NEOTROPICAL
BIOLOGY AND CONSERVATION

Neotropical Biology and Conservation
16(4): 539–563 (2021)
doi: 10.3897/neotropical.16.e71032

RESEARCH ARTICLE

# Human-wildlife conflicts and drought in the greater Calakmul Region, Mexico: implications for tapir conservation

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Academic editor: AM Leal-Zanchet | Received 3 July 2021 | Accepted 13 November 2021 | Published 17 December 2021

Citation: Pérez-Flores J, Mardero S, López-Cen A, Contreras-Moreno FM (2021) Human-wildlife conflicts and drought in the greater Calakmul Region, Mexico: implications for tapir conservation. Neotropical Biology and Conservation 16(4): 539–563. https://doi.org/10.3897/neotropical.16.e71032

## Abstract
Wildlife conservation efforts in the Mesoamerican Biological Corridor have focused on reducing negative interactions between humans and charismatic species. In recent years, droughts have increased in frequency and intensity in southeastern Mexico exacerbating conflicts with wildlife as they compete with humans for limited water. In the Yucatan Peninsula, Greater Calakmul Region of southeastern Mexico, Baird's tapirs (*Tapirus bairdii*) are increasingly encroaching into local villages (ejidos) in search of water. This behavior could increase tapir mortality from hunting by Calakmul ejidos residents. We evaluated the trends between annual precipitation and tapir sightings near or within Calakmul ejidos from 2008 to 2019 to determine if the frequency of reported conflicts increased relative to decreased precipitation. In addition, with community participation, from 2016 to 2018 we monitored one of the ejidos where human-tapir conflicts were reported to be increasing to better describe the nature of conflicts. We did not find any relationship between the number of tapir sightings reported and annual precipitation. However, more tapirs were documented near ejidos in 2019, which is one

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of the years with the lowest rainfall (626.6 mm) in the last decade. Tapirs were reported as the most common wildlife species observed at waterholes (35.4%) and apiaries (32.1%). Our findings suggested that water scarcity has increased tapirs' incursions into human-populated areas and subsequently the potential for human-tapir conflicts. We recommend that managers consider developing alternative water sources that could mitigate human-tapir conflicts and contribute to the long-term viability of other wildlife species that inhabit the Greater Calakmul Region of southeastern Mexico.

**Keywords**
Climate change, crop raiding, *Tapirus bairdii*, water scarcity, wildlife conservation, Yucatan Peninsula

## Introduction

The Mesoamerican Biological Corridor is a biodiversity hotspot and a natural land bridge that connects North and South America; it encompasses southern Mexico, Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama (Finley-Brook 2007; Harvey et al. 2008; Mendoza et al. 2013). Wildlife conservation efforts in the Mesoamerican Biological Corridor have typically focused on reducing conflicts between humans and large charismatic carnivore species such as jaguar (*Panthera onca*) and puma (*Puma concolor*; Garcia-Alaniz et al. 2010; Amit et al. 2013; Miller 2015; Steinberg 2016; Peña-Mondragón et al. 2017). The major conflict is increased predation on domestic livestock as ranching is the primary land-use throughout the geographical distribution of these species. However, livestock predation is not the only rural activity that could be affected by wildlife in this region. Other conflicts, whether perceived or actual may result when wildlife damages crops, are involved in collisions, or threaten and kills people (Messmer 2000; Madden and McQuinn 2014).

Efforts and resources to manage human-wildlife conflicts (HWCs) in Mesoamerica and worldwide are inequitable, with charismatic species receiving the majority of economic resources for conservation (Macdonald et al. 2015). Therefore, conflicts with non-charismatic species have been underestimated and understudied. In some rural areas of Latin America, the socio-economic and ecological impact, perceptions and attitudes of local people towards non-charismatic species such as monkeys, rodents, small omnivores, reptiles and birds have received little attention (Spagnoletti et al. 2016; de Lima et al. 2020; Salom et al. 2021). Despite the fact that HWCs are one of the main causes of the reduction and extinction of species populations (Nyhus 2016).

In Mesoamerica, 36.2% of the population lives in rural areas and are dependent on subsistence agriculture (World Bank-WB 2018). Concomitantly, agriculture and livestock production are steadily increasing to meet the growing demand for food (Laurance et al. 2014). As per capita consumption of natural resources in this region continues to increase, HWCs will likely increase in both frequency and severity (Messmer 2000).

