SRAS Final Report

Parental Care in *Caiman latirostris* (Crocodylia: Alligatoridae) in Coastal Populations of Brazil

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Abstract

Parental care in crocodilians includes behaviours related to reproduction, such as nest construction and maintenance, egg protection and assistance to hatchlings during pre- and post-hatching stages. In addition, these animals have social interactions and behavioral responses associated with intraspecific communication, vigilance, and defense. Although several species have their behavioural repertories described, there are still gaps to fulfill related manly to the occurrence of behaviours described in disturbed natural environments. One of those habitats are coastal environments which, usually, occurs in a gradient of anthropogenic disturbance. This study evaluated reproductive aspects of *Caiman latirostris* in two contrasting areas of the Cananéia-Iguape-Paranaguá estuarine-lagoon complex: the periurban area of Cananéia Island and the pristine Cardoso Island State Park, a protected area within the Atlantic Forest biome. Between November 2023 and August 2024, 90 sessions of field sampling were conducted to observe behaviour, monitor nests and river conditions with camera trapping, and actively search for individuals or signs of occurrence. Two nests were recorded, one in each study area. In Cananéia, the nest was monitored for 203 days with no hatching. This nest had 28 eggs at the end of the incubation period, but only one with an embryo at an early developmental stage. On Cardoso Island, the nest was identified after hatching had occurred, through eggshells remains and eight hatchlings observed at a nursery area. Taking together it suggests the viability of this nest. Behaviours such as nest maintenance by the female, vigilance to juveniles, and interactions with offspring from previous reproductive seasons were also recorded. In the periurban mangrove area, there was a high density of individuals, with up to 13 caimans recorded simultaneously. Also, there was opportunistic predation events associated with colonial bird nesting. All behaviours recorded reinforce the importance of long-term monitoring as a way to improve the understanding the reproductive ecology of *C. latirostris*, providing new informations to support the conservation and to improve the management strategies of caimans.

Introduction

Crocodilians have a complex behavioural repertoire with a wide range of intra-and interspecific social interactions (3, 11, 38, 29, 20). Among these behaviors, parental care stands out, including nest site selection and construction, as well as the protection and assistance of hatchlings during pre- and post-hatching stages (12).

Nest construction is a critical step for crocodilians. In general, these animals use plant material available in the environment to build mound nests or roles, to protect the eggs and to regulate the thermal microenvironment inside the nest (8, 32). Nest temperature directly influences embryonic development, affecting developmental rate, incubation duration, sex determination, and hatchling fitness (14, 4, 24). Consequently, variation in nest structure and environmental conditions may directly affect the reproductive output.

In addition to nest characteristics, parental care also involves active protection and interaction with resulting offspring (17, 13). These behaviors include agonistic responses to potential predators, particularly during incubation and hatching periods, as well as interactions mediated by acoustic signals (38, 20). Adults respond to hatchling vocalizations, whether natural or simulated, indicating a functional communication system associated with parental care (33, 37). Such responses suggest a

potential occurrence of alloparental care, which occurs in other vertebrates but is still poorly understood in crocodilians (26, 33). Although nesting is predominantly solitary, occasional records of communal nesting in some populations have also been described (27, 22).

Among Neotropical crocodilians, the broad-snouted caiman (*Caiman latirostris* [Daudin, 1802]) is a medium-sized species widely distributed across South America, primarily associated with lentic environments such as lagoons, marshes, and wetlands (6, 9). *Ca. latirostris* occur in both natural and anthropogenically altered environments (35), showing a potentially high tolerance to disturbance. Although *C. latirostris* is classified as Least Concern in global and national assessments (ICMBio/MMA, 2018), this status does not necessarily reflect local population conditions, particularly when populations occur in environments subject to anthropogenic disturbance.

C. latirostris has reproductive behaviors already described in the literature, including mound nest construction using plant material and parental care during embryonic development and hatching (32). However, if and how these behaviors are expressed under natural conditions, especially across different environmental conditions, remains poorly understood.

