

Use of water bodies by the collared peccary *Pecari tajacu* (Artiodactyla: Tayassuidae) in the Maya Forest, Mexico

Uso de cuerpos de agua por el pecarí de collar *Pecari tajacu* (Artiodactyla: Tayassuidae) en la Selva Maya, México

¹ KHIAVETT SÁNCHEZ-PINZÓN, ^{2,3} FERNANDO M. CONTRERAS-MORENO, ¹ DANIEL JESÚS-ESPINOSA, ¹ JOSÉ MÉNDEZ-TUN, ^{4*} LIZARDO CRUZ-ROMO

¹ Grupo de Monitoreo Socioambiental, calle 27 de febrero N° 127, 86930, Balancán, Tabasco, México.

² World Wildlife Fund Inc.-México, Av. Insurgentes Sur N° 1216, 03100, Ciudad de México.

³ Universidad Tecnológica de Calakmul. Carretera Xpujil-Dzibilchén Km. 2+260, 24640, Campeche, México

⁴ Facultad de Ciencias, Universidad Nacional Autónoma de México (UNAM), Av. Universidad 3000, Circuito Exterior s/n, Alcaldía Coyoacán, CP 04510, Ciudad Universitaria, CDMX, México



Acta Zoológica Mexicana (nueva serie)

*Corresponding author:



Lizardo Cruz-Romo

lizardo.cruz@ciencias.unam.mx

Responsible editor: Juan Carlos Serio Silva

How to cite:

Sánchez-Pinzón, K., Contreras-Moreno F., Jesús-Espinosa, D., Méndez-Tun, J., Cruz-Romo, L. (2024) Use of water bodies by the collared peccary *Pecari tajacu* (Artiodactyla: Tayassuidae) in the Maya Forest, Mexico. *Acta Zoológica Mexicana (nueva serie)*, 40, 1–13.

10.21829/azm.2024.4012681
elocation-id: e4012681

Received: 28 March 2024

Accepted: 01 November 2024

Published: 10 December 2024

ABSTRACT. Water availability is a critical factor influencing the abundance and distribution of species, particularly in environments where it is scarce. This study aimed to assess the visit frequency index (VFI, a proxy for abundance) and activity patterns of the collared peccary (*Pecari tajacu*) at various natural and artificial water sources in the Calakmul Biosphere Reserve, Campeche, Mexico. We employed camera trapping from January to December 2020, monitoring 30 water bodies: 10 artificial water troughs, 10 natural aguadas (depressions where rainwater accumulates), and 10 sartenejas (erosion-formed cavities in rocky soils that collect rainwater). Our results indicate that *P. tajacu* utilized



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Acta Zoológica Mexicana (nueva serie)

e-ISSN 2448-8445

Instituto de Ecología, A.C.

sartenejas (VFI = 29.92 records/trap-days) and water troughs (VFI = 22.08 records/trap-days) more frequently than aguadas (VFI = 6.54 records/trap-days). The daily activity patterns of *P. tajacu* were predominantly diurnal at water troughs and aguadas, while activity at sartenejas was cathemeral. Despite being a species known for its reliance on water sources, the VFI recorded in this study was lower compared to previous studies. This decrease is likely linked to increased water availability in the region during the study period, which may have led to avoidance behavior by *P. tajacu* due to the presence of white-lipped peccaries (*Tayassu pecari*) and predators such as jaguars (*Panthera onca*) and pumas (*Puma concolor*), which were more abundant at the aguadas. Considering the rapid progression of climate change and the increasing occurrence of extreme drought and rainfall events in the region, it is crucial to deepen our understanding of the relationships between water availability and the population dynamics of wildlife species. This knowledge will be essential for developing strategies to mitigate the adverse effects of climate change on biodiversity.

