

Baird's Tapir social interactions, activity patterns, and site fidelity at ponds of the Maya Forest

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The Baird's tapir is an endangered species of the Neotropical Forest. The Maya Forest of southern México hold one of the most important populations of the species. Tapir are solitary, shy, and nocturnal animals of which behavioral observations are very limited. Using camera traps, we revised the social behavior of tapirs that are visiting ponds in the Calakmul Biosphere Reserve along 10 years. In these sites, locally named "aguadas", and that are sites where social interaction may take place, we have found that tapirs are solitary animals, but dedicated some percentage of their time to socialize with other individuals and these associations can last for months, maybe years. We reported on individuals that have visited some specific sites for periods of 4 and 10 years. There is a male biased sex ratio among the individuals we could identified sexually, and tapirs are nocturnal most of the time, but preferences for early hours of the night was recorded. This is a unique study because it is the first time that social behavior, site fidelity, and sex ratio are presented for the species for several sites, and along 10 years. We hope to advance in the knowledge of the social and ranging behavior of this endangered species of the Neotropical forests.

El tapir de Baird es una especie en peligro de extinción de los bosques Neotropicales. La Selva Maya del sureste de México mantiene la población más grande de la especie en toda su área de distribución. El tapir de Baird es un animal solitario, nocturno y del cual las observaciones sobre su comportamiento son muy limitadas. Usando cámaras trampa revisamos el comportamiento social de los tapires que visitaron algunos cuerpos de agua en la Reserva de la Biosfera de Calakmul por 10 años. Estudiando estos cuerpos de agua, llamados localmente "aguadas" como posibles sitios de encuentro de individuos, encontramos que los tapires son solitarios la mayor parte del tiempo, pero dedican un porcentaje de su tiempo a interactuar con otros individuos y que estas interacciones pueden durar algunos meses. Reportamos algunos individuos que han visitado ciertos cuerpos de agua por grandes periodos de tiempo, desde meses hasta 10 años. Existe un sesgo hacia los machos en el número de individuos registrados por las cámaras en los cuerpos de agua. Los tapires son nocturnos, pero más activos en las primeras horas de la noche. Es la primera vez que se reporta el comportamiento social, fidelidad de sitio y radio sexual de la especie en diversos cuerpos de agua a lo largo de 10 años. Esperamos que podamos comprender más sobre el comportamiento de esta especie difícil de observar y que está en grave peligro de extinción.

Keywords: Activity patterns; aguadas; Calakmul Biosphere Reserve; social behavior; *Tapirus bairdii*.

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Introduction

In the last 40 years several mammalian species across the globe have suffered a decline in their populations due to human activities such as hunting, deforestation, habitat fragmentation and introduction of exotic species in the native habitats of the world. Tropical and large species of ungulates are the ones that have suffered the greatest reductions in their populations (Ripple *et al.* 2015). The Baird's tapir (*Tapirus bairdii*; although *Tapirella* is also used for this species; Álvarez-Castañeda *et al.* 2017) is a species that belongs to Tapiridae family and the order Perissodactyla, that lives in the Neotropical forests, and it is distributed from México to Colombia, but its distribution range has been highly reduced in the last 40 years due to habitat encroachment and hunting (Naranjo 2018). Tapirs have been described as one of the last megafauna of the Neotropics and also a unique species (from the evolutionary perspective) that is on the risk of extinction (Issac *et al.* 2007; Ripple *et al.* 2015).

Tapirs have been described as solitary, nocturnal animals, that visit frequently water bodies to reduce their cor-

poral temperature and to escape from danger due to predators (Meyer *et al.* 2022; Calme *et al.* 2022; Reyna-Hurtado *et al.* in press). They disperse seeds of some trees and also defecate in water bodies filling an important ecological role as material and seed transporters and dispersers (O'Farrill *et al.* 2014). Tapirs are associated to some pieces of the landscape visiting frequently ponds and other water bodies (Reyna-Hurtado *et al.* 2016). Although there have been some documented attempts of predation of tapirs by jaguars (Pérez-Flores *et al.* 2020), it is not clear yet if adult tapirs can be preyed by jaguars due to the massive size and hard skin of tapirs.