In this sense, coastal Atlantic Forest regions such as the municipality of Cananéia, located within the Iguape–Cananéia–Paranaguá estuarine-lagoon complex, are within areas of high environmental heterogeneity, including restinga vegetation, mangroves, and wetlands distributed along gradients of marine influence (28). This environmental diversity directly influences the conditions associated with nest site selection. Additionally, the region presents a contrast between areas under greater anthropogenic influence, such as Cananéia Island, and well-preserved areas such as Parque Estadual da Ilha do Cardoso, which has been the focus of previous studies on *C. latirostris* (16, 18, 19).

The environmental heterogeneity and the contrast between areas with different levels of disturbance make these regions particularly relevant for investigating reproductive behavior under natural conditions. Although parental care in *C. latirostris* and other crocodilians has received increasing attention in recent decades, there is still a need for a better understanding of how natural heterogeneous environments modify behavioural responses of *C. latirostris* and which is the effect of such differences in reproductive success and population dynamics (2).

Methodology

Study Area

Field activities were carried out in the Cananéia estuarine-lagoon complex, southern São Paulo State, Brazil, with operational support from the Instituto de Pesquisas de Cananéia (IPeC). Sampling areas included both peri-urban environments on Cananéia Island and the protected area of Parque Estadual da Ilha do Cardoso. These areas included an array of suitable habitats for *Ca. latirostris,* such as mangroves, restinga vegetation, wetlands, streams, and marginal lagoons.

The main sampling sites on Cananéia Island were located in the vicinity of Ponte do Carijó, Rio Olaria, and adjacent peri-urban lagoons. On Ilha do Cardoso, surveys were concentrated around the Rio Perequê, its marginal lagoons, and the northern portion of the protected area (Figure 1).

The sampling areas were progressively defined over the course of the study (Figure 2). On Cananéia Island, three main sites were selected (CA1–CA3). The peri-urban sites CA1 and CA2 were identified through interviews with local residents, who reported the presence of reproductive pairs and recent sightings of the species. These areas were subsequently surveyed to confirm the occurrence of *C. latirostris*, estimate relative abundance, and identify potential nesting sites. Site CA3, located near Ponte do Carijó, was selected based on suitable habitat characteristics and repeated reports of a reproductive pair associated with a nearby lagoon.