Key words: aguadas; drinkers; climate change; dry; sartenejas

RESUMEN. La disponibilidad de agua es un factor crítico que influye en la abundancia y distribución de las especies, especialmente en entornos donde es escasa. Este estudio tuvo como objetivo evaluar el índice de frecuencia de visitas (IVF, un indicador de abundancia) y los patrones de actividad del pecarí de collar (*Pecari tajacu*) en diversas fuentes de agua naturales y artificiales en la Reserva de la Biosfera de Calakmul, Campeche, México. Empleamos trampas cámara desde enero hasta diciembre de 2020, monitoreando 30 cuerpos de agua: 10 bebederos artificiales, 10 aguadas naturales (depresiones donde se acumula el agua de lluvia) y 10 sartenejas (cavidades formadas por erosión en suelos rocosos que recogen agua de lluvia). Nuestros resultados indican que *P. tajacu* utilizó con mayor frecuencia sartenejas (IVF = 29.92 registros/día-trampa) y bebederos (IVF = 22.08 registros/día-trampa) en comparación con las aguadas (IVF = 6.54 registros/día-trampa). Los patrones de actividad diaria de *P. tajacu* fueron predominantemente diurnos en bebederos y aguadas, mientras que en sartenejas la actividad fue catemeral. A pesar de ser una especie conocida por su dependencia de las fuentes de agua, el IVF registrado en este estudio fue inferior al de estudios previos. Esta disminución probablemente esté relacionada con un aumento en la disponibilidad de agua en la región durante el período de estudio, lo que pudo haber llevado a un comportamiento de evitación por parte de *P. tajacu* debido a la presencia de pecaríes de labios blancos (*Tayassu pecari*) y depredadores como jaguares (*Panthera onca*) y pumas (*Puma concolor*), que fueron más abundantes en las aguadas. Considerando el rápido avance del cambio climático y el aumento de eventos extremos de sequía y lluvias en la región, es crucial profundizar en la comprensión de las relaciones entre la disponibilidad de agua y la dinámica poblacional de las especies de vida silvestre. Este conocimiento será esencial para desarrollar estrategias que mitiguen los efectos adversos del cambio climático sobre la biodiversidad.

Palabras clave: aguadas; bebederos; cambio climático; secas; sartenejas

INTRODUCTION

Water is indispensable for biological processes and significantly influences the population dynamics and distribution of wildlife. In some cases, water availability can even cause behavioral changes in animals (Pacifi et al., 2015). In arid and seasonal environments, water availability often

limits the abundance and distribution of large herbivores, particularly when water needs cannot be met through food sources alone (Mandujano-Rodríguez & Hernández, 2019).

Recent years have seen increasingly extreme temperatures in the Yucatan Peninsula, with prolonged periods of high heat (Mardero *et al.*, 2020). Such conditions force wildlife to rely on water sources for thermoregulation, similar to what occurs in semiarid ecosystems (Bello *et al.*, 2004). In the Maya Forest of Southeastern Mexico, which lacks large rivers or extensive surface water bodies (García-Gil *et al.*, 2002), ungulates have shown a clear preference for habitats with available water (Pérez-Cortés *et al.*, 2012; Reyna-Hurtado *et al.*, 2019; Contreras-Moreno *et al.*, 2024a; Hidalgo-Mihart *et al.*, 2024).

In the Calakmul region, the implementation of artificial water troughs has proven to be an effective strategy to mitigate water scarcity during the dry season (Borges-Zapata *et al.*, 2020; Pérez-Flores *et al.*, 2021). This intervention helps maintain wildlife populations within natural protected areas (NPA; Sutherland *et al.*, 2018) by providing critical water access during dry periods (Borges-Zapata *et al.*, 2020; Contreras-Moreno, 2020). However, there are concerns that climate change could severely impact ungulate populations (Contreras-Moreno & Torres-Ventura, 2018). For instance, in the Maya Forest, tapirs (*Tapirella bairdii* Gill) are known to leave the jungle during the dry season in search of water in apiaries and livestock pastures, sometimes resulting in fatalities due to dehydration (Contreras-Moreno, 2020; Pérez-Flores *et al.*, 2021). The introduction of water fountains in this forest has yielded positive outcomes for species like deer (*Odocoileus virginianus*, *Mazama pandora*, *Mazama temama*) (Contreras-Moreno *et al.*, 2024a).

