# Diurnal use of space by captive adult broad-snouted caiman (*Caiman latirostris*): Implications for pen design

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## Abstract

Crocodilians generally present low reproductive success in captivity. The reasons for this are still unclear, but the faulty design of reproductive facilities can be a cause of stress, injuries and social disruption. This study explored the use of space by captive adult broad-snouted caiman in order to improve pen design for farming species. Caimans showed a predominant use of the pool and its margin during daytime. Even in our small ($9 \times 10$ m) pens, caimans used pools and their margins significantly more than areas farther removed from pools. This pattern suggests that caiman farmers should maximize pool area and perimeter in pen design.
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Crocodilians exhibit elaborate social behavior including a complex social structure, parental care, and a sophisticated communication system of vocalizations, displays, and scent marking (Ayarzaguena, 1983; Lang, 1987; Vliet, 1989). Some crocodilian species maintain individual territories (sensu Kaufmann, 1983) year-round. In other species, territoriality is largely restricted to the mating season, and females may establish a social hierarchy within a male's terri-tory (Lang, 1987). Such a seasonal pattern is typical of temperate species such as the American alligator (*Alligator mississippiensis*) and the broad-snouted cai-man (*Caiman latirostris*) (Lance, 2003; Piña et al., 2004). The use of space may be related to the indivi-dual social status (Grant, 1973). In general, aggressive and big individuals tend to dominate mating activities and habitat selection for nesting, foraging and basking (Gould and Gould, 1989).

Agonistic interactions can represent up to 15% of the total mortality in captivity for *C. latirostris* since in 80% of the fights at least one individual dies (Verdade, 1992). Under farming conditions, the broad-snouted caiman seems eventually to establish

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a social structure that decreases the occurrence of agonistic interactions (Verdade, 1992, 1995, 1999).

Because it is difficult to study crocodilian social behavior in the wild, many behavioral studies have been carried out in captivity (Lang, 1987; Vliet, 1989; Verdade, 1999; Piffer and Verdade, 2002; Piña, 2002). Such studies can show caiman farmers how to reduce negative effects of artificial environments on the welfare of captive crocodilians (Deag, 1981; Warwick et al., 1995).

The broad-snouted caiman is beginning to be commercially produced in Argentina and Brazil (Verdade and Piña, in press). In some provinces of Argentina, where healthy wild populations can still be found, sustained-yield exploitation is based on egg collection in wild and captive rearing of young animals (Larriera, 1990, 1992, 1993, 1994, 1995, 1998). In Brazil, *C. latirostris* has a larger geographical distribution, but its wild populations are generally smaller and more fragmented (Verdade, 1997; Verdade et al., 2002). Therefore, the establishment of a ranching program in Brazil is still unfeasible and the commercial management of the species requires captive maintenance of reproductive adults (i.e., "farming", according to Hutton and Webb, 1992).

Adult crocodilians generally exhibit a low reproductive rate in captivity (Cardeilhac, 1989, 1990). The reasons for this are still unclear, but the configuration of reproductive facilities can be a major cause of stress, injuries and social disruptions (Arena and Warwick, 1995; Huchzermeyer, 2003). This study aims to determine the use of space by captive adult broadsnouted caiman in order to improve pen design for farming the species.

## 1. Materials and methods

This study was carried out at the caiman facilities of the Animal Ecology Lab of the University of São Paulo, in Piracicaba, State of São Paulo, Brazil ($22°42.557'$S, $47°38.246'$W). The captive colony of the species was established in 1987 (Verdade, 2001). The reproductive groups of this study were assembled in 1992 and transferred to the current facilities in 1998. The caimans groups were assembled based on parenthood among individuals recorded in a local Studbook (Verdade and Kassouf-Perina, 1993) but

no caiman was housed with an animal >1.2 times its body-mass (as suggested by Verdade, 1992). Since 1992, 30% to 60% of females have nested every year (average of approximately 40%).

We used four adult groups of one male and two to four females in four reproductive enclosures (Table 1). Each enclosure was $9 \times 10$ m; each included a $6 \times 4$ m pool and five $2 \times 2$ m nesting shelters. Six "microhabitats" (sensu Douglas, 1976) were defined as indicated in Fig. 1.