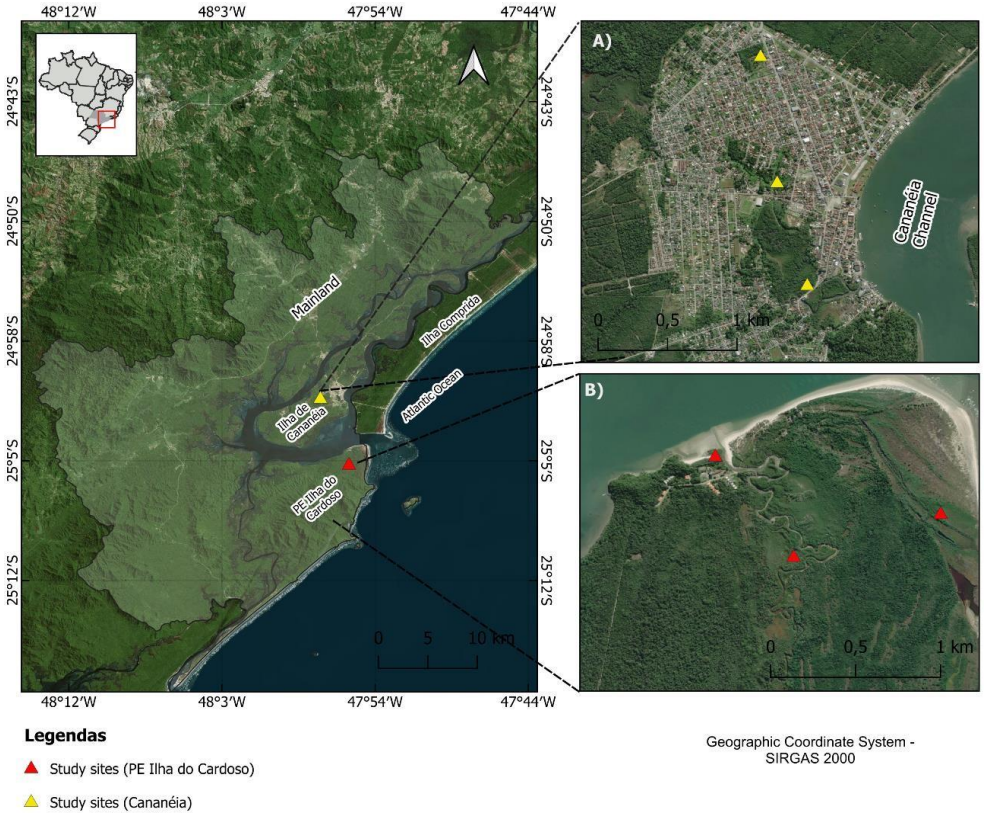


Figure 1. Location map of the municipality of Cananéia, São Paulo State, Brazil, with detailed views of the study areas: (A) Cananéia Island; (B) northern portion of Parque Estadual da Ilha do Cardoso.



Figure 2. Sampled areas on Cananéia Island: (A) view of Ponte do Carijó in a mangrove environment facing the interior of the island, used for behavioral observations; (B) view of Ponte do Carijó toward the estuarine-lagoon channel; (C) vegetation associated with lagoons in periurban areas of Cananéia.

In Parque Estadual da Ilha do Cardoso, sampling was concentrated in three localities (IC1–IC3) in the northern portion of the protected area (Figure 3). IC1 comprises the surroundings of Núcleo Perequê and adjacent lagoons, where local residents reported reproductive events and the presence of hatchlings. IC2 encompassed the entire Rio Perequê and its marginal lagoons, including areas previously studied by Moulton (19), with logistical support from environmental monitors and residents. IC3 consisted of two more isolated marginal lagoons characterized by herbaceous wetland vegetation and confirmed records of the species, representing sites with high potential for nesting.

Sampling Period

Fieldwork was carried out between November 2023 and August 2024. From November 2023 to March 2024, sampling occurred continuously, focusing on the recognition of the areas, behavioral observations, and nest monitoring. From March to August 2024, activities were conducted on a weekly basis, allowing the reassessment of previously surveyed areas and the identification of new sites with reproductive potential.

Nest Monitoring and Behavioral Observations

Morning surveys (06:00-12:00) focused on active searches for nests, tracks, adults, juveniles, and evidence of parental care. Once nests were detected, camera traps were installed nearby to record parental behavior, nest maintenance, predation events, or post-hatching interactions, while minimizing disturbance (5, 23)

In the afternoon, observations (13:00-19:00) were conducted using the focal animal method (1), allowing continuous monitoring of individual behavior. This approach was complemented by direct observations, photographic records and field notes. This monitoring scheme facilitates the record of behaviours such as vigilance, agonistic responses, vocalizations, interactions between adults and juveniles, and interspecific interactions.