The collared peccary (*Pecari tajacu* Linnaeus) is widely distributed across various habitats in Mexico. Although it is a common inhabitant of tropical humid forests, it is also found in dry habitats, having developed strategies to satisfy its water needs in areas where water is scarce (Sowls, 1997; Reyna-Hurtado *et al.*, 2014). In tropical environments, however, water bodies are crucial for their presence and abundance, underscoring the importance of these sites for the species (Hernández, 2013; García-Marmolejo *et al.*, 2015).

The collared peccary plays an important role as a seed disperser and influences the recruitment, demography, and spatial distribution of plants (Beck, 2005). Besides its ecological importance, it also holds nutritional and economic value in communal areas, being one of the main species hunted for sport and subsistence (Reyna-Hurtado *et al.*, 2009). Despite its significance, many aspects of its population status remain unknown, complicating the development of effective conservation strategies. This study aimed to determine the visit frequency index (VFI; a measure of abundance) and activity patterns of the collared peccary across natural (aguadas, sartenejas) and artificial (water troughs) water bodies in the Maya Forest. The goal was to better understand their use of these water sources and provide a foundation for future conservation efforts.

MATERIALS AND METHODS

Study Area. The Calakmul Biosphere Reserve (CBR) is located in the southeastern part of the Yucatan Peninsula, within the state of Campeche. It forms part of the Maya Forest, which includes the Maya Biosphere Reserve in Guatemala and the Río Bravo Dos Milpas conservation area in Belize. The CBR spans 728,908.58 hectares and features a warm, subhumid climate (Aw), with an average annual temperature ranging from 22 to 26°C. The elevation varies between 100 and 390 meters above sea level. Annual precipitation ranges from 1,200 to 1,500 mm in the central portion of the Reserve to 1,500 to 2,000 mm in the southern portion (García-Gil *et al.*, 2002). The dominant vegetation types include medium sub-evergreen forests, medium sub-deciduous forests, and low

sub-deciduous forests (Martínez & Galindo, 2002; Martínez-Kú *et al.*, 2008). The study area corresponds to the central zone of the CBR, covering approximately 50,000 hectares (Fig. 1).