We used a scanning observation method (Lehner, 1996) every hour and registered each animal's location in the microhabitats above, during daytime (07:00–18:00). Observations were conducted from a 10 m high tower located 2 m outside the facility perimeter. Individuals were identified by their natural marks and tail notching marks. However relevant, nocturnal observations were not carried out in this study because of the impossibility of identifying the caimans in the dark. The use of lamps could affect caimans' behavior, as usually reported for crocodilians (Woodward and Marion, 1978; Hutton et al., 1987); therefore they have not been used.

The study period comprised 90 days evenly distributed over 30 weeks from 10 March to 13 November 2003, for a total of 990 h of observation. This

Table 1
Space use for each animal at each reproductive enclosure

| Enclosure | Animal | Water | Margin | Reproduction | Land |
|---|---|---|---|---|---|
| 1 | ♀1 (repro) | ≈ | ++ | − − | ≈ |
| 1 | ♀2 (non-repro) | ≈ | ++ | ≈ | ≈ |
| 1 | ♂ | ≈ | ++ | − − | ≈ |
| 2 | ♀1 (repro) | − − | ++ | ≈ | ≈ |
| 2 | ♀2 (non-repro) | − − | ++ | − − | ≈ |
| 2 | ♀3 (non-repro) | − − | ++ | ≈ | ≈ |
| 2 | ♂ | ≈ | ++ | − − | ≈ |
| 3 | ♀1 (repro) | ≈ | ++ | − − | ≈ |
| 3 | ♀2 (non-repro) | ≈ | ++ | − − | ≈ |
| 3 | ♂ | ≈ | ++ | − − | ≈ |
| 4 | ♀1 (non-repro) | − − | ≈ | − − | ++ |
| 4 | ♀2 (non-repro) | − − | − − | − − | ++ |
| 4 | ♀3 (non-repro) | − − | ++ | − − | ≈ |
| 4 | ♀4 (non-repro) | − − | ≈ | − − | ++ |
| 4 | ♂ | ≈ | ++ | − − | ≈ |

++: Microhabitats used more than by chance. − −: Microhabitats used less than by chance based on its area. ≈: Microhabitats used by chance. M is the male of each enclosure. Reproductive females ("repro") laid eggs on the subsequent nesting season.
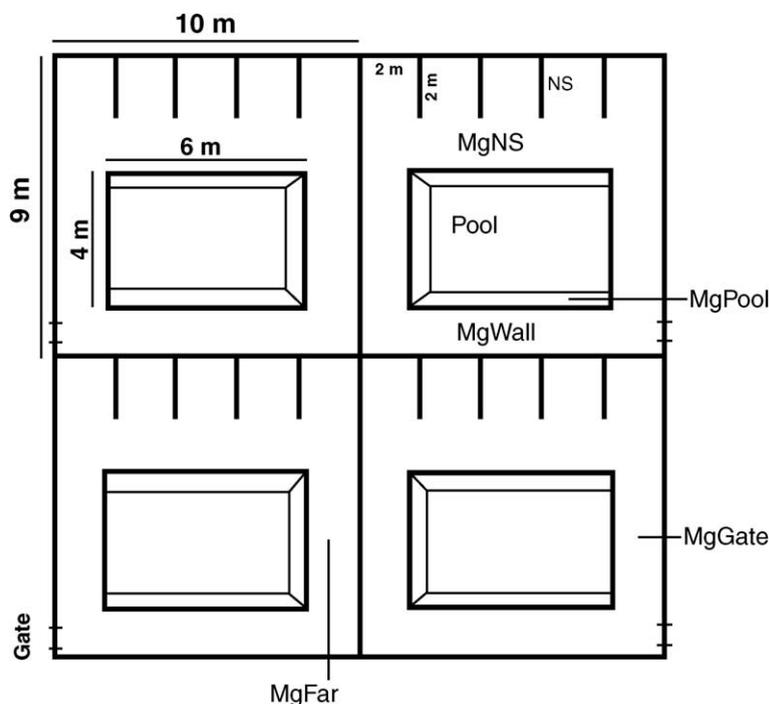
Fig. 1. Caiman reproductive facilities at Animal Ecology Lab, University of São Paulo. a) Nesting shelters (NS), as suggested by Bustard, 1975; b) Nesting shelter margins (MgNS); c) Margin opposite to the gates (MgFar); d) Margin close to the gates (MgGate); e) Inner margin (MgWall); f) Pool margin (MgPool); and, g) Pool.

period covered the entire year, except the nesting season (late November to early March in this region; Verdade, 1995), when animals exhibit specific reproductive behaviors (e.g., mating and nest attendance) that are beyond the scope of the present study. The frequency of microhabitat use by males and females during the study period was compared by $\chi^2$ test: expectation under Ho was that use would be proportional to area.

