

Ecology

Use of artificial water sources by tapirs in the Maya Forest, Mexico

Uso de fuentes de agua artificiales por tapires en la selva Maya, México

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Abstract

The scarcity of available surface water affects ungulates inhabiting sites where the effects of climate change are more evident, especially for endangered species such as the Central American tapir (*Tapirus bairdii*). The objective of this study was to estimate tapir water use in artificial water troughs in the Calakmul Biosphere Reserve (CBR), Mexico. Between January 2019 and August 2021, 8 digital camera traps were placed in 8 artificial watering holes. The Photographic Index of Visits (PIV) was obtained, and occupancy (Psi), detectability (p), and activity patterns were calculated, and analyzed. A sampling effort of 4,672 nights/camera, and 289 grouped records of *T. bairdii* were obtained. The PIV, occupancy, and detectability obtained in the present study were similar to those reported in natural water bodies in the Maya Forest, which supports the idea that the water troughs could temporarily supply maintenance functions for tapirs during the dry season or in periods when water is scarce in the landscape, being this the only source of water available to satisfy their requirements for this resource in the CBR.

Keywords: Climate change; Photo-trapping; Endangered; Drought; Ungulates

Resumen

La falta de agua superficial disponible afecta a los ungulados que habitan sitios en los que los efectos de cambio climático son más evidentes, sobre todo en especies en peligro de extinción como el tapir centroamericano (*Tapirus bairdii*). El objetivo de este estudio fue analizar el uso que el tapir hace del agua en bebederos artificiales en la Reserva de la Biosfera Calakmul (RBC), México. Entre enero de 2019 y agosto de 2021 se colocaron 8 cámaras

trampas digitales en 8 bebederos artificiales. Se obtuvo el índice fotográfico de visita (PIV) y se estimó la ocupación (Psi), la detectabilidad (p) y los patrones de actividad. Con un esfuerzo de muestreo de 4,672 noches/cámara se obtuvieron 289 registros de *T. bairdii*. El PIV, la ocupación y la detectabilidad obtenidos en el presente estudio fueron similares a lo reportado en cuerpos de agua naturales en la selva Maya; esto apoya la idea de que los bebederos podrían suplir temporalmente funciones de manutención de los tapires durante la época seca o cuando el agua escasea en el paisaje, esta sería la única fuente de agua disponible para satisfacer sus requerimientos en la RBC.

Palabras clave: Cambio climático; Fototrampeo; Amenazado; Sequía; Ungulados

Introduction

People have been supplying water to wildlife since a century ago in the old West, to mitigate the consequences of its scarcity (Leopold, 1933). The implementation of artificial water troughs for wildlife has been reported as a successful strategy (Epaphras et al., 2008). These have been conceived as a strategy that can contribute to the maintenance of wildlife populations in the short term, allowing access to hydric resources during the dry season (Borges-Zapata et al., 2020; Contreras-Moreno, Jesús-Espinosa, Sánchez et al., 2024; Mandujano-Rodríguez & Hernández-Gómez, 2019a; Pérez-Flores et al., 2021). Water is a limiting factor for large herbivores living in desert environments (Eliades et al., 2022; Krausman et al., 2006; Nagy & Gruchacz, 1994; Villarreal-Espino & Marín, 2005). But also in tropical ecosystems, lack of water is a serious threat to ungulates (Contreras-Moreno & Torres-Ventura, 2018; Contreras-Moreno, Jesús-Espinosa, Cruz-Romo et al., 2024), adding to the long list of threats faced by large herbivores (Ripple et al., 2015).

When water becomes scarce, some mammals change their usual behavior (Pacifci et al., 2015), concentrating on available water sources (Redfern et al., 2003). Although forage can compensate for some of the hydric needs, it is sometimes not sufficient to cover total metabolic functions and thermoregulatory processes (Morgart et al., 2005; Simpson et al., 2011). The Central American tapir (*Tapirus bairdii*) is the largest terrestrial herbivore in the Neotropics and plays an important role in ecosystems as a seed disperser (Brooks et al., 1997; Contreras-Moreno et al., 2020, 2022). It is estimated that its distribution has been drastically reduced, possibly by up to 50% in the last 30 years (García et al., 2016), largely due to habitat loss, fragmentation, and poaching (Naranjo et al., 2015). Both in Mexico and globally, it is listed as an endangered species according to Mexican environmental laws (Semarnat, 2010: NOM-059-SEMARNAT-2010) and the Red List of Threatened Species of the International Union for Conservation of Nature (García et al., 2016).