The Maya Forest, a forest composed by protected areas in México, Guatemala, and Belize, is one of the last remaining pieces of Neotropical forests in good stage of conservation in Mesoamerica and the largest in the region. In México, in the Maya Forest, the Calakmul Biosphere Reserve (CBR) is the core area along with several other reserves in México, in Guatemala and in Belize that hold probably, the largest population of Baird's tapir in Mesoamerica (Schank *et al.* 2020). The CBR is the largest protected tropical forest

of México and despite an increase of infrastructure around the reserve like highways and railways, the CBR is still the most important protected area for species like tapirs that need large areas to sustain a viable population (Reyna-Hurtado *et al.* 2019).

In the CBR there are not major rivers and most of the water that fell by precipitation goes underground due to the Karstic soil materials, and just in few sites of the ground surface the water remains (Reyna-Hurtado *et al.* 2010). These sites are locally called “aguadas” (ponds hereafter) and play an important role as source of water for wildlife during the critical dry season and even for human communities that live on the periphery of the CBR (Reyna-Hurtado *et al.* 2010, 2012, 2019).

In the last years, biologists trying to investigate wildlife habits, behavior, and population parameters in dense environments such as tropical forest, have relied on camera traps (Nichols *et al.* 2011). Camera traps are an essential technique because they function remotely every time an object that has a higher temperature than the environment is moving in front of the detection field of the camera, allowing researchers to capture species that live in dense, remote habitats that are shy or nocturnal, or that live in low densities. The technique has been refined in the last years and nowadays camera traps are cheaper, more sensible, durable and lighter. In terms of ecological analyses, camera trap data are useful to estimate several parameters of the population of species, of the behavior of individuals, of the associations of species, of habitat use and preferences, and even of the poaching or human perturbation levels (O’Connell *et al.* 2011).

Since 2008, camera traps have been deployed in ponds of CBR with the goal of estimate population parameters of endangered wildlife species, especially endangered ungulates (Reyna-Hurtado *et al.* 2010, 2016, 2019). The number of cameras varied from 3 to 17 but since 2014 at least 10 cameras have been working permanently in the same number of ponds. This camera trap monitoring research have been combined with radiotelemetry research on two species of ungulates, the Baird’s tapir and the white-lipped peccary (*Tayassu pecari*) in the CBR. This combination of research technique has allowed us to combine data in terms of movement ecology (radiotelemetry) and population dynamics (camera traps).

For forest dwelling species such as Baird tapir (Reyna-Hurtado *et al.* 2016), Malaysian tapir (*Tapirus indicus*; Tawa *et al.* 2021), Bongo antelope (*Tragelaphus eurycerus*; Klaus-Hügi *et al.* 2000), Forest buffalos (*Syncerus caffer nanus*; Melletti *et al.* 2007), and Forest elephants (*Loxodonta cyclotis*; Turkalo and Fay 1995; Reyna-Hurtado *et al.* 2023) among others, the use of salt licks, or water sources such as ponds, can be important for resources acquisition (water, minerals), but also as “social arenas”, sites where animals frequently visit to interact with other conspecifics, to search for mates, to strengthen social networks, or sites where young can learn to socialize, or probably sites where conspecifics exchange social information (Turkalo and Fay 1995).

In this study we used data from a long-term study to investigate to what extent Baird’s tapir are solitary, or if they have social interactions while visiting ponds (a key piece of the landscape), we also described the sex ratio of the adult population and when individuals could be recognized, we described site fidelity. Finally, we described the tapir’s daily activity patterns. These characteristics of the Baird’s tapir population rarely have been described elsewhere and never in the long term and for several sites and with the sample size of this research. We expect to advance into the knowledge of the social behavior and natural history of this endangered species of the Maya Forest.