## 2. Results

Reproduction occurred in three of the four enclosures. In all enclosures, there was a significant difference among individuals in relation to the use of microhabitats ($\chi^2 > 46.4$, $12 < df < 18$, $P < 0.001$); however, at ARN1, ARN2 and ARN3 the pools' margins (MgPool) were used more frequently than by chance alone (Table 1). In ANR4 (where there was no reproductive activity) the animals used the microhabitats in a different way, some used land more than by chance, others used margins and all but the male used water less frequently than by chance (Table 1).

We found a significant difference in microhabitat use between males and females ($\chi^2 = 1040.177$, $df = 18$, $P < 0.001$). Males used the microhabitats differently among each other either considering the whole period of study ($\chi^2 = 59.94$, $df = 9$, $P < 0.001$) or the seasons separately ($23.14 < \chi^2 < 48.89$, $df = 9$, $P < 0.005$). However, considering the area of each microhabitat, the four males stayed relatively longer in the edge of the water, relatively shorter near the nesting shelters, and equally in the water and on the ground (Table 1). The females, on the other hand, presented different time ratios at different microhabitats (Table 1).

There is a significant difference between females from distinct facilities in relation to the use of microhabitats ($\chi^2 = 534.035$, $df = 5$, $P < 0.001$). Reproductive females used the microhabitats differently among each other either considering the whole period of study ($\chi^2 = 169.96$, $df = 6$, $P < 0.001$) or during three of the four seasons separately (i.e., summer, falls and winter; $10.13 < \chi^2 < 147.12$, $df = 9$, $P < 0.001$); during the
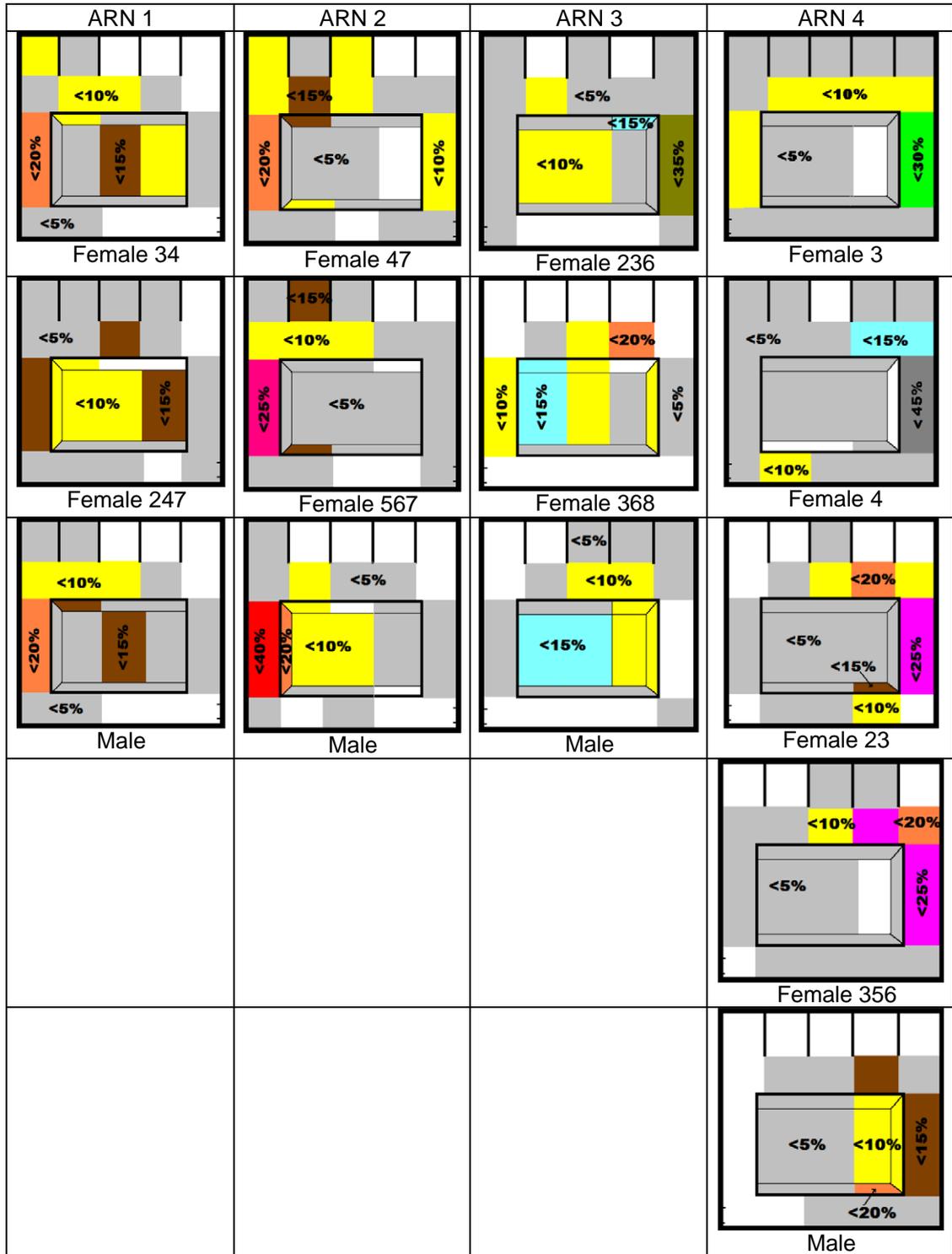
Fig. 2. Use of microhabitats (% of time) by adult captive broad-snouted caiman at the four reproductive facilities of the Animal Ecology Lab, University of São Paulo.