The Maya Forest is the largest tropical forest massif in Mesoamérica, located in southeastern Mexico, northern

Guatemala, and northeastern Belize, with more than 30,000 km² under some category of protection (Reyna-Hurtado et al., 2022). This region concentrates the largest population of tapirs in Mexico (Naranjo et al., 2015). In recent years, it has been documented that temperatures in the Yucatán Peninsula have become extremely high and have longer periods (Mardero et al., 2020), which forces wildlife to resort to water sources to thermoregulate (Contreras-Moreno, Jesús-Espinosa, Cruz-Romo et al., 2024; Contreras-Moreno, Jesús-Espinosa, Sánchez et al., 2024; Hidalgo-Mihart et al., 2024). This is accentuated in the Maya Forest where natural water bodies are restricted to “aguadas” (i.e., small ponds that fill with rainwater; Reyna-Hurtado et al., 2022) and “sartenejas” (i.e., hollows that form in rocky soil because of erosion and accumulated rainwater; Delgado-Martínez et al., 2018).

In this region, ungulates may be seriously affected by the effects of climate change, particularly drought (Contreras-Moreno & Torres-Ventura, 2018), as it has been shown that habitat selection of these mammals is strongly influenced by water availability (Pérez-Cortéz et al., 2012; Reyna-Hurtado et al., 2019). This close relationship could be accentuated in the coming years, as an imbalance in precipitation patterns has been recorded throughout the region (Mardero et al., 2020). Droughts are expected to reduce the available surface water and could lead to changes in population dynamics (Reyna-Hurtado et al., 2022), as well as in the behavior of species in the Maya Forest region (Contreras-Moreno & Torres-Ventura, 2018). It has recently been recorded that there is a growing conflict between tapirs and rural producers (farmers, beekeepers). In the Maya Forest, beekeepers put water in the apiaries for the bees to drink, and so that the ants do not climb on the boxes and eat them, however, during the dry season, tapirs enter the apiaries, drink the water and throw the boxes of bees, which causes the annoyance of the people, in the same way when people cultivate trees, tapirs break the young species trees to eat the leaves of (i.e., *Bursera simaruba* and *Brosimum alicastrum*), which could increase with the effects of climate change in the Maya Forest region (Pérez-Flores et al., 2021).

In Mexico, the water troughs strategy has been used for decades in northern Mexico, in UMAs (Wildlife Management Units) mostly in semi-desert and xerophytic scrub sites (Mandujano-Rodríguez & Hernández-Gómez, 2019b; Villarreal, 2006). Since 2018 placing water in artificial water troughs in the Maya Forest has been conceived as a measure that can contribute to the maintenance of wildlife populations in the short term, allowing access to hydric resources during the low water season (Contreras-Moreno, Jesús-Espinosa, Cruz-Romo et al., 2024; Contreras-Moreno, Jesús-Espinosa, Sánchez et al., 2024).

This study describes for the first time the supplementation of water in artificial drinking troughs for the Central American tapir. Understanding the functionality of water supply for tapirs in artificial drinking troughs, as well as the patterns of use, would contribute to improve conservation programs (Fulbrigh & Ortega, 2007), therefore the objective of this study was to analyze the use that tapirs make of water in artificial drinking troughs placed in the Maya Forest region of Campeche, in southeastern Mexico.

Materials and methods

The Calakmul Biosphere Reserve (CBR) is located within the Yucatán Peninsula in the southeastern part of the state of Campeche (Fig. 1). It has an area of 728,908.58 ha (Reyna-Hurtado et al., 2022). The CBR has a warm and sub-humid climate (Aw), with a mean annual temperature of 24.6 °C. The maximum altitude is found at Cerro Champerico at 390 m asl and the minimum altitude varies from 100 to 150 m. The dominant vegetation in the area are medium sub-evergreen forests, medium, and low sub-deciduous forests (Martínez & Galindo, 2002; Martínez-Kú et al., 2008).

