent on body temperature (Lang, 1979; Diefenbach, 1988; and Larriera *et al.*, 1990). Food consumption is highest at approximately at 32 °C, decreases sharply from 25 to 20 °C, and is practically absent below 20 °C (Coulson & Hernandez, 1983). Hatchlings of broad-snouted caiman avoid feeding during the coolest period of the day, from 04:00 to 10:00 h (Verdade *et al.*, 1992). Regurgitation can occur during inadequate body temperatures during digestive processes (Diefenbach, 1981). The time of food passage through the gastro-intestinal tract, as well as the speed of nutrient digestion speed also vary according to body temperature (Diefenbach, 1975a and 1975b, and Coulson & Hernandez, 1983).

Growth rate is also affected by temperature in crocodilians. The maintenance of the water pool at 30 °C, even in open facilities, resulted in a significant increase in the growth rate of American alligators in captivity (Coulson *et al.*, 1973). Environmental chambers with temperatures varying from 23.5 to 27.0 °C also resulted in a significant increase in the growth rate of the animals (Joanen & McNease, 1976). Broad-snouted caimans kept at 27 °C grew faster than those kept at temperatures between 22 to 25.1 °C (Larriera *et al.*, 1990). However, the highest growth rates of captive crocodilians have been obtained through the utilization of environmental chambers with temperatures varying between 32.2 and 33.3 °C (Joanen & McNease, 1977). The maintenance of hatchlings at 30 °C results in a rapid absorption of the yolk, and can represent a significant decrease in the initial mortality rate of a captive colony (Joanen & McNease, 1976; Coulson & Hernandez, 1983; and Lang, 1987). On the other hand, the maintenance of crocodilians in captivity may affect their thermoregulatory capacity by the lack of an adequate thermal gradient (Lang, 1987), which may result in a breakdown of immunological resistance and consequent pre-disposition to the appearance of diseases

(Cooper, 1978; Marcus, 1981; and Foggin, 1987). Although, the maintenance of animals at constant high temperatures has resulted in extremely high growth rates in the American alligators in captivity, it might result in thermal stress and in an increasing propensity for bacterial diseases in captive tropical crocodilians (Lang, 1987).

Tropical crocodilians like *Caiman crocodilus*, and temperate species like *Alligator mississipiensis*, exhibit different responses to low temperatures. This could limit their geographical distributions (Brandt & Mazzotti, 1990). The American alligator seeks heat sources after feeding, in apparent thermophily (Lang, 1987), while the common caiman (*Caiman crocodilus*) apparently does not (Diefenbach, 1975c). The following intra and inter-specific factors can affect thermal selection in crocodilians: body size (Diefenbach, 1975c and Lang, 1987), individual health status, hierarchy position of the individual in the group and/or some other social aspects, and also individual previous conditioning to certain thermal regimes (Lang, 1987). Environmental factors like water temperature, wind speed, and presence of vegetation may affect thermoregulatory behavior of crocodilians (Loveridge, 1984). Radiation of the sunlight on the surface of the water and the water flow can also affect the energy exchange between a turtle and its environment (Hutchinson, 1989), similarly to a crocodilian.

The broad-snouted caiman's geographical distribution extends from around Lat. 5° S in Northeastern Brazil to Lat. 35° S in Northern Argentina (Groombridge, 1982 and Brazaitis *et al.*, 1990). The thermoregulatory behavior of the species in São Paulo State in Brazil (Lat. 23° S) is similar to that of the American alligator (Sajdak & Molina, 1992). However, since their northern populations live in a tropical zone, while their southern populations live in a sub-tropical or even temperate zone, distinct populations under considerable distinct climates may present particular thermoregulatory patterns.

Potential applications of studies on thermoregulatory behavior of crocodilians are severalfold. They may lead to a decreased mortality rate, an increased growth rate and an increased quality of commercial skins from captive animals.

Materials and Methods

Studies were conducted in either an unheated greenhouse, where all modules presented a water pool 4 x 1 m with a 50 cm maximum depth, or in a heated shed, where all modules were inclined floors fitted halfway to a maximum depth of 20 cm.The animals had been acclimatized for at least two months to the experimental conditions. The animals had also been habituated to feed five days a week. This study was conducted during a two day fasting period to avoid the direct influence of feeding on the thermoregulatory behavior.