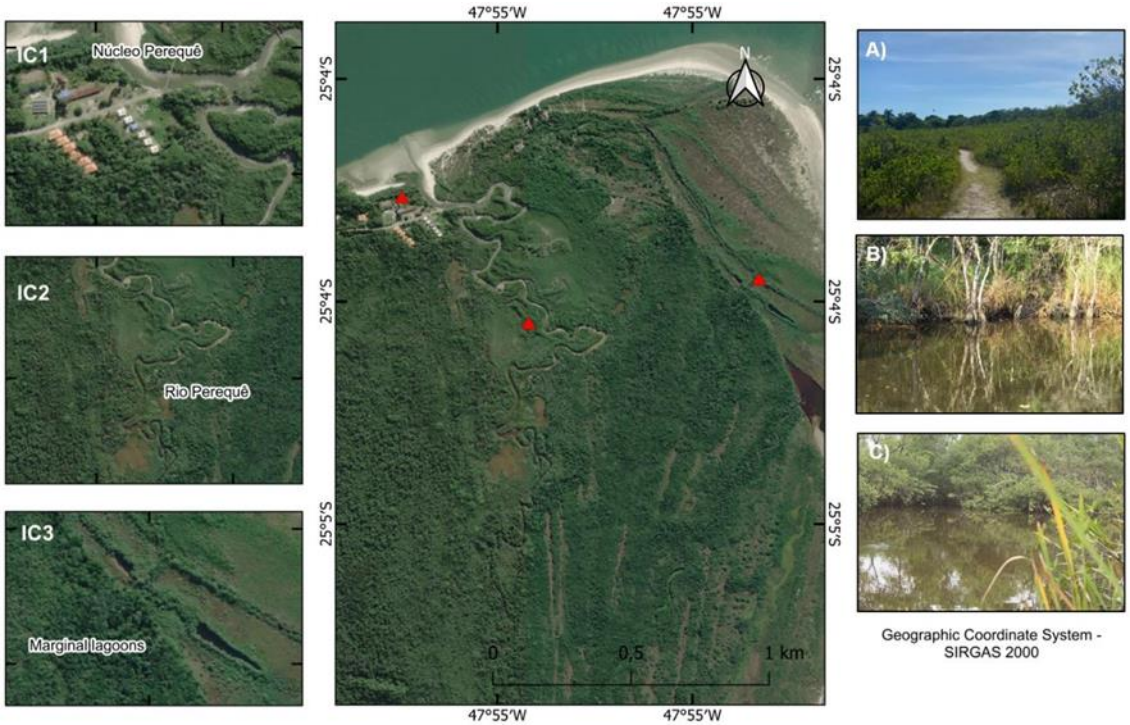


Figure 3. Sampled areas in Parque Estadual da Ilha do Cardoso: (A) access trail to Rio Perequê within restinga vegetation; (B) lagoon associated with the Rio Perequê course; (C) marginal lagoons located farther from the main river channel.

Density Analysis

To identify areas with higher spatial concentration of *C. latirostris,* we performed a kernel density analysis in QGIS 3.34.15 (25). Kernel density estimation is a non-parametric approach widely used to detect hotspots of occurrences intensity from georeferenced records (39). The analysis was applied to a point layer comprising direct records of adults and juveniles obtained during field activities. We use a 100 m bandwidth and a spatial resolution of 5 m pixel size to improve the spatial representation of individual distribution across the sampling period.

Results

Nest Monitoring

During the sampling period, two nests of *Ca. latirostris* were recorded, one located in the peri-urban area on Cananéia Island and another in the Parque Estadual da Ilha do Cardoso. The nest on Cananéia was detected early and monitored throughout the sampling period. In contrast, the nest on the Ilha do Cardoso was detected only after hatching had already occurred, which limited the possibility of monitoring earlier stages of development.

Nest 1 – Cananéia

The nest was identified on 16 January 2024 in a restinga area near Ponte do Carijó, approximately 2 m from the margin of a lagoon. It was built beneath shrub vegetation in a predominantly shaded environment. The nest was composed of leaf litter, branches, roots, soil, and marginal vegetation, and also contained anthropogenic material, including solid waste and fragments of tire.

Following its detection, a camera trap (Figure 4) was installed and remained active for 203 days, allowing continuous monitoring of the site. During this period, records showed nest maintenance behavior by the female, such as the manipulation and repositioning of leaf litter using the hind limbs. Throughout the incubation period, the nest structure was kept intact and was not opened to avoid disturbance and minimize predation risks associated with nest manipulation (30).

After six months with no evidence of hatching, the nest was opened for inspection (Figure 5). A total of 28 eggs were recorded, of which 20 were intact, seven were broken, and only one contained an embryo at an early developmental stage (5). All material was collected under SISBio/ICMBio permit nº 95289 and deposited at the Museu de História Natural do Capão da Imbuia.

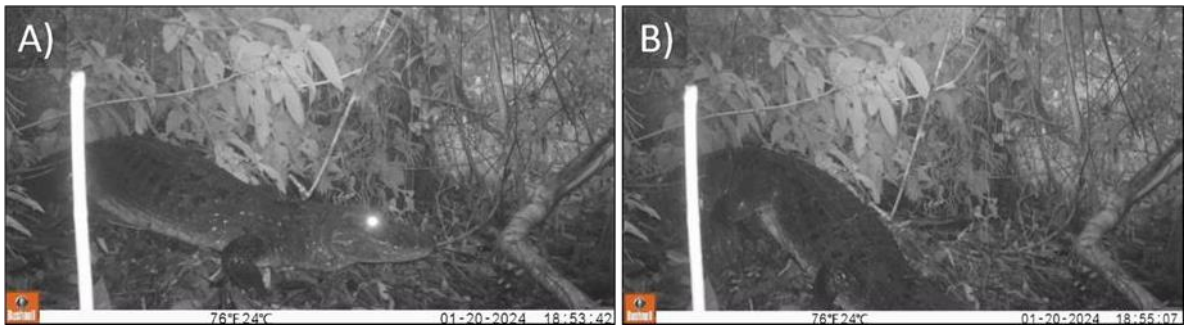


Figure 4. (A) Female of *Caiman latirostris* positioned on the nest; (B) Nest maintenance behavior, moving leaf litter with the hind limbs.