In the center of the Mesoamerican Biological Corridor resides the Greater Calakmul Region, which is part of the Selva Maya, the second largest area of tropical forests in the Americas (O'Farrill et al. 2014). Around 90% of the Calakmul region is protected either by federal (Calakmul Biosphere Reserve [CBR]) or state reserves (Balam-kin and Balam-Kú). The CBR is divided in two areas: the strictly protected area (core area 248,260 ha) and the surrounding buffer zone (474,924 ha) (Instituto Nacional Electoral [INE] 1999). In the latter, there are communal lands called "ejidos", whose main economic activity is subsistence agriculture. Agriculture activities include planting corn (*Zea mays*), beans (*Phaseolus vulgaris*), jalapeño (*Capsicum annuum*) and citrus fruits, beekeeping, forestry, handcrafting, non-timber forest extraction, cattle (*Bos taurus*) ranching and subsistence hunting (Mercer et al. 2005; Porter-Bolland et al. 2006). Many activities of the ejidos are changing the landscape through habitat loss, fragmentation, land-use change, and habitat degradation and contributing to increasing trends in negative interactions between humans and wildlife (Pérez-Flores et al. 2020).

In addition to landscape changes, recent droughts could exacerbate HWCs in the region (Pérez-Flores et al. 2020). According to the Campeche State Climate Change Action Program, maximum temperatures in the Calakmul Region will increase less than 1 °C average between 2015 and 2039 ( Secretaria de Medio Ambiente y Recursos Naturales de Campeche [SEMARNATCAM] 2015). However, this slight increase in temperature in association with recurrent droughts can lead to increased habitat desiccation and HWCs (Trenberth et al. 2014). For instance, in Africa, rising temperatures and habitat loss have increased movement of large mammalian herbivores in search of water and high-quality food, which has increased HWCs incidents due to competition for limited resources (Mukeka et al. 2019).

Regional climate projections for the Yucatan Peninsula suggest the area will experience more extreme droughts (Intergovernmental Panel on Climate Change [IPCC] 2007, 2013; Orellana et al. 2009). Across Calakmul, drought frequencies have increased over the last 50 years (Mardero et al. 2012). Some of the reported consequences for wildlife include water scarcity, fires, and increased animal movements in search of food and water (Reyna-Hurtado et al. 2009; O'Farrill et al. 2014).

Water available for wildlife consumption in Calakmul is stored in natural (called aguadas) and artificial (called jagüeyes) waterholes, and in small seasonal streams (Fig. 1). Some of these waterholes may remain flooded throughout the year, but during the dry season (December to May) many dry out (García-Gil et al. 2002). Because of the extended drought some aguadas have dried up and loss their water-retention capability (Reyna-Hurtado et al. 2010). Since 2008, more tapirs have been observed near or inside different communal lands of the municipality of Calakmul; most of them were in poor body condition and were dehydrated (Pérez-Flores et al. 2016). The lack of available water resources forces tapirs to search food and water in places where people store water and carry out productive activities.

Large bodied species such as Baird's tapirs (*Tapirus bairdii*; Fig. 2) could be the most affected wildlife species, as they require 10–15 L of water per day (MacFarlane and Howard 1972). Tapirs adapt their behaviour to the extent that they become completely nocturnal because their low surface/volume ratio makes it difficult to disperse