As part of the efforts made by the CBR in collaboration with the Global Environmental Facility (GEF) Species at Risk Project and World Wildlife Fund (WWF Mexico), to counteract the effects of climate change in the region, artificial water troughs were installed in 2018, establishing a water supply network of about 105 water troughs, of which 42 are located within the core areas of the CBR. The artificial water troughs placed in the CBR correspond to black plastic structures (Rotoplas® brand), with a capacity of 300 L each. The troughs were distributed along the access road to the CBR, with a minimum distance of 2 km between each trough (Fig. 1). The water supply at the beginning of the dry season was generally maintained twice a month (every 15 days); however, as the dry season progressed (became more severe) the supply could even be every 7 days.

Camera-trapping for mammals' recording has been a widely used and efficient method in southeastern Mexico and particularly for the Calakmul region (Borges-Zapata et al., 2020; Contreras-Moreno, Simá-Pantí, Zúñiga-Morales et al., 2019; Contreras-Moreno et al., 2020, 2021; Delgado-Martínez et al., 2021; Hidalgo-Mihart et al., 2017). Between January 2019" and August 2021, 8 digital camera traps Bushnell HD119876c (Tropy Cam; Outdoor Operations LLC.), Browning Strike force 850 (Browning Trail Cameras), or Cuddeback IR-20 (Cuddeback IR; Non-Typical Inc.) were placed in 8 artificial water troughs, distributed along the study area (Fig. 1) to detect and perform the analyses related to the presence of tapirs. The study area corresponds to zones adjacent to the road that leads to the archaeological zone of Calakmul (from km 20 to km 47).

The placement site of the camera traps corresponded to the same site where the water troughs were established (Fig. 1). At each site the number of days that they remained active varied depending on the operation of each device, on which the minimum sampling effort was 143 days. The cameras were placed 50 cm above the ground, in trees adjacent to the drinking trough, and were programmed to take photographs 24 hours a day, with 5-second intervals between each picture. A minimum distance of 2 km was maintained between cameras and after the placement of the cameras, they were checked for 3 weeks. In each revision, the photographs were downloaded, which were assigned a registration key. Finally, the proper functioning of the cameras was verified, and the batteries were replaced if necessary. Species identification was performed manually, generating a spreadsheet with the following data: station, camera name, date, time, species, image name, and number of individuals. After obtaining the photographs, a database was constructed using the CamtrapR package in the R 3.4.0 program (Niedballa et al., 2019; R Core Team, 2017).

To estimate the Photographic Index of Visit (PIV) the formula: $PIV = C/SE * 100$ trap-days was used, where C = recording events, SE = sampling effort (number of camera traps per monitoring day) and 100 trap-days (standard unit) (Hernández-Pérez et al., 2020). To avoid overestimating the number of individuals recorded we grouped photographs of individuals of the same species recorded in the same site within 24 h periods. When more than 1 individual was recorded in the same picture, it was classified as a single record. Kruskal-Wallis tests were performed to compare species visitation rates by season. A Mann-Whitney test was used to compare records by year (Contreras-Moreno et al., 2020), analyses were performed in R 3.4.0 (R Core Team, 2017).