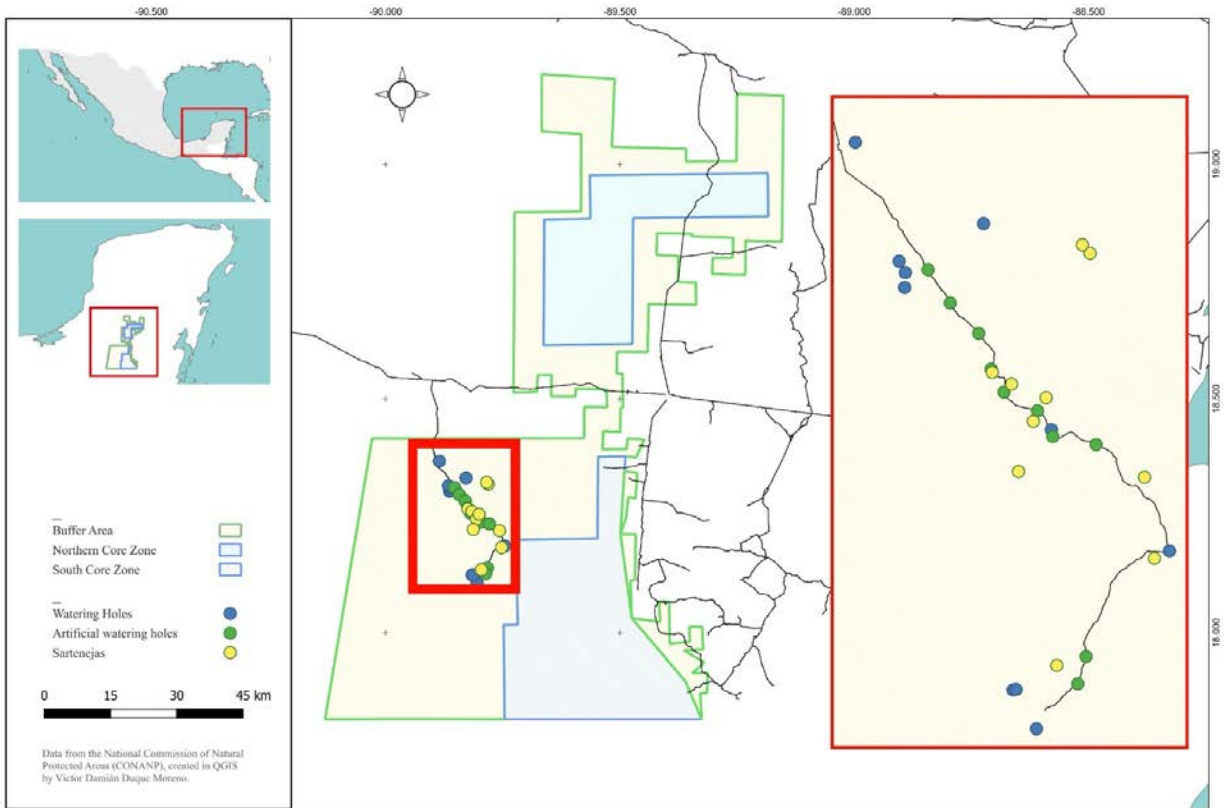


Figure 1. Map showing the location of monitored water bodies in the Calakmul Biosphere Reserve, Mexico, where the study was carried out.

Installation of Artificial Water Troughs. As part of the CBR's conservation efforts in collaboration with the Global Environment Facility (GEF) and the World Wildlife Fund (WWF), artificial water fountains were installed in the Maya Forest starting in 2018 as a strategy to mitigate drought conditions in the region. The water troughs installed in the CBR are black plastic structures (Rotoplast®) with a capacity of 300 liters each (Contreras-Moreno *et al.*, 2024b).

Camera Trapping. From January to December 2020, 30 digital camera traps of various brands and models were deployed at 30 water bodies, including 10 artificial troughs, 10 aguadas, and 10 sartenejas, distributed across the study area (Fig. 1). The objective was to verify the presence of collared peccaries. The camera models used included Bushnell (TropyCam; Outdoor Operations LLC.), Browning (Strike Force; Browning Trail Cameras), and Cuddeback (Cuddeback IR; Non-Typical Inc.).

Cameras were mounted 50 cm above the ground on trees adjacent to water bodies and programmed to operate 24 hours a day, with a 5-second interval between photographs. A minimum distance of 2 km was maintained between camera stations. Cameras were checked every three weeks to download photographs, verify their proper functioning, and replace batteries if necessary. Species identification was performed manually, and a spreadsheet was generated with the following data: station, camera name, date, time, species, image name, and number of

individuals. The photographs were then organized into a database using the CamtrapR package in R 3.4.0 (R Core Team, 2017).

Data Analysis

Photographic Visit Index. The Photographic Visit Index (PVI) was calculated using the formula: $PVI = C / EM * 100$ trap days, where C represents captures or independent events photographed, EM is the sampling effort (number of camera traps per monitoring day), and 100 trap days is the standard unit. To avoid overestimating the number of individuals, only independent records were considered for analysis (Nichols *et al.*, 2011). Photographs separated by more than 24 hours were considered independent records. In cases where multiple individuals were observed in a single photograph, only one record was taken.

Kruskal-Wallis tests were conducted to compare visit frequencies between different water bodies. All analyses were performed using R 3.4.0 (R Core Team, 2017).

Activity Patterns. To describe the activity patterns of the collared peccary, the schedules of independent records were fitted as Kernel density functions using the R package overlap (Ridout & Linkie, 2009). This analysis aimed to identify differences in visiting schedules across various sampling months. A Watson-Williams U test was performed for each water source using Oriana 4.0 software (Kovack Computing Service, 2011). Recordings made between sunrise and sunset (approximately 06:00 to 18:00 in the tropics) were classified as diurnal, while those between sunset and sunrise (18:00-06:00) were considered nocturnal.

Using Kernel density estimators, the overlap coefficient (Δ) between water bodies was calculated, representing the similarity between two circular density curves, with values ranging from 0 (no overlap) to 1 (complete overlap) (Ridout & Linkie, 2009; Meredith & Rideout, 2014).