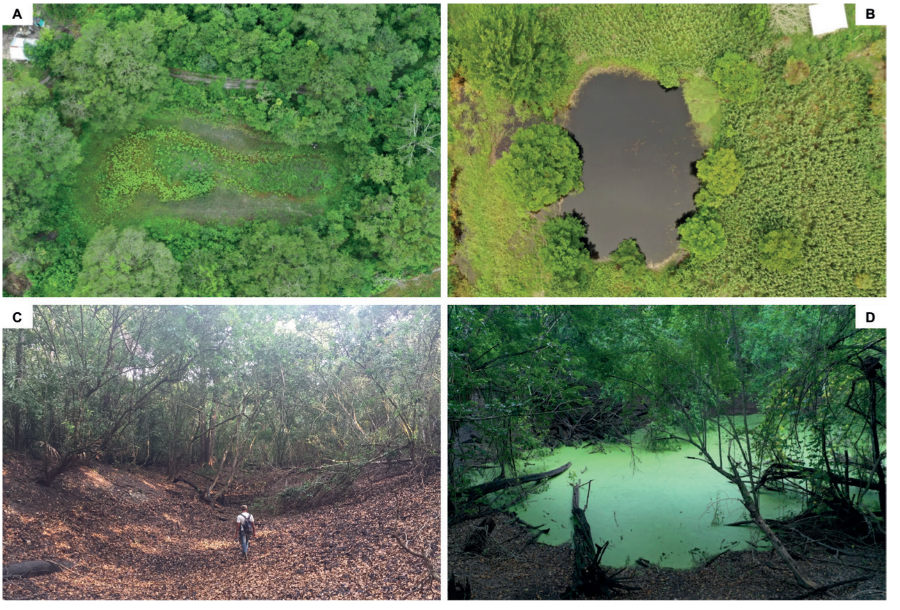


**Figure 1.** Different waterholes locally known as aguadas of the Calakmul region, Campeche, Mexico: A) aerial drone photography of a dry aguada of the ejido "Bel-ha" in 2019 B) aerial drone photography of a full aguada of the ejido "Nueva Vida" in 2019 C) a dry aguada of the ejido "Nuevo Becal" in 2017 and D) an aguada of the Calakmul Biosphere Reserve in 2019.

**Figure 2.** Baird's tapir (*Tapirus bairdii*) in the Yucatan Peninsula, Greater Calakmul Region of southerneastern Mexico.

**Figure 3.** Baird's tapir (*Tapirus bairdii*) drinking through the steel mesh from a livestock watering trough at ejido "Nueva Vida" in May of 2017, in the Yucatan Peninsula, Greater Calakmul Region southeastern Mexico.

body heat (Foerster and Vaughan 2002; Medici 2010). Same way, tapirs also spend more time in the water to cool down as temperatures increase (Pérez-Flores pers. obs.). Their dependence on water is forcing tapirs to move closer to human settlements, where habitat may be better because of increased water availability (O'Farrill et al. 2014; Fig. 3). However, the principal documented conflict between tapirs and humans is crop raiding, which has resulted in the killing of tapirs that exhibit this behaviour (Suarez and Lizcano 2002; Haddad et al. 2005; Koster 2006; Waters et al. 2006; Reyna-Hurtado and Tanner 2007; Waters 2015; Serrano-MacGregor 2017). Tapirs' populations continue to decline worldwide (García et al. 2016), and although several of the primary drivers contributing to their declines are present in the Calakmul region, few studies have focused on understanding how serious a threat HWCs are and how they can affect the survival of one of the world's largest Baird's tapir populations.

The purpose of our study was to determine precipitation trends from 2008–2019 near Calakmul ejidos where increased tapir sightings have been recorded, as well as to identify potential areas of conflict between humans and tapirs under communal land management. Based on our research, we proposed strategies to mitigate water scarcity in the region and promote human-tapir coexistence in the Greater Calakmul region.

## Methods

### Study area

The Calakmul Region is located in the southeastern portion of the state of Campeche, Mexico (19°12'–17°48'N, 89°09'–90°28'W; Fig. 4). The municipality of Calakmul covers 13,849 km$^2$ with a total population around 30,000 inhabitants (Instituto Nacional de Estadística Geografía e Informática [INEGI] 2015). Eighty-five percent of the population lives in 157 rural settlements and 15% in Xpujil City (INEGI 2015). Many of these ejidos border Mexico´s largest protected tropical forest the CBR, which encompasses 7,238 km$^2$. The climate is tropical sub-humid with summer rains (Aw) (García-Amaro 2004). Annual average precipitation is highly variable, ranging from 900 mm in the northwest to 1400 mm in southeast and characterized by two seasons: a dry season between December to May, followed by a rainy season from June to November (Vidal-Zepeda 2005; Mardero et al. 2012). Average annual temperature ranges from 24 to 26 °C (Vester et al. 2007), and the predomi-