Figure 5. (A) Nest recorded in January 2024; (B) nest after opening for inspection, with eggs surrounded by roots; (C) eggs collected for transport and analysis; (D) egg biometric measurements; (E) opening of eggs to evaluate possible fertilization; (F) hatchling found in an early stage of development.

Nest 2 - Ilha do Cardoso

The second nest was recorded on 08 August 2024 in Parque Estadual da Ilha do Cardoso, when it was already in the post-hatching stage (Figure 6). Eggshell fragments were scattered around the nest, and eight hatchlings were observed grouped in a nearby marginal lagoon, which appeared to be used as a nursery area.

The nest was located approximately 15 m from the river margin and 3 m from the nursery lagoon, in a slightly elevated area beneath restinga shrub vegetation, with partial shading. Its structure consisted mainly of leaf litter, branches, roots, and porous soil.

Following its detection a camera trap was installed and remained in operation for 86 days. However, few behavioral interactions were recorded during this period, with no clear evidence of direct parental interactions documented.

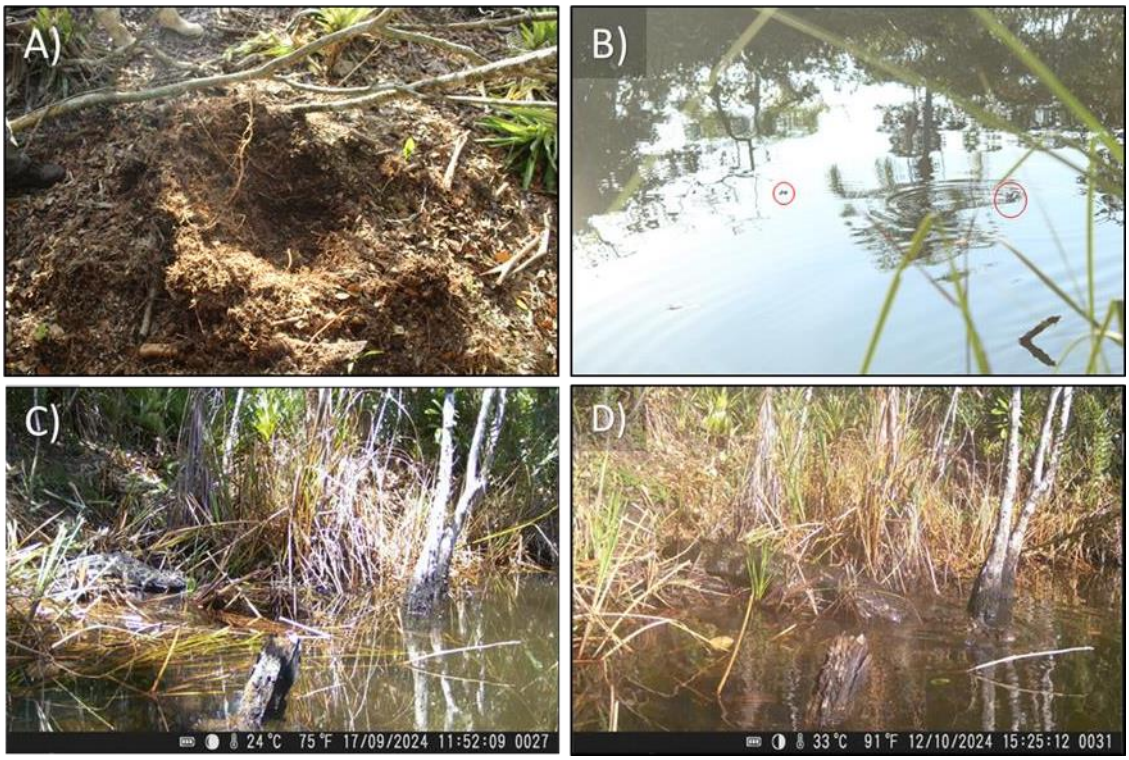


Figure 6. (A) Nest identified in August 2024; (B) two hatchlings in the nursery area, one of them recorded during vocalization; (C) hatchling displaying thermoregulatory behavior on the lagoon margin; (D) adult female entering the nursery area.