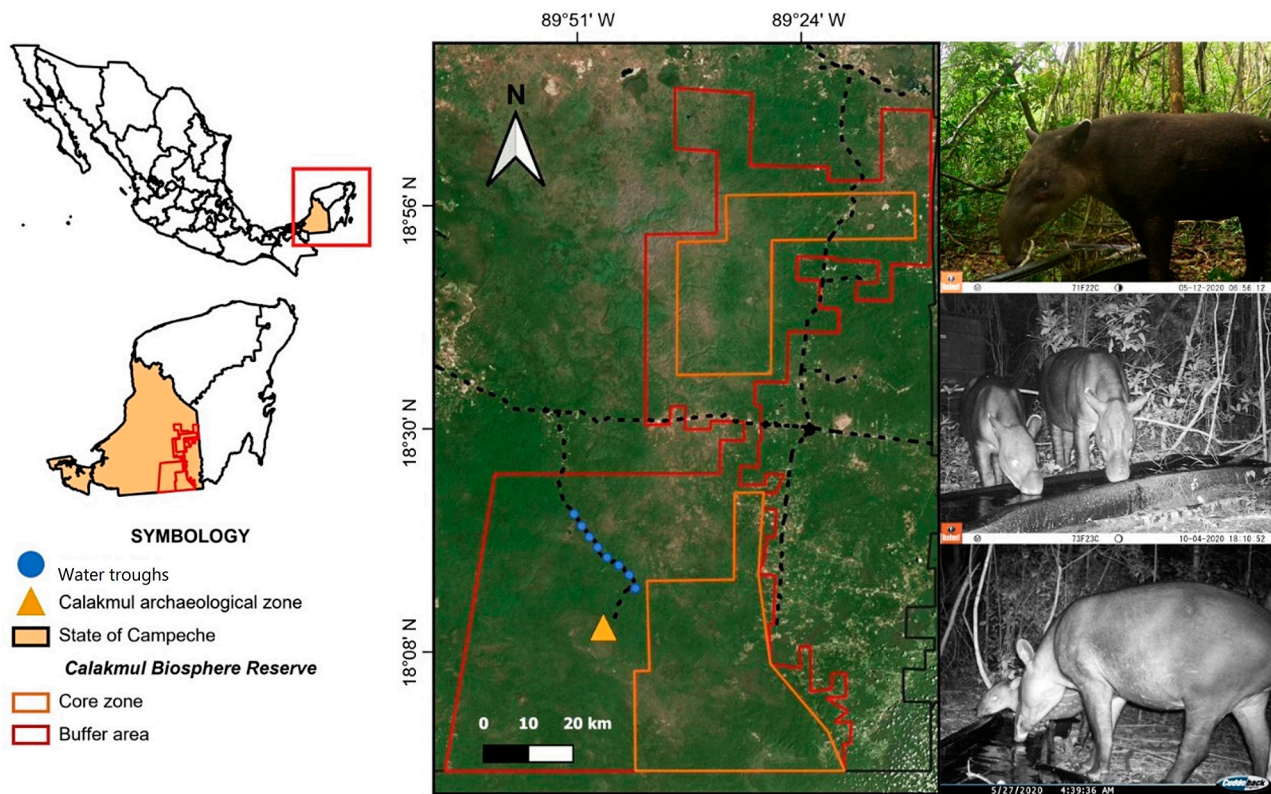


Figure 1. Map showing the location of the monitored watering places in the Calakmul Biosphere Reserve, Mexico, where the study was carried out. Map by F.M. Contreras-Moreno.

The activity pattern was evaluated for Central American tapir in the study. To compare the statistical differences between the hours of greatest activity a Kernel density analysis we used the activity and overlap packages in R 3.4. 0. (R Core Team, 2017; Ridout & Linkie, 2009; Rowcliffe, 2016).

The probability of tapir occupancy (Ψ) and detection (p) were modeled with standard error (SE) estimates following the methodology proposed by MacKenzie et al. (2006). Fifteen-day capture histories with a total of 22 sampling occasions were created using a single-station occupancy model without covariates using R software (R Core Team, 2019). Models were evaluated using Akaike's

Information Criterion corrected for small sample size (AICc) and Akaike's weights (w) (Burnham & Anderson, 2002), with 95% confidence intervals.

Results

With a sampling effort of 4,672 camera-trap days, 289 independent tapir records were obtained, and a PIV of 61.21 records/1,000 trap days in artificial water troughs in the CBR (Table 1). Regarding tapir records, highly significant differences were observed when comparing the 3 sampling years ($H = 17.78$, $df = 2$, $p < 0.001$; Fig. 2a), with the use of the troughs in 2019 being significantly

Table 1

Independent tapir records and the photographic index of visitation (PIV) for the 3 years of sampling in the Maya Forest, Mexico.

	2019		2020		2021		Total	
	Records	PIV	Records	PIV	Records	PIV	Records	PIV
<i>Tapirus bairdii</i>	242	85.45	43	31.64	1	2.08	286	61.21

