SRAS Final Report: Effect of Fire on Populations of Caiman yacare in Iberá National Park, Corrientes – Argentina

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Abstract

Fire is a significant disturbance that shapes biological communities, with its effects varying according to the burning season, accumulated fuel load, and meteorological conditions. Wet savannas are highly vulnerable to burning due to the large amount of organic matter they present, and during dry seasons, they are susceptible to wildfires. During periods of drought, when water bodies decrease in depth and surface area, crocodilians can exhibit poor body condition and employ varied survival strategies. This study evaluated the effects of historical fire frequencies, drought conditions, and severe burn events on the density, distribution, body condition, and reproductive parameters of *Caiman yacare* within the Iberá wetland system in Corrientes, Argentina. Field surveys were conducted across lagoons and designated plots with varying fire histories to evaluate spatial distribution, size-class structures, and body condition scores (BCS). Active nest searching was deployed during reproductive seasons utilizing intensive ground campaigns and drone technology. Spectral analysis via the Normalized Difference Vegetation Index (NDVI) was used to assess variations in vegetation cover. The results revealed a significant reduction in vegetation cover following major fires, coinciding with a total absence of detected nesting mounds across monitored polygons during the evaluated seasons. This nesting failure suggests a severe lack of building materials or physiological stress within the population. Nighttime population surveys revealed highly variable relative densities across the landscape, displaying massive individual aggregations during hyper-drought conditions followed by sharp declines as water levels rose. Furthermore, individuals inhabiting fire-degraded lagoons exhibited significantly lower body condition scores compared to those in unburned control areas. These findings indicate that while *Caiman yacare* populations aggregate in remaining water bodies during climatic stress, the cumulative impacts of fire and prolonged drought severely compromise their health status and immediate reproductive potential.

Introduction

Within the wetland regions of Argentina, the Esteros del Iberá basin stands out as an area of high biological diversity, where *Caiman yacare* represents a prominent vertebrate species (Giraudo et al., 2006). Following a historical recovery from intense commercial hunting pressures due to international trade regulations established in the early 1990s (Waller & Micucci, 1995), wild populations now face modern climate-driven and anthropogenic challenges. Globally, more than half of all crocodilian species are endangered due to climatic and anthropogenic effects (Somaweera et al., 2020). Climate change alters ambient temperatures and increases the probability of high-intensity wildfires and prolonged droughts (Tomas et al., 2021). These compounding stressors cause periods of water and food scarcity, which can elevate mortality rates and decrease long-term reproductive potential (Campos & Mourão, 2020).

Fire shapes biological communities by altering soil parameters, reducing plant biomass, suppressing woody vegetation, and modifying habitat attributes such as environmental heterogeneity and cover. Wet savannas accumulate substantial communities of aquatic and floating plants that are highly vulnerable to large-scale burning during dry seasons (Benzaquen et al., 2017; Minotti et al., 2013). Despite the known importance of *Caiman yacare* as an ecosystem engineer that builds nests, creates trails, and acts as a vital link in food chains (Somaweera et al., 2020), the specific ecological impacts of fire and drought on their population dynamics remain poorly understood. Crocodilian reproduction depends on stable hydro-climatological variables (Campos et al., 2015; Grigg & Kirshner, 2015). Variations in available vegetation cover can alter

the thermal environments of nests, elevate incubation temperatures, skew hatchling sex ratios, and escalate nest predation risks (Elsey, 1996; Piña et al., 2003; Somaweera et al., 2019). This study aims to quantify the impacts of severe fire events and drought on the density, distribution, population structure, body condition, and reproductive success of *Caiman yacare* within Iberá National Park.

Methods

Fieldwork was conducted within the core conservation sectors of Iberá National Park, Corrientes, focusing on the San Nicolás and Cambyretá. To characterize historical fire frequencies and vegetation degradation, remote spectral assessments were conducted using the Normalized Difference Vegetation Index (NDVI) derived from Google Earth Engine and integrated into a QGIS Geographic Information System.