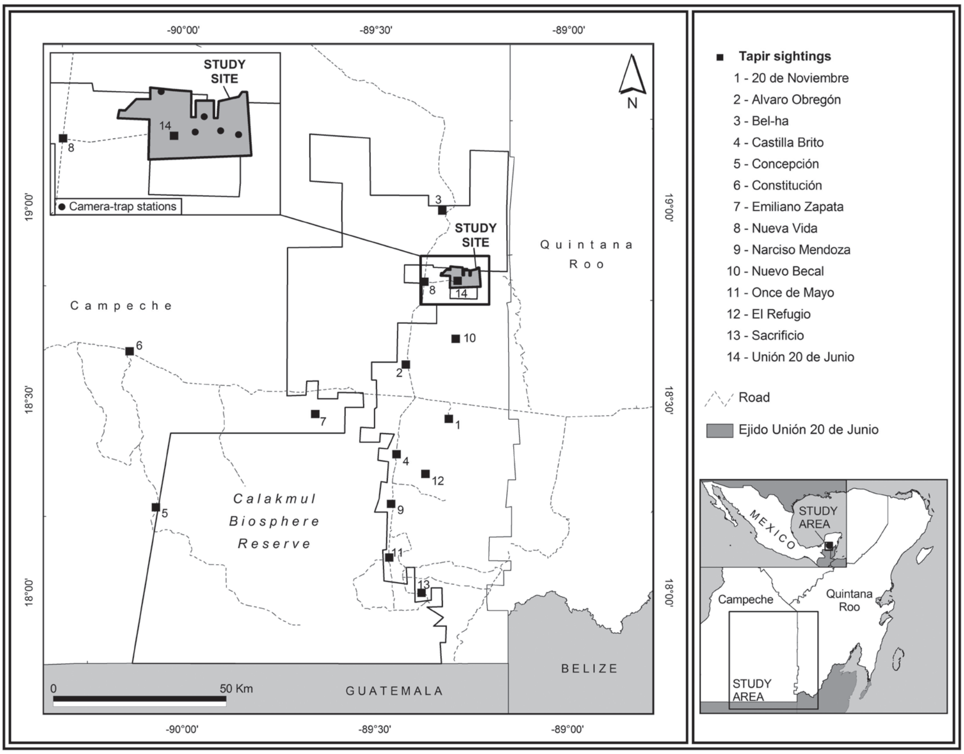


**Figure 4.** Location of the 14 villages (ejidos) where Baird's tapirs (*Tapirus bairdii*) were sighted during 2008 to 2019 in the municipality of Calakmul, Campeche, Mexico. We deployed camera-traps only at ejido "Unión 20 de Junio" during the rainy seasons of 2016 to 2018 to document tapir activity and identify areas of potential conflicts.

nant vegetation type is tropical subdeciduous and deciduous forests with heavy clay soils with poor drainage (causing water-logged areas locally called Ak'alches; Morales 1999; Vester et al. 2007).

To identify the potential areas of conflict between humans and tapirs, we select the ejido Unión 20 de Junio (U20J) because Pronatura Península de Yucatán A.C. has been collaborating on different projects with this community for 5 years, so we were aware of previous reports of tapir sightings in potential conflict areas, especially during droughts. Unión 20 de Junio (18°48'38"N, 89°16'59"W) is an ejido in the northeast portion of the municipality of Calakmul, Campeche that encompasses approximately 60 $km^2$ and is inhabited by 449 people. The majority of its population is indigenous people from Chiapas (INEGI 2015). The main land uses are subsistence agriculture, beekeeping, forestry, handcrafting, and small-scale cattle production. The water available in U20J for consumption by domestic and wild animals, and for productive activities is stored in aguadas and jagüeyes. The size of waterholes varies between 50 to 20000 $m^2$ and the depth between 1 to 5 m.

## Tapir observations

From 2008 to date, we asked local residents, researchers, rangers, police and tourists about photographic records of tapirs sighted close or inside ejidos of the Calakmul region, in an area of approximately 8000 $km^2$. For each record, we obtained the name of the person, coordinates of the place where the animal was observed, as well as the date and time of the last sighting. In most of the cases, tapirs were sighted and clinically assisted by the authors.

## Precipitation trends

We used monthly data from the Zoh Laguna, Campeche meteorological station (located in the center of the municipality of Calakmul), available from the Comisión Nacional del Agua (CONAGUA) to analyze the annual precipitation from 2008 to 2019. We conducted a Mann-Kendall test to test for the presence of monotonic increasing or decreasing trend, and the Sen´s Slope Estimates for calculating the slope of the linear trend (Yue and Wang 2004; Mavromatis and Stathis 2011). Although our research occurred from 2008–2019, we also calculated the trend and the slope for all the available data from the Zoh Laguna Station (1951 to 2019) to show a more general picture of rainfall behavior in the area.