Preliminary temperature reports showed a higher thermal amplitude in the greenhouse (around 20 °C) than in the heated shed (around 5 °C), with no significant variantion between modules in the same facility. Thirty animals were distributed into the facilities as showed in Table 1, below.

Table 1: Distribution of the animals on the facilities

Facility	Module #	# of animals	Age (years)
Greenhouse	1	3	0.5
	2	4	1.5
	3	4	2.5
	4	4	5.5
Heated shed	1	3	0.5
	2	4	1.5
	3	4	2.5
	4	4	5.5
		N = 30	

Bulb termometers with a precision of 0.5 °C were placed in three different sites in the facilities: water-floor, water-border and dry-floor (Fig. 1). Temperatures were sampled hourly during a 48 hour period in modules without animals in both facilities in order to avoid disturbing them during temperature recording. The animal's locations were recorded simultaneously through direct observation (Lehner, 1979 and Martin & Bateson, 1986). Animal distributions through these temperature zones were analyzed by X^2 Test (Sokal & Rolf, 1969). We designated as "Selected Temperature" (ST) the temperature registered in the zone occupied at a specific moment by a majority of the animals. This was not a reflection of their body temperature at that time (Pough & Gans, 1982), but rather the temperature of the place occupied by most of caimans.

Results and Discussions

The temperatures varied from 25 to 30 °C in the heated shed (Fig. 2), while external temperatures varied from 14 to 34 °C. Greenhouse temperatures ranged from 16 to 36 °C (Fig. 3), being on average 3 to 6 °C above external ambient temperatures. The degree of ST preference varied between both facilities, and reflected the dispersion of individuals under both situations. In the heated shed, the mean ST frequency was 72 %, ranging from 53 to 93%, with a CV of 13.03%, while in the greenhouse it was 66 %, ranging from 33 (random dispersion) to 100% (absolute preference), with a CV of 26.22 %.

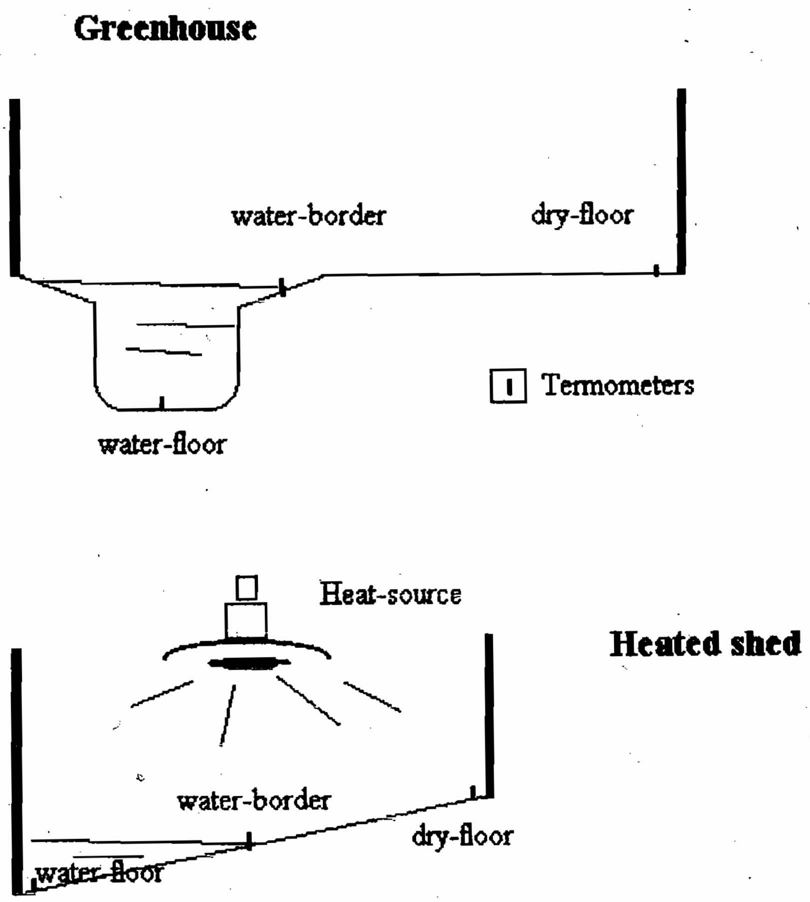

Figure 1. Cross section of a module of each of the facilities

The thermal amplitude of the water-border and dry-floor of the greenhouse was very close to that of the external ambient temperature (around 20 °C). However, in the water-floor it was lower (around 4 °C). Study animals exhibited a lower ST frequency in the greenhouse than in the heated shed, what means that they dispersed significantly more in the former than in the latter. This is probably due to the distinct thermal amplitude of each facility, with higher thermal amplitude making the animals disperse more, possibly in search of a more satisfactory temperature.