Material and methods

Study site description. The Calakmul Biosphere Reserve (CBR) with 7,289 km² is the largest protected tropical forest in México and is located at the core of the Maya Forest in Southern Mexico at 18° 07’21” N and longitude of -89° 48’ 56” W (Figure 1). The area is a semi-perennial tropical forest where trees height reaches up to 25 meters in most of the landscape. CBR is a flat area with some rolling hills of karstic origin, the Calakmul climate is warm and sub-humid (Aw), with a mean annual temperature of 24.6 °C. There is seasonal rainfall, mainly in summer and early fall, with an annual average of 1,076 mm. Of the different forest associations (Pennington and Sarukhan 1998), four are widely distributed: Medium Sub-Perennial Forest (Medium), the more humid of the region, where trees are between 15 to 25 m high; Low-Flooded Forest (Flooded) that gets seasonally inundated after 2 to 3 months of heavy rains, and where trees are between 5 to 15 m high; and the Medium and Low Semi-Deciduous Forests, which both can be classified as dry forest (Dry) where trees range from 8 to 25 m high, but species composition differs from that of the Medium Semi-Perennial Forest. These four types of forest are highly intermingled within the area, although the humidity from northwest (driest) to southeast (wettest) has an impact on the forest types too. The water in the area is obtained through precipitation since there is no permanent river system. Most of the rainfall percolates through the limestone, but some drains superficially and stores in ponds (“aguadas”). These ponds constitute the only source of water for wildlife through the dry season (Reyna-Hurtado *et al.* 2010).

Study Design. As part of an ongoing research on ungulates of the Maya Forest some camera traps were deployed in as many ponds as possible since 2008. The number of ponds monitored range from 3 to 17, but since 2014 the number of ponds monitored ranged from 10 to 17. The ponds were selected so as to occur at least 1.5 km from each other. All these ponds are in the southern area of the CBR, an area that is isolated from any human community by two checkpoints of the CBR authorities, and have one single road that leads to an archeological site but with very few cars every day (less than 10 on average). These ponds were monitored by setting up a single camera trap (Reconyx PC800 Hyperfire professional Reconyx, Inc., Cuddeback Inc