## Camera trap monitoring system

From 2016 to 2018, the NGO Pronatura Península de Yucatán, A.C. and local people of U20J operated a community-based wildlife monitoring program. The principal objectives of the monitoring program were to determine species richness, and to identify potential areas for HWCs. We placed camera traps in sites where people carried out productive activities (e.g., beekeeping, cultivation zones, areas where animals graze and drink water) and in sites where there was enough evidence that wildlife was passing by or causing some damages, especially tapirs. We used one camera model (Cuddeback Black Flash E3, Non-Typical Inc., Green Bay, WI, USA; www.cuddeback.com).

We placed camera traps in two jagüeyes (one per jagüey), two cultivation zones (one per cultivation zone) where people grow mainly corn, squash (*Cucurbita* spp.) and beans, and an apiary (one). Only five cameras were used as they could be stolen because many people pass through these sites. The cameras remained active 24 hours per day and were checked every 30 to 45 days, to change batteries and empty memory cards during the dry season (December to May) of each year (2016–2018).

The visitation frequency of each species at each site was defined as the mean number of visits (independent records) during the dry seasons of 2016–2018. We only considered independent records in the analyses to avoid under and overestimation. We considered one independent record as a single photograph of the species every 24 h. In cases where more than one individual was recorded on a photograph, the number of independent records was considered to be equal to the number of individuals observed on the same photograph (Monroy-Vilchis et al. 2011).

### Data analyses

We assessed annual precipitation behavior during two periods (1951–2019 and 2008–2019) using the Mann-Kendall test to test the presence of trends, and the Sen´s Slope Estimates to calculate the slope of the linear trend (for more details see Hussain et al. 2015). By analyzing trends, we also described examples that show the great interannual variability and mentioned some years in which precipitation was below the average in the area. We assessed relationships between annual precipitation trends and annual tapir sightings using Pearson's product-moment correlation with R 3.6.0 (R Core Team 2019).

## Results

### Tapir observations

Since 2008, 26 tapir sightings were recorded by residents near or inside the ejidos. The years with the highest number of sightings were 2017 and 2019 with 4 and 13 sightings, respectively (Fig. 5). Seventy-seven percent of the observations (n = 20) occurred during the dry season. Twenty-three (88.5%) of the individual tapirs observed were in poor body condition, and in the cases where the animals were clinically evaluated, we observed dehydration, emaciation, low alertness and responsiveness (in many cases no aggressive behaviour was evident). The age classes documented included 24 adults and two offspring. We recorded tapirs at 14 different ejidos (Fig. 4).

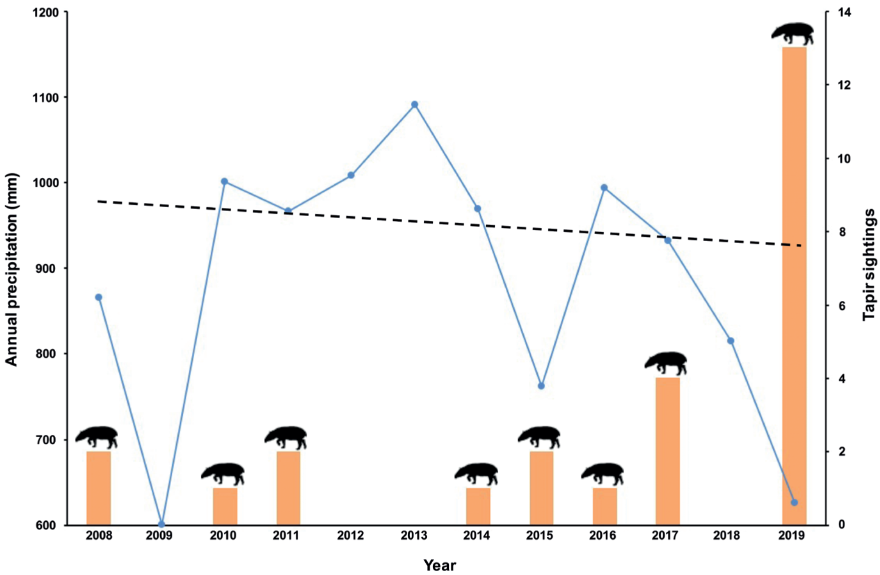


**Figure 5.** Average annual precipitation and number of Baird's tapirs (*Tapirus bairdii*) sighted in the ejidos of the municipality of Calakmul, Campeche, Mexico from 2008 to 2019.