Animals of different ages did not exhibit differences in thermoregulatory behavior or dispersion in relation to thermal regimes. Maybe this sample size was not big enough to allow us to perceive differences between different age groups, since six month old hatchlings usually weight less than one tenth of five year old caimans. On the other hand, *Crocodylus niloticus* in the weight range 75 g - 4 kg exhibited similar patterns of heating and cooling, in the absence of radiant heat (Loveridge, 1984).

Heated shed

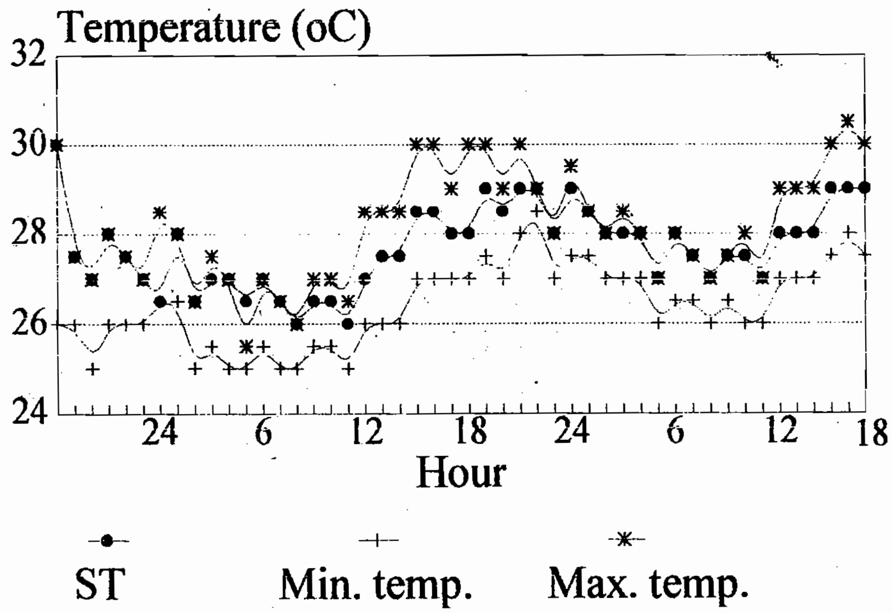

Figure 2. Thermal selection of *Caiman latirostris* in the heated shed

Greenhouse

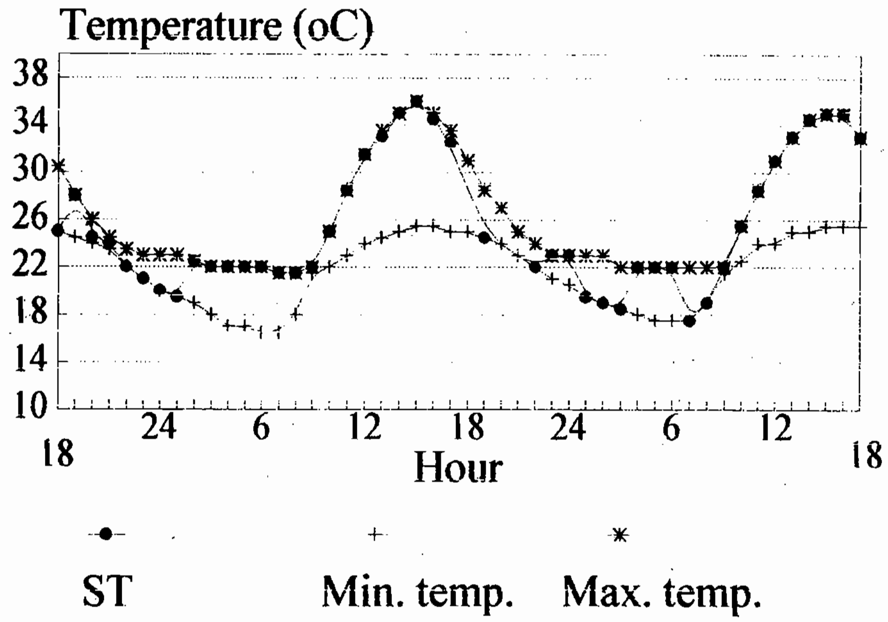

Figure 3. Thermal selection of *Caiman latirostris* in the greenhouse

Animals under the low thermal amplitude regime (heated shed) showed an intermediate ST between maximum and minimum temperatures, with an average of 27.7 °C, ranging from 26 to 30 °C, with a CV of 3.33%. From 14:00 to 03:00 h, ST varied from 28 to 29 °C, below the maximum temperature of the same period that varied from 29 to 30 °C (Fig. 2). Animals under the high thermal amplitude regime (greenhouse) showed an average ST of 25.4 °C, ranging from 18.5 to 36 °C, with a CV of 21.31% (Fig. 3). When the maximum temperature dropped from 30 to 22 °C caimans tended to remain at the sites of lowest temperature in apparent hypothermia. They showed this tendency until temperatures lowered to 19 °C. Then, they conspicuously started to seek the maximum temperature zone until the maximum temperature in the facility reached 36 °C (Fig. 3), in apparent thermophily (Lang, 1987). This shows a possible influence of the previous temperature on thermal selection at a certain moment, contrary to what was stated by Crawshaw (1980) and Crawshaw *et al.* (1980). Thus, caiman could be compensating for periods of low temperature with subsequent periods of thermophyly, or at least exposing themselves to higher temperatures for a longer period in order to reach an adequate body temperature.

The term *hypothermia* is considered with some restrictions for reptiles (Regal, 1967; MacLean et al., 1975; and Gregory, 1987). However, the term appears to be adequate for this study. A temperature of 19 to 20 °C coincides with the limit below which food consumption ceases in crocodilians (Coulson & Hernandez, 1983), while the temperature of 36 °C is an intermediary value between the optimum and the critical temperature for the American alligator (Brattstrom, 1965; Murphy, 1969; Bellairs, 1970, and Cooper & Jackson, 1981; and Cooper, 1986;). The temperatures most sought by the animals varied through the day. A possible reason for this is the nutritional status of the animals at a certain time. The American alligator shows thermophily after food ingestion, while fasting animals keep their body temperatures lower by avoiding heat sources (Lang, 1987).