RESULTS

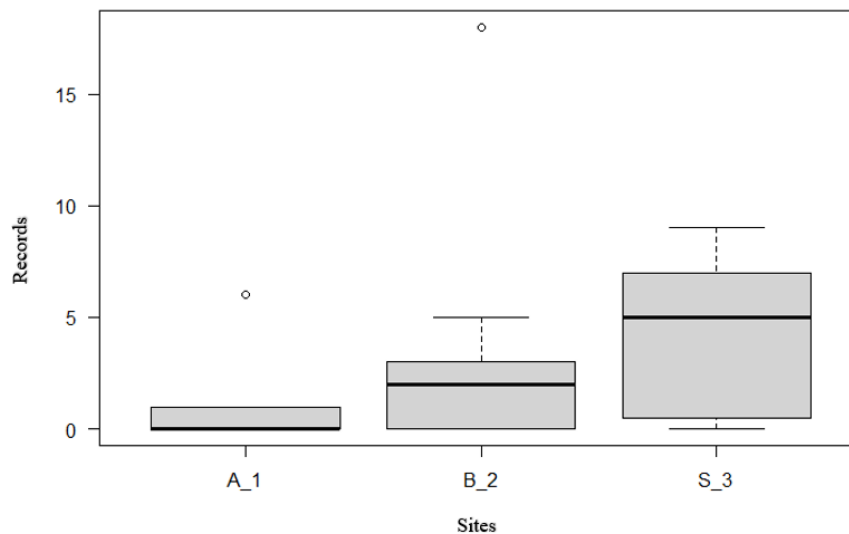


Figure 2. Independent recordings of the CP in aguadas (A_1), (B_1) and sartenejas (S_1)

A total sampling effort of 4,699 trap-days was recorded in 2020 (Aguadas: 1,836 trap-days, Sartenejas: 1,504 trap-days, Water Troughs: 1,359 trap-days). The collared peccary's visit frequency

across all three water bodies was $PVI = 58.33$ records/1000 trap-days. Significant differences were observed in visit frequencies between the water bodies ($H = 6.59$, $df = 2$, $p = 0.04$) (Fig. 2), with higher usage of sartenejas ($PVI = 29.92$ records/trap-days) and water troughs ($PVI = 22.08$ records/trap-days) compared to aguadas ($PVI = 6.54$ records/trap-days).