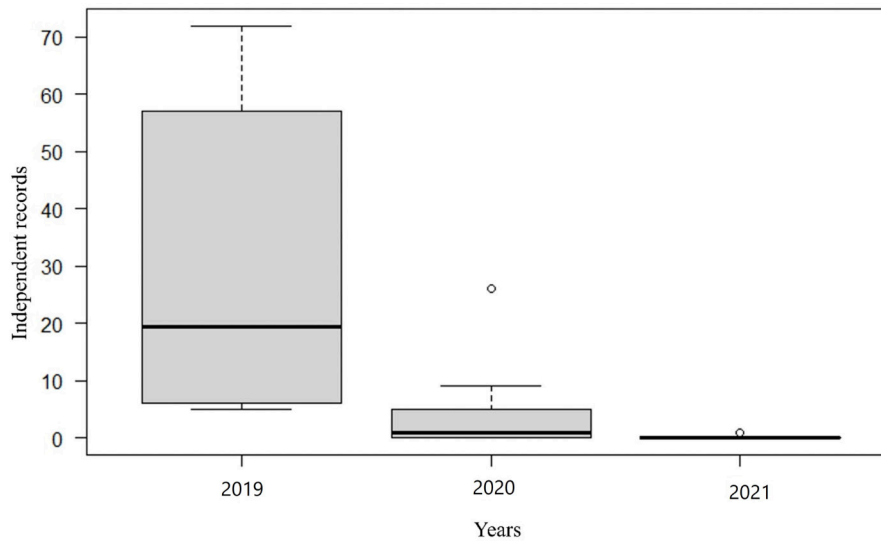


Figure 2. The independent records obtained from the tapir for the 3 years of sampling in artificial watering holes in the Maya Forest are shown.

higher than in 2020 and 2021. When comparing tapir records between sampling stations, no significant statistical differences were observed ($H = 4.73$, $df = 7$, $p = 0.69$).

Tapir records showed a circular mean obtained at 21:25 h. and an angular dispersion that goes from approximately 20:00 to 21:00 h. Tapirs were found to be mainly nocturnal, with peaks of activity approximately 3 hours after sunset, the number of nocturnal records in contrast was lower (Fig. 3). Tapirs showed an occupancy (Ψ) at water troughs of 0.601 and a probability of detection (p) of 0.304 ($ES = 0.0688$).

Discussion

The water troughs are constantly used by the tapirs, which is demonstrated by the number of records obtained (Table 1). The PIV showed a clear difference in records between sampling years, the number of records in 2019 was notably higher than 2020 and 2021 (Table 1), this could be related to the accumulated precipitation rate that was reflected in 2019, nationally this year presented extreme drought conditions both in intensity and prolongation (Pérez-Flores et al., 2021; SMN, 2019). The year 2019 was one of the most difficult for tapirs (in terms of lack of water) in the Maya Forest region (Fig. 4), as dehydrated tapirs were recorded on roads, entering livestock ranches and apiaries and in some cases the reports referred to dead animals near communities, so it was considered an environmental crisis (Contreras-Moreno et al., 2020).

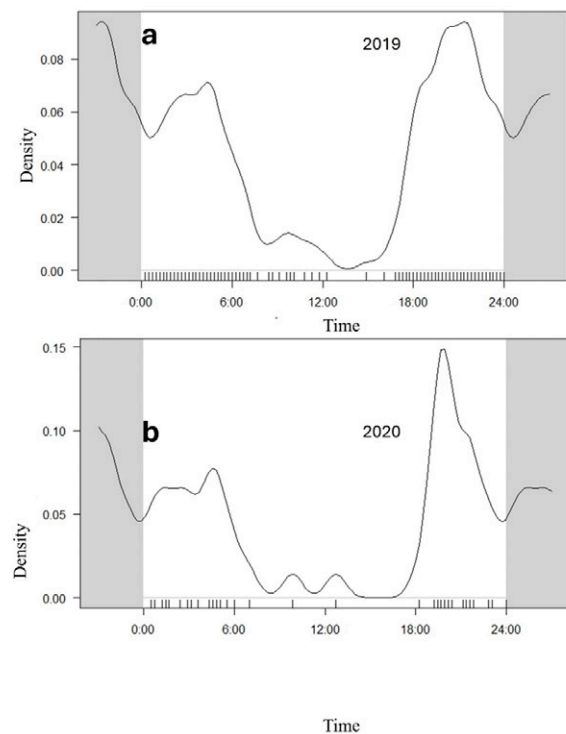


Figure 3. Graphical representation of tapir activity patterns in the Maya Forest between 2019 and 2020.