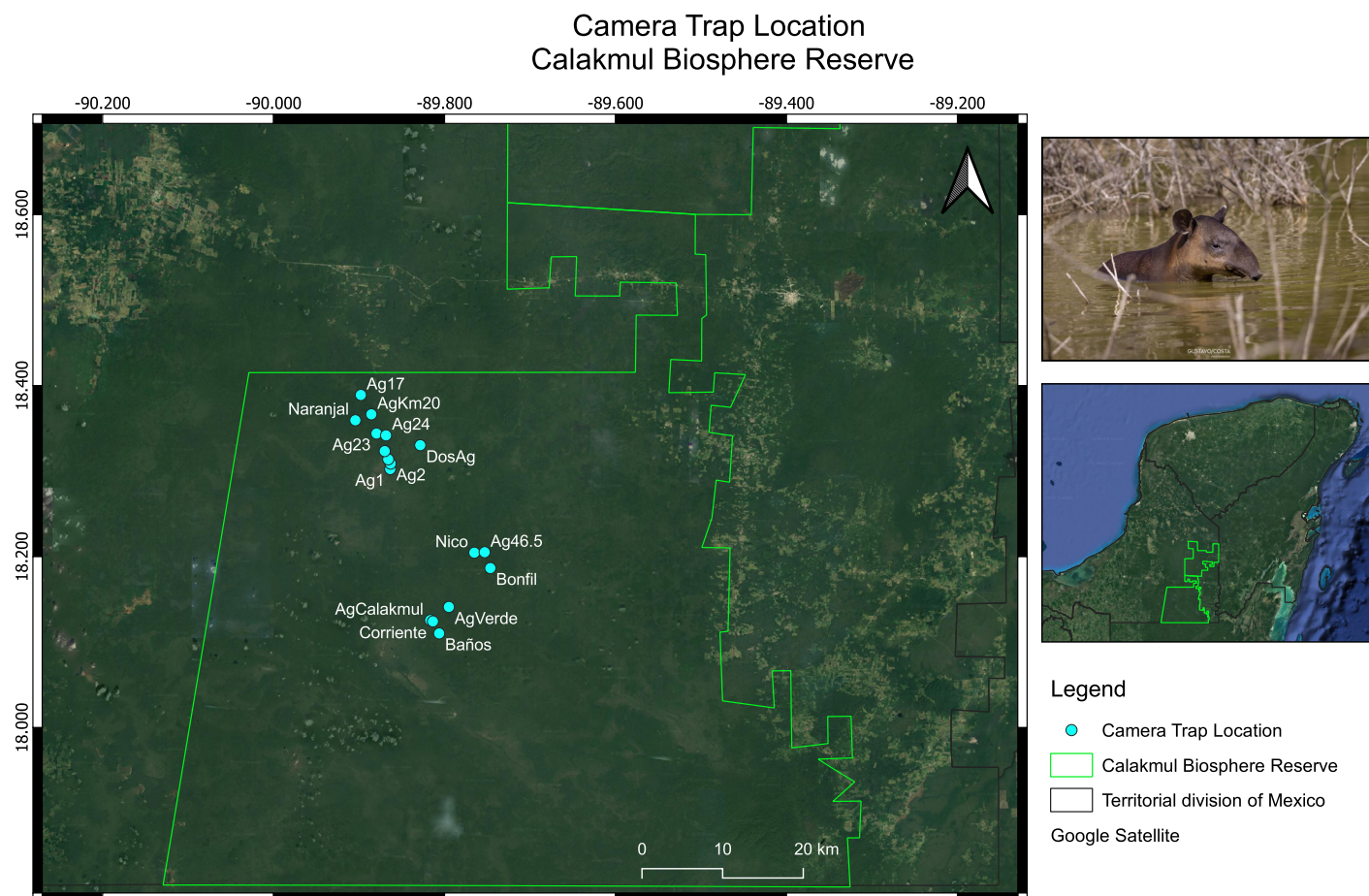


Figure 1. Map of the ponds ("aguadas") where camera traps were deployed on this study and the Calakmul Biosphere Reserve, Campeche, México.

and Browning Strike force Co.) at 50 cm high in some ponds from February 2014 to August 2023. The cameras were programmed to take five consecutive photos (one photo per second) each time the sensor detected movement and were checked every two months in average in the period 2014 to 2023 to change batteries and memory cards.

The photos obtained were sorted by species and here, we analyzed all the photos obtained of Baird's tapirs (13,068) from February 2014 to mid 2023. Then, we examined these records and counted the number of independent events (separated by 60 minutes) where tapirs were solitary, or when they had some social interactions. For social interactions we described any associations between two individuals, either female with newborn or juvenile, or male and female, or male and male, or female and female, or male and female with a juvenile, or more than two tapirs, etc. In addition, we counted the number of females and males when it was possible to identify sexually the individuals. The photos were also examined to visually identify as many as possible different individuals in each pond. We looked for scars in the face, for cuts in the ears, or scars in the back of the individuals, also other characteristics such as unique color marks, or leg problems (individuals limping). With these marks we tried to recognize individuals in the same pond but different years or in different ponds.

Finally, we used a couple of tapirs ("Emiliano" and "Eli") that were radio-collared with purposes of studying their movement patterns (Reyna-Hurtado *et al.* 2016). At the time these tapirs were collared, there were no other tapir with collar in the whole Maya Forest, so these individuals could be identified without doubt.

Analyses and software used. Once we selected a record every 60 minutes, it turned out to be 834 independent records. These records were analyzed with the statistical software R, using RStudio 2023.09.0 version (R Core Team 2023). Using the package "CampttrapR", and "Activity" and an R-Code developed by Andrade *et al.* (2022), we analyzed the time that Baird's tapirs were active in these years and in these sites and we constructed a graphic that shows the time preference along 24 hours for Baird's tapirs in the CBR.