Reproductive success indicators were estimated during January, February, and March across the 2022/2023 and 2023/2024 breeding seasons. Active searches for nesting mounds were performed across eight designated plots of approximately 10 hectares each: four polygons located on both banks of the Carambola stream (San Nicolás Nucleus) containing fire-affected areas (P1, P2) and unaffected control areas (P3, P4); and four polygons in the Isipoó lagoon (Cambyretá Nucleus), all of which were fire-affected zones. Drone-based aerial tracking was added during the 2023/2024 season to expand search efficiency across ten additional polygons near the main road of the San Nicolás.

Table 1. Summary of survey sites and total hectares sampled

Nucleus	Polygon	Area (Hectares)
Cambyretá	PC 1	10.3
Cambyretá	PC 2	10.9
Cambyretá	PC 3	10.4
Cambyretá	PC 4	10.7
San Nicolás	P 1	9.97
San Nicolás	P 2	10.3
San Nicolás	P 3	10.3
San Nicolás	P 4	13.0

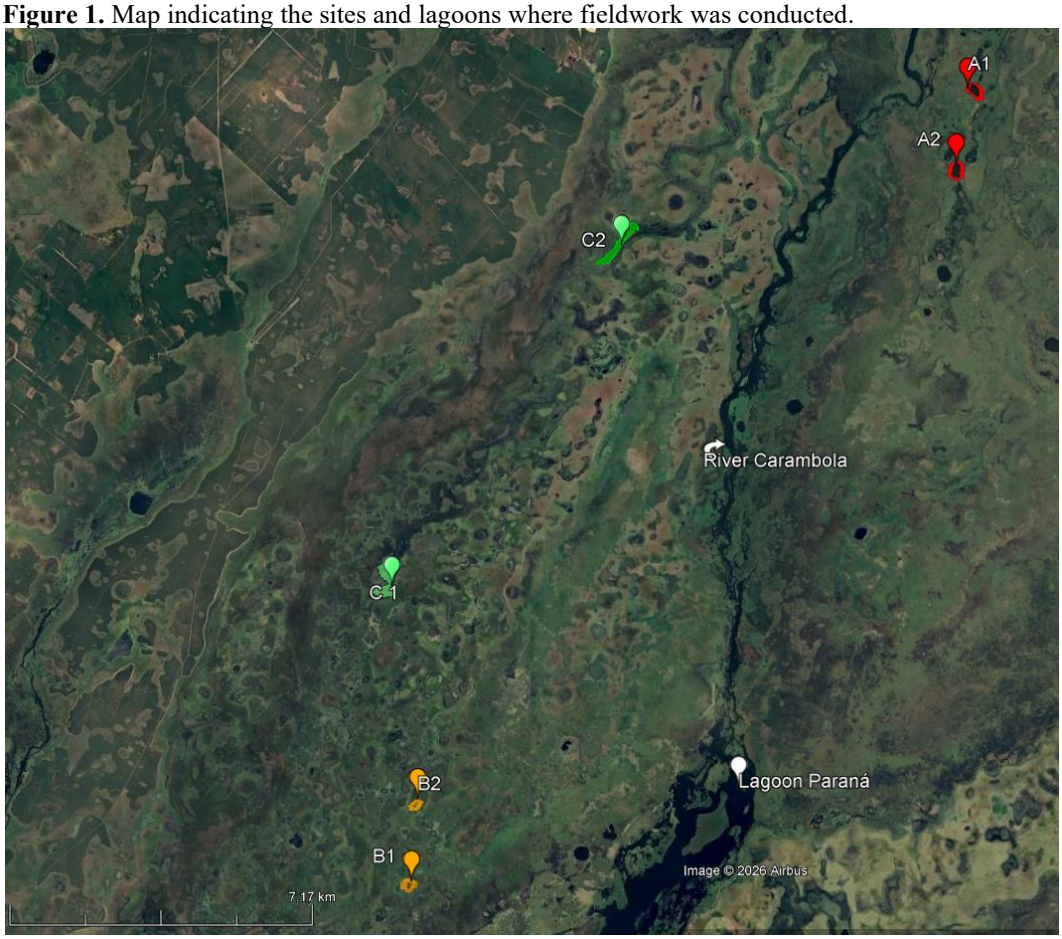
Population monitoring, size-class categorization, and body condition assessments were conducted across six distinct lagoons within the San Nicolás Nucleus, categorized by fire history: lagoons A1–A2 (affected by fires in both 2022 and 2023), B1–B2 (affected by fires in 2023 only), and C1–C2 (unaffected control baselines) (Figure 1).