Later analyses showed that 2019 was the year in which more cases of dehydrated tapirs were recorded in the Maya Forest; necropsies, although not conclusive,



Figure 4. Example of a photographic record of *Tapirus bairdii* collected in the Maya forest, Mexico.

pointed to organ damage due to lack of water (dehydration; Cervantes, 2021). The greater presence of tapirs during 2019 at the watering holes could be due to the need for thermoregulation through water as happened with other ungulates that year (Contreras-Moreno, Jesús-Espinosa, Cruz-Romo et al., 2024), so that tapirs visited the watering holes more frequently to satisfy their water needs (Pérez-Flores et al., 2021). It has been mentioned that, for large species, such as the Central American tapir (Fig. 2), the lack of water can create serious imbalances in their metabolism, since they need between 10 and 15 L of water per day (MacFarlane & Howard, 1972).

In arid regions, water is a limiting resource for several vertebrate species (McKee et al., 2015). The PIV recorded in the Maya Forest showed a large variation in the number of records per year, our PIV for artificial watering holes was higher (61.21) than that recorded by Delgado-Martínez et al. (2018) in “sartenejas”. Variation in PIV across years is something previously recorded in natural water bodies (“aguadas”) in the Maya Forest (Pérez-Cortez et al., 2012; Reyna-Hurtado et al., 2019). Pérez-Cortez et al. (2012) recorded that the tapir was present in 14 of 15 “aguadas” with an estimated relative abundance of 37.57, in contrast, Reyna-Hurtado et al. (2019) estimated an average relative abundance of 27.6 and added that the values per year exhibited a decreasing

trend between sampling periods. The PIV recorded in Maya Forest in troughs was higher than that recorded in Los Chimalapas Forest in Oaxaca where the relative abundance was 6.77 (Lira-Torres et al., 2014).

Reyna-Hurtado et al. (2019) in a multi-year study found that tapir populations in the Calakmul Biosphere Reserve remained stable but decreased slightly, and in parallel, there was a drastic decrease in the availability of water in the “aguadas”, likewise the authors found that the detailed analysis on the visitation rate of each pond provided evidence that tapirs are becoming stressed due to water scarcity and that this may have important consequences at the population and behavioral level. The fact that the PIV recorded in artificial water troughs is higher than that recorded in the natural watering holes supports the idea that water troughs could temporarily supply maintenance functions for tapirs during the dry season in the Maya Forest. Placing water in water troughs in the Maya Forest has been controversial to various groups, recently studies have shown that in addition to the “aguadas” in the Maya Forest there are other natural water bodies, the “sartenejas” (Delgado-Martínez et al., 2018), and that these are of great importance for wildlife, given the constant use of tapirs, it is likely that the artificial water troughs are providing the species with real sustenance, simulating in functions a “sartenejas”

(with an average capacity of 100 L; Delgado-Martínez & Mendoza, 2020).

For this study in Maya Forest, the visitation rate of tapirs decreased notably for the last 2 years (2020 and 2021), very similar to that recorded for deer (*Odocoileus virginianus*, *Mazama temama*, and *M. pandora*) in the same period in Maya Forest (Contreras-Moreno, Jesús-Espinosa, Cruz-Romo et al., 2024). Contrary to what has been suggested that herbivores over time recognize water troughs as an alternative water source and resort more to them once they have located them (Berbert & Fagan, 2012). The high availability of water in the natural reservoirs of the Maya Forest for the years 2020 and 2021, could have influenced the decrease in tapir records at the artificial water troughs, as 2020 was a relatively rainy year where the first rains occurred in April (Hernández-Cerda et al., 2021), followed by tropical storm systems in May (Arthur and Bertha); ending with tropical storm Cristóbal (June 1-8) which flooded much of the region (NOAA, 2020), so natural water bodies held water until the middle of 2021 (Contreras-Moreno pers. comm.).

Regarding the estimated values of occupancy ($\Psi = 0.601$) and detection probability ($p = 0.304$) for *T. bairdii* in watering holes are like values obtained in other studies in the Maya Forest. Reyna-Hurtado et al. (2019) obtained an occupancy rate of 0.70 and a detection probability of 0.40 in watering holes in the Calakmul Biosphere Reserve. In Belize, Martínez et al. (2021) obtained an occupancy of 0.97 and a detection probability of 0.14 in water bodies and in Guatemala in the Naatchun Dos Lagunas Protected Biotope, García et al. (2019) obtained an occupancy of 1.0 and a detection probability of 0.35. As for the PIV, the values obtained for occupation and detention in drinking troughs are very similar to those obtained in watering holes in the CBR, which corroborates the use that this species makes of these artificial water bodies and their functionality, especially in the dry season or in periods when water is scarce in the landscape, being this the only source of water available to meet their requirements for this resource in the CBR.