Under the low thermal amplitude regime, the animals did not show significant thermophily, which is similar to the pattern described by Diefenbach (1975c) for *Caiman crocodilus*, a tropical crocodilian, and could be considered as *thermoconformity* (Lang, 1987). On the other hand, under the high thermal amplitude regime, the animals apparently showed thermophily, searching for the highest temperatures available in certain moments, which is similar to the pattern described by Lang (1987) for *Alligator mississipiensis*, a temperate species. The distinct thermoregulatory patterns, exhibited by the animals under different thermal regimes, stressed the high adaptive capacity of the broad-snouted caiman to different thermal conditions as well as its complex thermoregulatory behavior. The capacity of the species to show thermoregulatory patterns similar to that of a tropical crocodilian, as well as that of a temperate species, depending on the thermal regime the animals are experiencing, may be related to the wide geographical distribution of this species, extending from tropical to temperate regions.

The maintenance of animals in environmental chambers under constant high temperatures has yielded high growth rates for American alligators in captivity (Joanen & McNease, 1987). However, this management system entails high operating costs. It also requieres expensive nutritional and sanitary management systems. Besides, tropical crocodilians might not respond so well to such system because of the lack of thermal gradients (Lang, 1987). A possible alternative to the management of tropical crocodilians in captivity could be the adjustment of the ambient temperature according to the feeding management of the animals. Thus, the temperature of the facility (or chamber) should be increased after feeding the animals and kept high during the necessary period of time for the digestive process, returning then to the initial level. This may significantly reduce costs in large scale breeding projects.

Comparative studies between constant and variable temperatures in captivity are required for the broad-snouted caiman. Thermal regimes to be tested might be based on studies on physiology of digestion like those of Diefenbach (1975c, 1975a, and 1975b) and Coulson & Hernandez (1983), Coulson & Coulson (1986), and Coulson *et al.*,1990).

Aknowledgements

We wish to thank Lydia Flewelling, Dr. Phill Hall, Dr. John Kaufmann, Dr. Wayne King, Dr. Perran Ross, and Carlos Pedreira for their critical reading of this manuscript.

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