Nighttime spotlight counts were carried out along lagoon shorelines (Piña et al., 2012). Count data were converted to mean relative densities (individuals observed per kilometer of shoreline surveyed), excluding Class I individuals (< 50 cm) from density models due to high natural mortality rates. Observed caimans were classified into biological size categories: Class II (50–139.9 cm), Class III (140–179.9 cm), and Class IV (> 180 cm). Individual Body Condition Scores (BCS) were evaluated morphologically based on skeletal characteristics at four diagnostic validation points: the articular bone of the mandible, the cervical vertebrae, the scapular bones, and the cervical fossa. Individuals were categorized into five conditions: Emaciated (BCS-1), Thin (BCS-2), Normal (BCS-3), Stout (BCS-4), or Obese (BCS-5) (Ojeda-Adame et al., 2020).

Statistical evaluations included Analysis of Variance (ANOVA) for density variations, Kruskal-Wallis tests for body condition ranks, and Spearman's correlations for environmental associations. Semi-structured

interviews with park rangers and long-term residents provided additional context for tracking occupied habitats.

Figure 1. Map indicating the sites and lagoons where fieldwork was conducted.

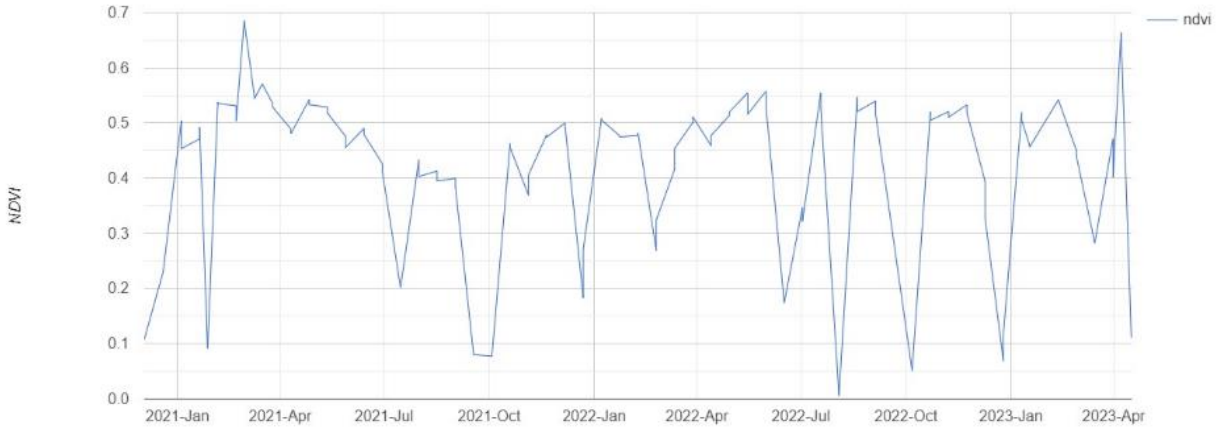


Results

Characterization of Historical Fire Frequency

Analysis of the NDVI temporal series between December 2020 and April 2023 highlighted profound structural changes in wetland vegetation cover (Figure 2). The lowest NDVI spectral values were recorded between July 2022 and January 2023. This decline directly reflected the combined impacts of reduced winter photosynthetic activity and severe wildfires that burned across the San Nicolás and Cambyretá nuclei in January 2023, causing a substantial loss of the plant biomass required for nest building (Benzaquen et al., 2017).

Figure 2. Variation in NDVI (Normalized Difference Vegetation Index) for the study area between December 2020 and April 2023.



Population Dynamics, Densities, and Size Structure

Population indicators varied sharply between the two monitoring seasons, driven by changes in hydric conditions and fire history:

2022/2023 Season (Drought/Fire Event): Surveys covered 7.38 km of lagoon shorelines, recording a total of 1,723 *Caiman yacare* individuals. Relative densities were exceptionally high, ranging from 96.2 ind/km to 524.6 ind/km, with an overall mean relative density of 241.2 ± 64.8 ind/km. The highest mean densities occurred in lagoons A (432.2 ind/km; burned twice), followed by lagoons B (162.4 ind/km; burned once), and lagoons C (149.1 ind/km; unburned). Size class analysis showed a dominance of subadults (Class II: 48%), followed by breeders (Class III: 35%), and a smaller adult male fraction (Class IV: 17%) (Figure 3). Lagoons affected by the 2023 fires (Lagoons B) exhibited a noticeable drop in the percentage of Class II individuals (Figure 4). No Class I hatchlings were observed in any location.