Behavioral Records

Intra and Interspecific Interactions

Along the Rio Olaria, near Ponte do Carijó, several interactions between *Ca. latirostris* and other organisms were recorded in a mangrove area characterized by a high concentration of adults. During observation sessions, up to 13 individuals were observed simultaneously. Larger individuals were repeatedly observed in the same locations, suggesting site fidelity and the recurrent use of specific areas.

Vocalizations accompanied by water vibrations, bubbling, and body movements consistent with the "bellowing display" described for crocodilians were frequently observed following the researcher's approach (20, 38). In many observation sessions, a larger individual would emerge and adopt a vigilance posture, while the juvenile either remained active or submerged completely.

Predatory interactions involving aquatic birds were also recorded. An individual of [*Egretta thula* (Molina, 1782)] was captured after falling into the water during a territorial dispute. Also, we observed opportunistic predation of fallen nestlings of *E. thula* and [*Egretta caerulea* (Linnaeus, 1758)] below nesting colonies (7), consistent with previous records for crocodilians (21). The recurrent presence of individuals beneath bird colonies suggests opportunistic exploitation of these areas. However, it was not possible to assess specific behaviors related to active foraging strategies, such as the use of vegetative structures as bait, as described for other crocodilians (7).

In Parque Estadual da Ilha do Cardoso, behavioral records were more limited. Individuals were less conspicuous during boat and kayak approaches, although repeated observations at the same locations also suggested spatial fidelity along Rio Perequê.



Figure 7. (A) Record of the individuals that preyed upon *Egretta thula;* (B) young *Ca. latirostris* accompanying a hatchling of *E. thula* that had fallen into the lagoon; (C) lateral view of *Ca. latirostris* covered by branches; (D) dorsal view.

Parental Care

During the monitoring of the Cananéia nest, the female was observed caring for juveniles from previous reproductive seasons in both the lagoon adjacent to the nest and in a nearby nursery area. In one recorded event, following alarm vocalizations emitted by a captured juvenile, the female performed a defensive approach and remained in vigilance posture near the researcher (38).

Nest maintenance behavior was recorded on four occasions in January 2024, mainly during the late afternoon and early night, often on rainy days. These activities involved the female actively moving and repositioning leaf litter over the nest using the hind limbs.

Although the female was not continuously present near the nest and did not show direct defensive responses during most observation sessions, she was more frequently recorded in close proximity to the nest during the expected hatching period and later remained associated with the nearby lagoon.

Potential Occurrence Areas

On Cananéia Island, juveniles and adults were recorded in peri-urban streams and lagoons connected to the Rio Olaria (Figure 8). The highest concentration of individuals was observed near Ponte do Carijó (CA3), where a nursery area was also identified.

In peri-urban areas, hatchlings were observed using drainage structures such as culverts, apparently for thermoregulation. Some individuals were also recorded in temporarily flooded isolated areas, where they may become more exposed to urban related threats.