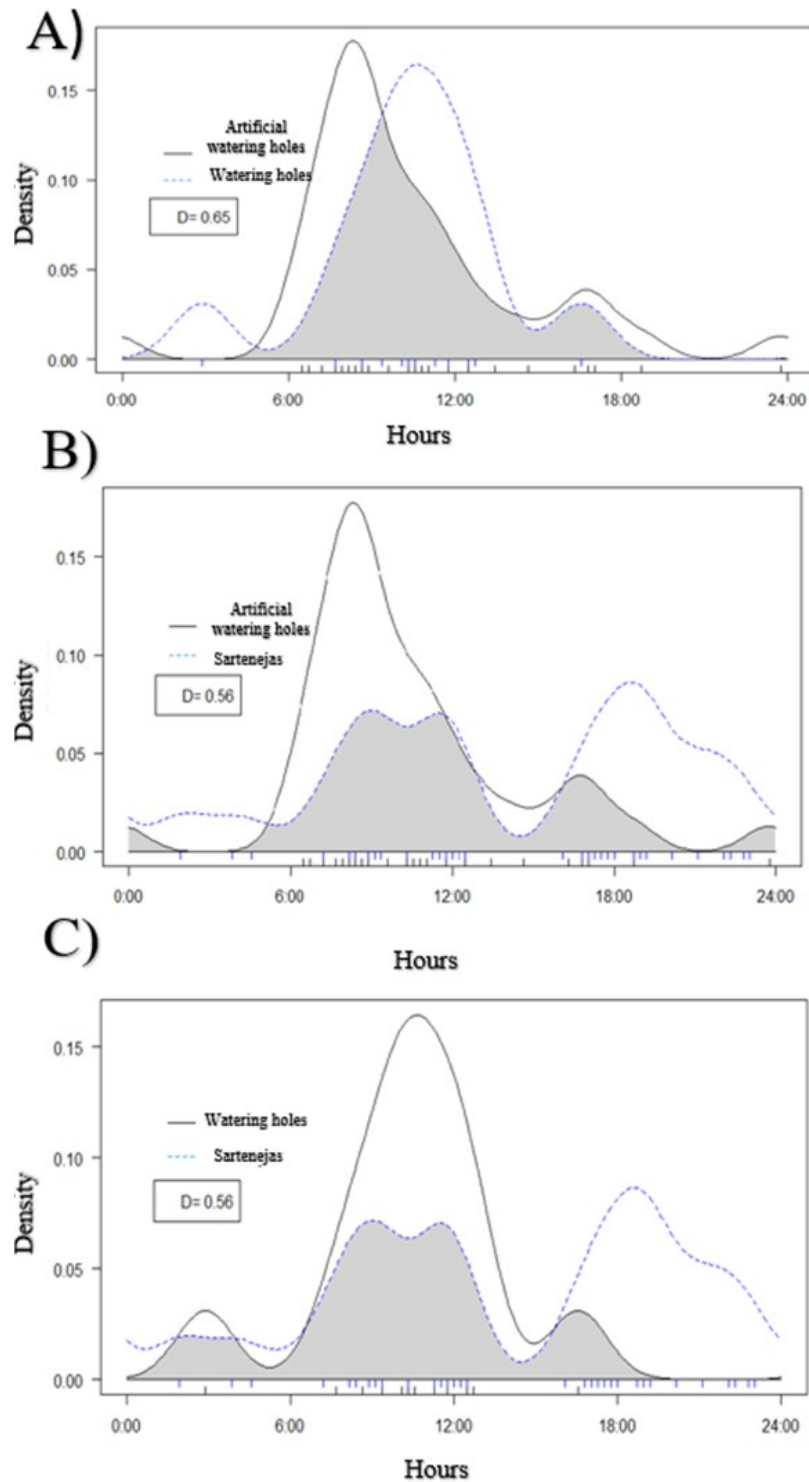


Figure 3. Proportion of overlap (D: overlap coefficient) in the activity patterns of A) water troughs-sartenejas, B) Aguadas-Sartenejas and C) Water troughs-Aguadas.

Daily activity patterns of collared peccaries at water troughs and aguadas were predominantly diurnal (06:00-18:00 h, $p = 0.031$). Activity at water troughs peaked between 07:30 and 11:00, while at aguadas it peaked between 08:00 and 10:00. Activity at sartenejas was primarily nocturnal, with a peak between 20:30 and 02:00 ($p = 0.05$).

The highest level of overlap in PC activity patterns was obtained between water troughs and aguadas ($\Delta = 0.65$). And the same level was recorded between water troughs and sartenejas ($\Delta = 0.56$) and aguadas and sartenejas ($\Delta = 0.56$) (Fig.3).

DISCUSSION

In the Calakmul Region, the collared peccary (CP) has been recognized as one of the most abundant species and the most frequent visitor to water sources (Reyna-Hurtado *et al.*, 2010; Sánchez-Pinzón *et al.*, 2020). The frequency of visits observed in the present study for this species at water troughs and sartenejas aligns with previous studies in the Calakmul region. However, the frequency recorded for aguadas was notably lower compared to other studies conducted on water bodies in the area (Briceño-Méndez *et al.*, 2016; Sánchez-Pinzón *et al.*, 2020). A similar decline in CP visitations to aguadas was observed throughout the Maya Forest, with a decrease from 19.10 records/trap-days in 2019 to 3.76 records/trap-days in 2020 (Regional Report, 2020).

This decrease in CP visits to aguadas in 2020 may be attributed to the above-average rainfall that began in May, compounded by the impact of two tropical systems. These rain events caused significant flooding and damage in the region (CONAGUA, 2020), likely increasing water availability across the landscape. Consequently, peccaries may have shifted their reliance towards water troughs and sartenejas, reducing their use of aguadas. A similar shift in water body usage was noted in other ungulate species (Contreras-Moreno *et al.*, 2024a, b).