Figure 3. Size class distribution of Caiman yacare across sampling sites (2022/2023).

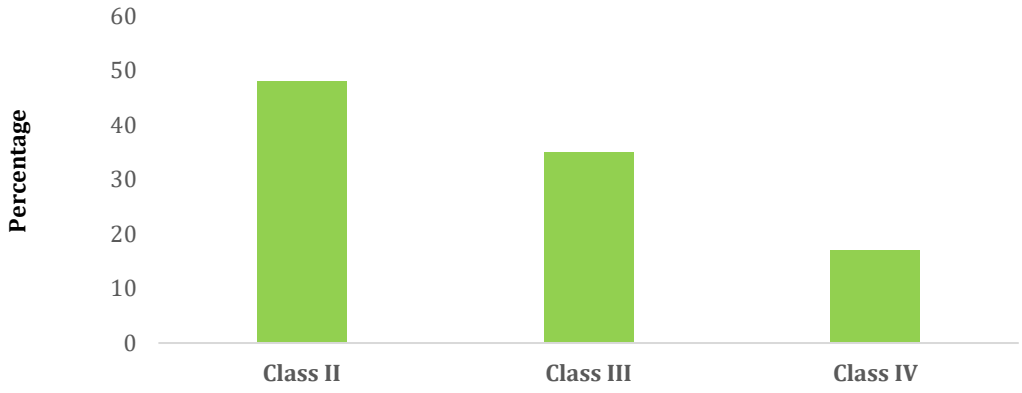
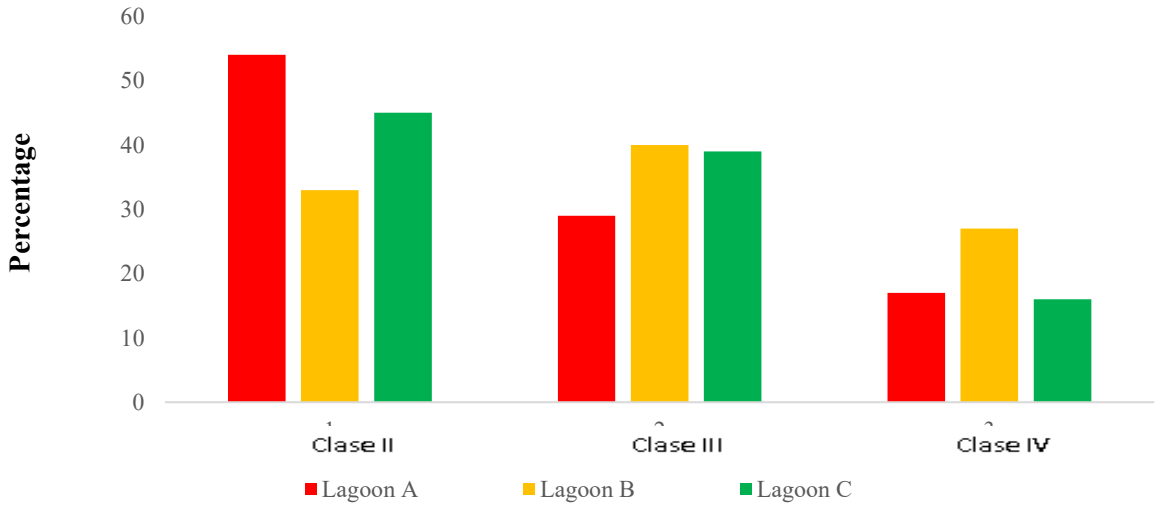


Figure 4. Size class distribution of Caiman yacare in Lagoons A, B, and C.



2023/2024 Season (High Water Recovery): Surveys covered 10.02 km of lagoon shorelines, but counted only 67 individuals. The overall mean relative density dropped sharply to 6.3 ± 2.2 ind/km (ranging from 4.3 to 16.5 ind/km). The highest average densities were recorded in lagoons B (10.4 ind/km), followed by lagoons C (6.75 ind/km), and lagoons A (1.7 ind/km). Size-class distributions changed markedly, showing a complete absence of Class IV individuals in twice-burned lagoons (Lagoons A) and an absence of Class II individuals in unburned lagoons (Lagoons C). No Class I individuals were observed.