## Precipitation trends

The average annual precipitation at Zoh Laguna station was 1007 mm. During the period 1951–2019, annual precipitation declined ($Z = -2.97$, $p = .0029$), decreasing around 375 mm on average, according to the Sen's Slope Estimates (Fig. 6). In addition to a general trend of decreasing precipitation, there was greater interannual variability, observed for example in years with round 1500 mm of precipitation, followed immediately by a year with 700 mm.

During our study period (2008–2019), rainfall also showed a negative trend of up to 70 mm less rain in the last 12 years. However, these numbers should be taken with caution because the trend was not significant ($Z = -0.34$, $p = 0.7338$). Although the negative trend of precipitation in the last 12 years was not significant, in 8 of the 12 years of that period the precipitation was below the average in the area, with 2009 and 2019 having the highest precipitation deficit (60% and 62% below average, respectively). We also observed high interannual precipitation variability; for example, a difference of 500 mm between one year and the following, such as is the case of 2014–2015 period.

According to the Pearson's product-moment correlation test, we did not detect a relationship between annual precipitation trends and annual tapirs sighted during our study period (2008–2019).

## Camera traps

We monitored our five camera traps for 13,104 hours over 78 weeks during the dry season from 2016–2018 and documented 187 visits of 22 species visiting the two

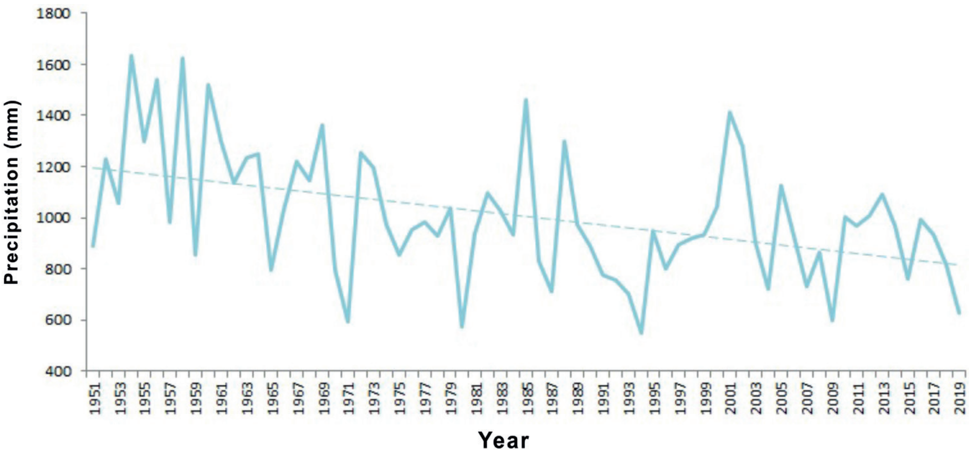


**Figure 6.** Precipitation in the Calakmul region, Campeche, Mexico (1951–2019).


**Figure 7.** Crop raiding species identified with camera traps during the dry seasons at ejido"Unión 20 de Junio", Calakmul, Campeche, Mexico: A) Baird's tapir (*Tapirus bairdii*) B) white-tailed deer (*Odocoileus virginianus*) C) coati (*Nasua narica*) and D) armed villagers walking through cultivation zones.

cultivated sites. The most frequent visitors to cultivated crops were the gray fox (*Urocyon cinereoargenteus*) 18.7% (n = 35) and Central American agouti (*Dasyprocta punctata*) 14.9% (n = 26) (Table 1; Fig. 7). At the apiary, we recorded 28 visits of 7 species, with tapir's 32.1% (n = 9) and being the most frequent species that visited this site (Table 1; Fig. 8). Finally, at the jagüeyes we documented 347 visits of 36 species, with tapirs the most frequent visitor 35.4% (n = 123; Table 1; Fig. 9). All visi-

**Table 1.** Species identified and visit frequency during the dry seasons of 2016 to 2018 for the three potential conflict areas (jagüey, apiary and crop) at ejido "Unión 20 de Junio", Calakmul, Campeche, Mexico.