Additionally, white-lipped peccaries (*Tayassu pecari*) have been observed to use water troughs infrequently (only 2 records in 1 year; Contreras-Moreno, Pers. Comms.), while consistently favoring aguadas (Reyna-Hurtado *et al.*, 2009). The smaller size of the CP, its tendency to form smaller groups (typically no more than 10 individuals), and its adaptability to environmental changes likely enable it to exploit smaller water bodies such as sartenejas with an average capacity of 100 liters (Delgado-Martínez & Mendoza, 2020) and water troughs (with a capacity of 300 liters). These smaller water sources appear to adequately meet the CP's needs for drinking, bathing, and resting (Delgado-Martínez *et al.*, 2018, 2023). In the Tehuacán-Cuicatlán Biosphere Reserve, CPs were observed to use artificial troughs throughout the day and night, particularly during the dry season (Mandujano & Hernández-Gómez, 2019).

Moreover, the higher visitation rates of white-lipped peccaries, jaguars (*Panthera onca*), and pumas (*Puma concolor*) to aguadas in the Calakmul Biosphere Reserve (CBR) may influence CP behavior, restricting this medium-sized ungulate to smaller water bodies like sartenejas and water troughs. This could be a strategy to avoid direct competition with white-lipped peccaries and to evade predation by jaguars and pumas (Regional Report, 2020; Sánchez-Pinzón *et al.*, 2020). Similar patterns have been recorded in other large mammals, such as jaguars, pumas, and tapirs, which show a preference for aguadas over water troughs and sartenejas in the Maya Forest (Pérez-Cortez *et al.*, 2012; Moreira-Ramírez *et al.*, 2016; Delgado-Martínez *et al.*, 2018, 2023; Gaitán *et al.*, 2021; Martínez *et al.*, 2021).

The CP is predominantly a diurnal species (Cuéllar & Noss, 2003; Maffei *et al.*, 2002). In this study, CP groups primarily visited aguadas and water troughs during the day, a pattern consistent with previous reports from the Calakmul Region (Briceño-Méndez *et al.*, 2016; Sánchez-Pinzón *et al.*, 2020). Peak activity at these sites occurred between 06:00 and 13:00, with a significant drop



Figure 4. Photographs of the CP in A) Aguadas, B) Water troughs and C) Sartenejas

during the hottest hours of the day, possibly as a strategy to conserve energy and avoid predators (Taber *et al.*, 1994). In contrast, CP activity at sartenejas was cathemeral, with individuals active throughout the day. This observation aligns with various studies indicating that while CPs are mainly diurnal, they can adjust their activity to nocturnal hours (Maffei *et al.*, 2002; Tobler *et al.*, 2009; Moreira-Ramírez *et al.*, 2015), possibly due to reduced competition and predator activity at these sites.

Monitoring different water bodies within the CBR, both natural and artificial, provides a comprehensive understanding of their roles for various species. The results indicate distinct differences in species composition across water bodies, and these differences can be dynamic (Delgado-Martínez *et al.*, 2018) (Fig. 4). Given the accelerating pace of climate change and the increasing frequency of extreme drought and rainfall events, it is crucial to deepen our understanding of the relationships between water availability, variability, and wildlife population dynamics. This knowledge is essential for developing more effective tools to mitigate the impacts of climate change on biodiversity. In recent years, water supplementation through artificial waterholes has proven to be an effective strategy in the Selva Maya (Contreras-Moreno *et al.*, 2024a, b). However, it is equally important to strengthen the conservation of natural waterholes to ensure that during dry seasons, these areas can serve as refuges where peccaries and other mammals can sustain their biological processes.

ACKNOWLEDGMENTS. The authors express their gratitude to Project 00092169: "Strengthening the management of the Protected Areas System to improve the conservation of species at risk and their habitats," supported by the United Nations Development Program (UNDP), implemented by the National Commission of Natural Protected Areas (CONANP), and funded by the Global Environment Facility (GEF). Special thanks are extended to our colleagues from the Calakmul Biosphere Reserve for their unwavering support in the monitoring project. We also acknowledge the World Wildlife Fund (WWF-Mexico) for providing funding through the "Monitoring of Water Bodies in the Calakmul Biosphere Reserve" program, as part of the project "Saving the Jaguar: Ambassador of America." We are grateful to Víctor Duque for his assistance in processing the map.

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