Results

Tapir social behavior and sex ratio. The independent records of tapirs visiting ponds collected over 10 years in 17 different ponds of the Maya Forest confirmed that tapirs are predominantly solitary animals but have a number of social interactions of some way in a percentage of their life. Here, 87 % of their records were recorded as solitary animals, but 13 % of the records showed more than one tapir interacting in some way with another individual.

Of the social interactions recorded in the 17 sites and over 10 years the more common one was an association between male and female (59 % of which we recorded one that lasted for more than three months), followed by an association between female and juvenile (28 %) and the rest (13 %) were rare associations between two males (fighting) and a male following a female and a juvenile (Figure 2). Of the adult tapirs that visited the ponds that could be identified in term of sex, we recorded a male biased sex ratio of 67 % males *versus* 33 % females.

Tapir site fidelity. This long-term study showed that tapirs show fidelity at some sites and for times up to 10 years or more. We have information on at least three tapirs that presented distinguished characteristics such as marks in the ear, or that we radio-collared, that we could distinguish over several years and allowed us to describe how many years they were present in some sites. Table 1 shows the long-term persistence of three tapirs: "Oreja mocha", "Emiliano" and "Eli". "Oreja mocha" has been sighted by 10

years at least, and we followed "Emiliano" for four years, and "Eli" only for nine months, however in an intensive way due to the radio-collar we deployed on it. These three tapirs showed fidelity to some sites always coming back to some specific sites. "Oreja mocha" was highly attached to "Bonfil" and we saw it for first time in May 2011 (with a short camera monitoring program that was not included in this study), then in 2014, 2015, 2020 and 2021 in the same pond (Figure 3); while Emiliano was a frequent visitor of "Aguada Verde", "Baños", "Calakmul", and "Corriente" ponds visiting them frequently during the four years we followed it (Figure 4). "Eli" was followed intensively due to the radio-collar that was recording geographic positions every two hours, we recorded "Eli" in five sites several times during the nine months with "Aguada Km 17" being the most visited pond (Figure 5).

Tapir activity patterns. The 834 independent records of visits to ponds determined that tapirs are nocturnal and that the peak of activity occurs between 19:00 to 22:00