The activity pattern of the tapirs during the visits to the water troughs was mainly nocturnal (Fig. 3), something that has been recorded in several studies, particularly the activity peaks between 21:00 and 22:00 are very similar to those recorded in the “aguadas” of the Maya Forest (Sánchez-Pinzón et al., 2020), and in Los Chimalapas forest in Oaxaca by Lira-Torres et al. (2014), in this regard, it has been suggested that tapirs tend to become more nocturnal in response to human disturbance (Naranjo, 2009). The activity schedule of tapirs is not strictly static in the different locations, for example, in El Triunfo Biosphere Reserve tapirs recorded

an average tapir mean angular mean at 18:00 (Carbajal-Borges et al., 2014), in Costa Rica that diurnal activity levels represented 20.2% and nocturnal activity 80.4%, coupled with this, during the wet season more diurnal and less nocturnal activity was observed compared to the dry season (Foerster & Vaughan, 2002). Several studies have documented that mammalian prey makes various behavioral adjustments to minimize the risk of predation by their natural predators (Mukherjee & Heithaus, 2013), in some cases noting that hunting may force ungulates to change their visits to watering holes from diurnal to nocturnal, but that the magnitude of this change may be limited by the risk of predation imposed by large nocturnal carnivores (Crosmary et al., 2012).

It was observed that the water troughs, besides allowing access to fresh water, make it possible for individuals from different populations to interact with each other, which could be considered as a site for socialization and predation, which needs a specific approach to understand these behaviors. Likewise, more studies are needed to examine both the consumption patterns of tapirs in all seasons, and ways to improve the efficiency of the current network of water troughs for large species such as tapirs.

The environmental contingency that happened in the Maya Forest in 2019 (Contreras-Moreno, 2020), could be an indicator of the effects that tapirs are suffering from climate change in the Yucatán Peninsula, several models indicate a disruption in precipitation patterns (Mardero et al., 2020) and it is considered that ungulates will be directly affected by these alterations derived from climate change (Contreras-Moreno & Torres-Ventura, 2018). Models suggest that temperature will increase, and precipitation will decrease in the Maya Forest soon (O’Farrill et al., 2014). It has been proposed that water scarcity could lead to increased negative intra- and interspecific interactions between fauna and increased metabolic costs (as animals face the need to move further to find water supplies; Delgado-Martínez et al., 2018). Added to this, the tapir has been identified as one of the species that has increased its level of conflict with people in the Maya Forest because of drought linked to climate change in the region (Pérez-Flores et al., 2021). This is of concern for the species, as climate change is considered a critical amplifier of human-wildlife conflict, as it exacerbates resource scarcity, alters human and animal behaviors and distributions, and increases human-wildlife encounters (Abrahms et al., 2023).

Artificial water troughs could play a key role in mitigating the negative effects of drought on tapirs in the Maya Forest, as they complement the functions of natural water bodies such as “aguadas” and “sartenejas”. However, further research is needed to understand and

rule out possible negative effects on tapir populations, as it has been suggested that being artificial structures arbitrarily introduced into a natural system, could lead to alterations in the behavior, ecology, and health of tapirs (i.e., they could act as a focus of zoonosis).

The use of water troughs has been little analyzed in Mexico, however, in some parts of the world such as the arid western USA people have been providing water to wildlife for more than 70 years (Leopold, 1933), and mammals have been reported to respond positively (Mandujano-Rodríguez & Hernández-Gómez, 2019a, b; Borges-Zapata et al., 2020; Contreras-Moreno, Jesús-Espinosa, Cruz-Romo et al., 2024; Contreras-Moreno, Jesús-Espinosa, Sánchez et al., 2024), and within wildlife conservation management units in Mexico it is a common practice (UMA; Gastelum-Mendoza et al., 2014). This study documents for the first time the implementation of artificial drinking troughs for water supply for tapirs, thus providing relevant information for the understanding of new strategies to maintain populations of large species such as the tapir and opens the door for further studies to develop strategies to mitigate the effects of climate change in tropical environments.

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