spring there was no difference among them ($\chi^2 = 10.13$, $df = 6$, $P = 0.1194$). Female 4 was the only one that stayed relatively shorter at the edge of the water (Table 1). In her group (ARN4) the animals presented the biggest variation in the use of micro-habitats and did not breed (Fig. 2).

## 3. Discussion

This study was carried out during daylight time when crocodilians spend most of their time basking (Ayarzaguena, 1983). Although there is some general difference between males and females, an individual pattern of space use seems rather predominant. Individual behavioral patterns have been described in mammals (Box, 1990) and birds (Ligon and Ligon, 1991), and may also occur with crocodilians. This may be related to territoriality and should be investigated on future studies. Captive caimans tend to form stable reproductive groups (one male: some females) when animals' body sizes do not differ more than 20% from each other (Verdade, 1992).

Caimans showed a predominant use of the pool and its margin during daytime. Even on the small facilities of this study, the areas more distant from the water were used significantly less, especially those near the gate. This pattern is relevant to the design of caiman breeding facilities for which the pool perimeter should be enlarged as much as possible, but not necessarily increasing the total pen area. As the animals use the pool margin (with shallow water) more frequently than the ground around them, those margins should also be enlarged and the "dry" ground decreased. This can be easily done by enlarging the pool area and decreasing the ground around. Considering the current pen design, an increase in the pool margin from 75 to 100 cm would result in an increase of approximately 17% in the pool area (from 24 to 28.1 m$^2$), and an increase of approximately 38% in the pool margin (from 10.9 to 15 m$^2$). Cemented margins in platform (like a step) instead of ramp form are possibly more adequate as they allow the animals to bask in shallow water and also to exit the water without crawling across companions, which can result in bites or fights.

It is noteworthy that in this study reproductive females presented similar patterns of space use during the non-reproductive period. During the spring, female American alligators store energy for the breeding season in the forthcoming summer (Lance, 2003). It is likely that caiman reproductive females exhibit stereotyped thermoregulatory behavior in order to optimize energy storage and egg production. As a matter of fact, captive adult reproductive broad-snouted caiman were warmer than non-reproductive females during the spring, 4 to 6 weeks prior to egg-laying (Bassetti, 2002).

Although the nesting shelters were not frequently used during this study, they are used extensively by females to nest in and thereby possibly avoiding agonistic interactions during that period (Verdade, 1995). Therefore, they should be kept in future designs of caiman reproductive facilities. However, their form and number should take into consideration the number of females per reproductive group as well as the logistics of egg collection and transportation during management.

As crocodilians generally exhibit nocturnal behavior quite distinct from diurnal behavior, future studies should focus on the use of space by caimans during nighttime. In such situation, observations might be significantly improved by the use of new technologies such as starlight cameras, as their costs become more accessible to researchers in developing countries.

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