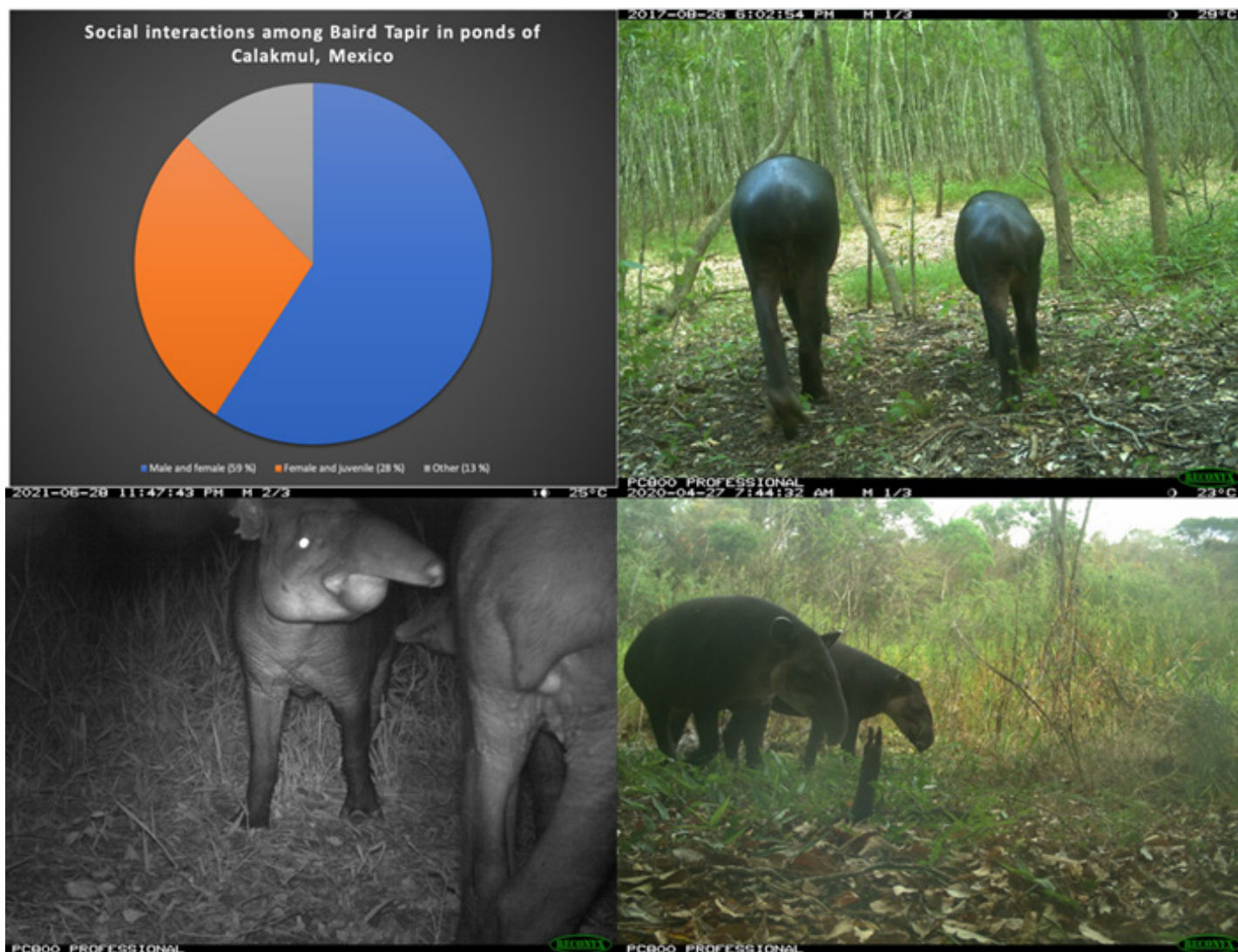


Figure 2. Percentage and photos of different social associations of *Tapirus bairdii* visiting ponds of the Calakmul Biosphere Reserve, México. Top left: Percentage of social interactions found in Baird's tapir from 2014 to 2023. Top right: a mother and a calf. Bottom left: a male ("Oreja mocha") and a female. Bottom right: another male and female.

Table 1. Individuals of *Tapirus bairdii* that were recognized over several periods of time in ponds of Calakmul Biosphere Reserve, México.

Tapir name	Description	First time sighted	Last time sighted	Site (ponds)
"Oreja mocha"	Male with right ear severed cut	May 2011	June 2021	"Bonfil"
"Emiliano"	Radio-collared male	May 2011	Jul 2015	"Verde", "Baños", "Calakmul", "Corriente"
"Eli"	Radio-collared male	Apr 2022	Jan 2023	"Naranjal", "Km 15", "Km 17", "Km 23", "Km 24"

hours (Figure 6). These data were collected across several sites, seasons, years and with an estimation of at least 30 (but could be more than 45) different individuals making it one of the most solid estimations of activity patterns of the species in the Maya Forest and in the whole distribution range of the species.

Discussion

Tapir social behavior. Here we demonstrated that despite Baird's tapir has been described as solitary species, it associates to some degree of their lives in rich social interactions with other individuals, while showing site fidelity that can last for several years. We confirmed that is a noc-

turnal species but preferences for being active early in the night was found.

It has been described that Baird's tapir is a solitary species where individuals travel and live most of their lives alone but that occasionally partner with other individuals for some part of their lives (Calme *et al.* 2022; Meyer *et al.* 2022). Our study, which confirm the previous sentences, was done across several years, sites, and individuals, so the finding of a small percentage of their live as social individuals is important because reflects the real degree of social relationships that tapir performs in the Maya Forest across seasons and years in different conditions.