Body Condition Appraisals

The body condition of evaluated caimans differed significantly between fire histories and altered water conditions across both years. During the 2022/2023 drought, an evaluation of 402 individuals revealed that 9% were Emaciated (BCS-1), 62% were Thin (BCS-2), 27% were Normal (BCS-3), and only 1% were Stout (BCS-4) according to the scale by Ojeda-Adame et al. (2020). Kruskal-Wallis testing confirmed that individuals in fire-affected lagoons had significantly lower body condition scores ($z = -3.10$; $p = 0.001$). Lagoons B (recently burned) had the highest proportion of emaciated individuals (20%), while unburned lagoons C maintained the highest proportion of normal individuals (43%). Class IV adults exhibited the highest percentage of emaciated specimens (19%) compared to younger classes.

During the 2023/2024 high-water season, an evaluation of 36 individuals indicated a slight shifting trend: 16% were Thin (BCS-2), 58% were Normal (BCS-3), and 25% were Stout (BCS-4), with a complete absence of emaciated (BCS-1) individuals, even within the twice-burned lagoons A. Class III breeders represented the highest percentage of normal body conditions (27.8%).

Reproductive Success Indicators

Intensive active ground tracking across the eight primary sampling plots in the 2022/2023 season resulted in a total absence of detected nests. Similarly, despite expanding the survey using drone flights over the Carambola stream, San Nicolás road plots, and Isipoó lagoon during the 2023/2024 season, no nests were found. This lack of nests prevented the gathering of direct nesting metrics or predator data for those seasons. However, ongoing monitoring during the subsequent 2024/2025 season successfully located nests and

deployed camera traps; these records are currently being analyzed to evaluate reproductive success and identify nest predators, focusing on the impacts of the invasive wild boar (*Sus scrofa*).

Discussion

The preliminary results confirm that severe wildfires and prolonged droughts alter the population dynamics and health status of *Caiman yacare* within Iberá National Park. Severe regional drought and the drying of smaller water bodies forced caimans to gather in the remaining deep water bodies The high population densities recorded during the 2022/2023 season do not indicate an expanding population, but rather reflect an aggregation effect typical of crocodilians under water stress (Campos & Mourão, 2020). This aggregation explains why densities exceeded historical provincial baselines (Piña et al., 2012), particularly in twice-burned areas where adjacent vegetation was completely lost. Conversely, the sharp decline in density observed during the 2023/2024 season reflects a dispersal response as rising water levels allowed individuals to spread back into newly flooded environments, reducing their visibility during counts (Campos et al., 2015).

The body condition scores support these habitat stress patterns. The high percentage of emaciated (BCS-1) and thin (BCS-2) individuals in burned areas during the drought highlights the impact of fire on wetland ecosystems. Wildfires consume aquatic and littoral plant biomass, destroying structural cover and disrupting local food webs (Somaweera et al., 2019; Tomas et al., 2021). This habitat degradation leaves caimans, particularly larger adults (Class IV), with limited nutritional options and lower body condition scores. The absence of emaciated individuals in the 2023/2024 season indicates that returning water levels help mitigate acute physiological stress and support body condition recovery (Campos & Mourão, 2020).

The total absence of nesting mounds during the 2022/2023 and 2023/2024 seasons highlights a major disruption in recruitment. This reproductive failure is directly linked to fire impacts on nesting habitats, a phenomenon previously observed in other alligators (Elsey, 1996). Burning suppresses woody vegetation and reduces the plant biomass, leaf litter, and organic matter required for mound construction (Somaweera et al., 2019). Without adequate nesting material, females face nesting constraints, which are likely exacerbated by drought-induced physiological stress (Campos et al., 2015). The lack of young-of-the-year classes (Class I) across both survey periods confirms a complete absence of local recruitment. This structural gap is visible in the declining proportion of subadults within recently burned zones. Long-term demographic monitoring and the incorporation of remote sensing tools (NDVI/NBR) remain essential for managing wetland habitats and protecting critical nesting areas from altered fire regimes.

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