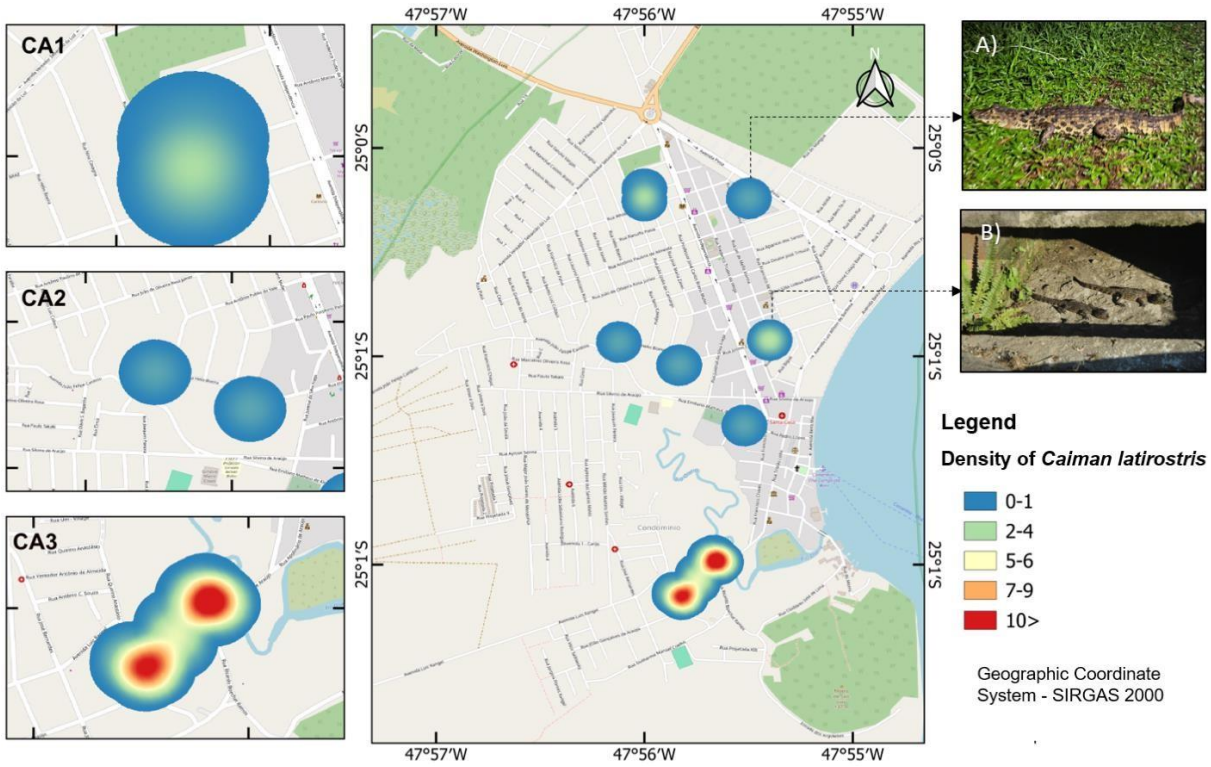


Figure 8. Density map of *Ca. latirostris* occurrence generated by Kernel analysis on Cananéia Island. A) Record of a juvenile individual in an isolated area previously affected by flooding; B) Record of two hatchlings thermoregulating inside a drainage culvert.

In Parque Estadual da Ilha do Cardoso, individuals were less conspicuous, but repeated records indicated recurrent use of specific sites. The highest number of observations were in the area where the active nest was located, near Rio Perequê. Besides it, marginal lagoons situated farther from the main river channel had high potential for nesting as indicated by the repeated observations of multiple individuals within the same habitat.