Despite the percentage of social relationships was small (13 %), some of these associations lasted for several

**Figure 3.** "Oreja mocha" photos from 2015 to 2021 in Bonfil pond of Calakmul Biosphere Reserve, México.



Figure 4. "Emiliano" photos from 2011 to 2015 in several pond of Calakmul Biosphere Reserve, México.

months (male and female) and probably for years (female and juvenile pairs were seeing repeatedly in same sites in consecutive years). Here, we documented some associations between male and female that lasted at least four months and we found associations between female and juvenile in same site, but several years, that probably are the same individuals, however there were no definitive marks that allowed us to recognized them with certainty. It has been found that juveniles spent some time with their mother after being born. This time varies from one year (Naranjo 2014) to more than a year (Calme et al. 2022; Garcia 2016). The possibility of, larger than one-year associations, between female and newborn is evident here due to the photos of similar pairs (female and newborn) being showing consistently in the same sites but different years. That is a topic for future research using camera traps or genetic techniques to identify individuals with certainty. Castellanos et al. (2021) found similar results for the mountain tapir (*Tapirus pinchaque*), where they found associations among recognized tapirs that lasted more than two years (mother and calf), and they also found mountain tapirs to aggregate in temporal groups from three to nine (Castellanos et al. 2021).

We found a male biased sex ratio of the fraction of the population we could identify. There is not sex ratio reported previously in this species so we have no means to compare

our results. This is contrasting with a population of the Amazonian tapir (*Tapirus terrestris*) where a female biased population was found in the adult section, and a male biased among the juvenile population that visited a salt lick place in the Colombian Amazon forest (Montenegro 1998). In that case, the researcher argue that female adults and male juveniles may have a higher minerals requirement (Montenegro 1998). In our case, our results could mean that the



Figure 5. "Eli" photos from 2022 to 2023 in several pond of Calakmul Biosphere Reserve, México. Top right photo credit: Daniel Nuñez.

population is truly male biased, or that males travel more and are visiting the ponds with higher frequency. However, the male sex ratio has been described previously in camera traps for jaguars and has been attributable to differences in behavior and ranging patterns, rather than population differences, with females being a lot less captured by camera traps than males, and probably avoiding camera traps deliberately (Srbek-Araujo *et al.* 2018). There is no information on the behavior of the female tapir, neither on the differences in the ranging behavior. In this study we got information from two males that were captured and attached with radiotelemetry collars but we have not followed any female yet. The fact that we found a great male-biased sex ratio raises a couple of interesting questions, these are: Do females' tapirs move less and have smaller ranges than males' tapirs? and, do females' tapirs avoid camera traps, or ponds, deliberately?

There are very few studies of Baird's tapir movement patterns. In Nicaragua, Jordan *et al.* (2019) followed actively only two males as the female they captured dropped the collar short after they radio-collared her. In Belize, Martinez *et al.* (in press) followed a female that ranged similar distances than two males they followed for several months with radiotelemetry collars.

There is the need of more studies to confirm if the male sex ratio we found is due to population parameters, or due to behavior differences between the sex. We hope that in the near future the ranging behavior of females can be described in greater detail.

Tapir site fidelity. We found Baird's tapirs to show high fidelity so some sites and that that fidelity can last for years. The fact that one individual was sighted after 10 years in the same site was an interesting one that demonstrated that tapirs could associate themselves to some sites and remain, or visit, these sites for long periods of time. In 2011, when we sighted for first time "Oreja Mocha" he was already a full-grown adult tapir that showed several scars at that time already. This individual showed itself several times along 10 years in the same site and in 2021 he was there associated with a female and in apparently good health status. Two more tapirs that we followed by radiotelemetry also showed close associations to some sites for some periods of time, "Emiliano" who is probably using spatial memory to find and reach some ponds as was reported in Reyna-Hurtado *et al.* (2016) and "Eli" who was sighted several times returning to specific ponds (R. Reyna-Hurtado unpublished).