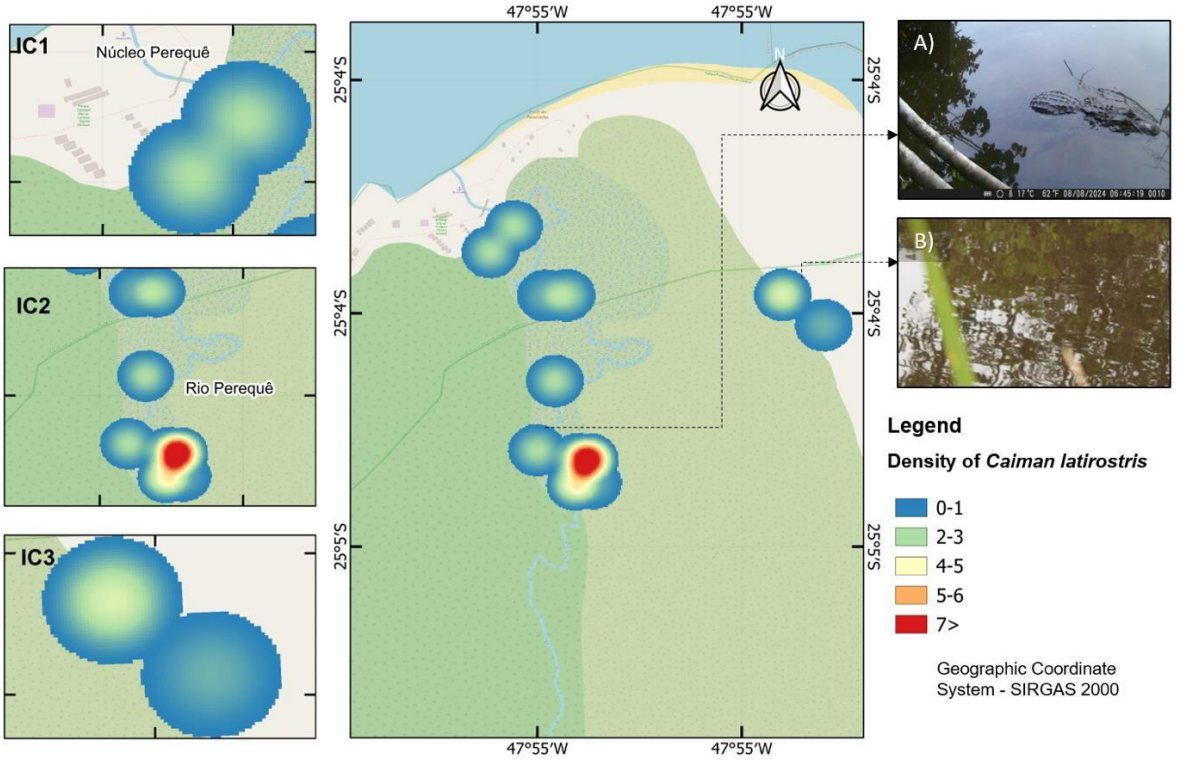


Figure 10. Density map of *Ca. latirostris* occurrence generated by Kernel analysis in the Parque Estadual da Ilha do Cardoso. A) Record of an individual obtained by camera trap installed to monitor behavior and habitat use; B) Record of an individual in a marginal lagoon.

Discussion

The observations revealed distinct patterns of behavior and habitat use of *Ca. latirostris* between the sampled areas, which differed in environmental characteristics and levels of anthropogenic disturbance. In Cananéia, individuals were more frequently observed and exhibit greater exposure, particularly near Ponte do Carijó, an area with intense human activity. In contrast, in the Parque Estadual da Ilha do Cardoso, individuals were less conspicuous, although repeatedly recorded at specific locations throughout the sampling period. These patterns suggest differences in behavioral responses to environmental conditions, possibly associated with varying levels of disturbance and tolerance to human presence over time, as previously described for crocodilians [31].

These spatial differences are also reflected in abundance estimates. In Cananéia, records from the Rio Olaria region indicated a higher number of individuals than previously reported by Merege [16], who recorded four adults and two juveniles along the entire river. In the present study, up to 13 individuals were observed simultaneously at a single sampling site, with a predominance of adults. However, methodological differences between studies should be considered, as Merege [16] employed standardized nocturnal surveys along the entire river, whereas this study was based on continuous daytime observations concentrated in specific areas. These differences in sampling design may directly influence detectability and relative abundance estimates.

Reproductive outcomes also differed between areas. The nest monitored in Cananéia showed no evidence of hatching, whereas the nest on Ilha do Cardoso had clear signs of reproductive success, including eggshell remains and hatchlings in the nursery area. Although direct causal relationships cannot be established, factors such as substrate characteristics, vegetation cover, and local disturbance are known to play a key role in embryo development and nest success in crocodilians [30]. In this context, environmental heterogeneity and varying levels of anthropogenic influence likely contribute

to the difference in reproductive outcomes observed between sites, as highlighted in studies emphasizing the importance of long-term monitoring for understanding reproductive success under natural and disturbed conditions (15, 23).

Behavioral observations associated with parental care included nest maintenance by the female, vigilance responses, and interactions with offspring from previous reproductive seasons. These findings reinforce the importance of parental care in the reproductive ecology of *Ca. latirostris* and are consistent with previous descriptions of nest defense and offspring protection in crocodilians [20]. In addition, the interspecific interactions observed, particularly opportunistic predation associated with bird nesting colonies, indicate the exploitation of locally available resources, a pattern previously described for crocodilians [21].

Along the Rio Perequê, the records suggest a greater use of marginal lagoons compared to the main river channel, possibly reflecting an increased shelter availability and more favorable nesting conditions. Similarly, in Cananéia, the connectivity between peri-urban channels and the Rio Olaria may facilitate habitat use across different environments, expanding the potential distribution of *Ca. latirostris* in the region.

Acknowledgements

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