Tapirs ranging behavior can be complex and interesting. Probably, they are using the spatial memory to reach small ponds that are located in a flat, uniform, and extensive environment such as the CBR and that are found in low densities (Reyna-Hurtado *et al.* 2012; 2016). The knowledge of the location of these ponds can be a very valuable skill to survive in dense tropical forest and here we demonstrated that tapirs returned repeatedly and for several years

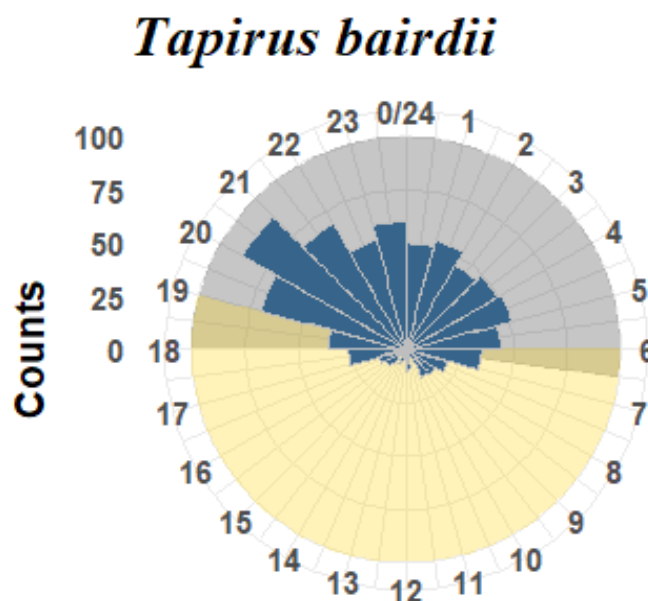


Figure 6. Activity patterns of *Tapirus bairdii* from 2014 to 2023 in several ponds of Calakmul Biosphere Reserve, México.

to some specific sites located in dense environments of the CBR. More studies on this topic following individuals through radiotelemetry techniques can be very interesting to confirm it and elucidate the ways they associate with ponds and other features of the landscape.

Tapir activity patterns. Previously we have found that tapirs are more active at night and that they were affected by moon light in some way (Sanchez-Pinzon *et al.* 2019). Here we confirmed these patterns and also found that there is a preference for early hours of the night to be active. The 834 independent records showed that tapirs are more active at night but especially between 19:00 to 24:00 with a peak between 19:00 to 22:00 hours. These nocturnal patterns were consistent among several years, sites and seasons showing that tapirs are well adapted to the environment by moving at night and visiting repeatedly some specific sites. Probably, these behavioral patterns were adaptations to the hot environment of tropical forest such as CBR. It was evident that in the instances when tapirs were photo-captured during the day, they were visiting the ponds to cool down in the water in very hot days. Similar results were found for several Amazonian tapirs in Colombian forest that were visiting salt lick sites in a behavior markedly nocturnal with a peak between 18:00 to 04:00 (Montenegro 1998).

Tapirs are shy, elusive, nocturnal species that live in low density populations across a Neotropical forests range that is being decreasing every year. Information on the social behavior, sexual ratio, movement patterns and the site fidelity like the ones presented in this study may help to elaborate informed conservation actions. Research like this, also pointed out in the direction of more needed research to advance in the ecological knowledge of this

enigmatic species, that has been described as a conservation priority (Isaac *et al.* 2007) and the tenth rarest species of the Neotropics mammals (Dobson and Yu 1993). Here, we presented information about social behavior, sex ratio, activity patterns and site fidelity of a long-term study across several sites, years, and individuals. We also showed that ponds can be places where different social interaction are occurring. In the future, we need to test these sites to find if they are been used as “social arenas” for tapirs. We hope that in a near future, studies about ranging patterns, genetic composition, and population dynamics can be conducted and we learn more about this endangered species of a Neotropical ungulate.

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