| Camera trap records dry seasons of 2016 to 2018 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Mammal Species** | **Jagüey % (n)** | **Apiary % (n)** | **Crop % (n)** | **Avian species** | **Jagüey % (n)** | **Apiary % (n)** | **Crop % (n)** |
| *Bos taurus* | 0 | 0 | 0.5 (1) | *Aramides cajaneus* | 1.1 (4) | 0 | 0 |
| *Canis lupus familiaris* | 2.3 (8) | 0 | 0.5 (1) | *Ardea herodias* | 0.6 (2) | 0 | 0 |
| *Cuniculus paca* | 6.9 (24) | 0 | 4.3 (8) | *Buteo albicaudatus* | 0.3 (1) | 0 | 0 |
| *Dasyprocta punctata* | 1.4 (5) | 0 | 14.9 (26) | *Buteo plagiatus* | 0.3 (1) | 0 | 0 |
| *Didelphis virginiana* | 1.1 (4) | 0 | 0.5 (1) | *Buteogallus anthracinus* | 1.4 (5) | 0 | 0 |
| *Herpailurus yagouaroundi* | 0.3 (1) | 0 | 1 (2) | *Buteogallus urubitinga* | 1.4 (5) | 0 | 0 |
| *Homo sapiens* | 2 (7) | 25 (7) | 4.8 (9) | *Butorides virescens* | 0.3 (1) | 0 | 0 |
| *Leopardus pardalis* | 2.6 (9) | 10.7 (3) | 4.8 (9) | *Cathartes aura* | 1.7 (6) | 0 | 0 |
| *Leopardus wiedii* | 1.1 (4) | 0 | 0.5 (1) | *Coragyps atratus* | 4.9 (17) | 0 | 0 |
| *Mazama* sp | 1.7 (6) | 14.3 (4) | 11.8 (22) | *Crax rubra* | 2.6 (9) | 0 | 0 |
| *Nasua narica* | 5.8 (20) | 10.7 (3) | 6.9 (13) | *Crypturellus cinnamomeus* | 0 | 3.6 (1) | 0 |
| *Odocoileus virginianus* | 3.7 (13) | 0 | 2 (4) | *Egretta caerulea* | 0.3 (1) | 0 | 0 |
| *Panthera onca* | 0 | 3.6 (1) | 1 (2) | *Leptotila verreauxi* | 1.4 (5) | 0 | 2 (4) |
| *Pecari tajacu* | 0 | 0 | 3.2 (6) | *Meleagris ocellata* | 0 | 0 | 1 (2) |
| *Procyon lotor* | 0 | 0 | 0.5 (1) | *Micrastur semitorquatus* | 1.4 (5) | 0 | 0 |
| *Puma concolor* | 0.6 (2) | 0 | 0.5 (1) | *Mycteria americana* | 0.3 (1) | 0 | 0 |
| *Spilogale angustifrons* | 0.3 (1) | 0 | 0 | *Ortalis vetula* | 2.6 (9) | 0 | 8.6 (16) |
| *Tapirus bairdii* | 35.4 (123) | 32.1 (9) | 11.8 (22) | *Patagioenas nigrirostris* | 0.9 (3) | 0 | 0.5 (1) |
| *Urocyon cinereoargenteus* | 6.3 (22) | 0 | 18.7 (35) | *Ramphastos sulfuratus* | 4.3 (15) | 0 | 0 |
| | | | | *Sarcoramphus papa* | 0.3 (1) | 0 | 0 |
| | | | | *Spizaetus ornatus* | 0.3 (1) | 0 | 0 |
| | | | | *Spizaetus tyrannus* | 0.3 (1) | 0 | 0 |
| | | | | *Tigrisoma mexicanum* | 1.4 (5) | 0 | 0 |

tors could be identified to species level, except brocket deer which were identified only up to genus because it is difficult to distinguish between the Central American red brocket (*Mazama temama*) and Yucatan brown brocket (*Mazama pandora*) in photos, especially from night or poor quality photographs.

## Discussion

We designed our study to identify relationships between precipitation trends and tapir sightings in the communal forests in the Calakmul region of Mexico's Yucatan Peninsula; however, our results did not detect a relationship between the number of tapir sightings and annual rainfall, although we observed a dramatic increase in tapir sightings during the dry season of 2019. We identified jagüeyes and apiaries as the areas with the highest potential for human-tapir conflicts due to the availability of water at these sites during the dry season. In addition, we documented that tapirs were not the main raiders of cultivated crops despite what people believed. Through our results we found that during the dry season tapirs will be forced to visit more frequently communal forests, which could precipitate negative events that lead to HTCs.

### Precipitation trends

Our analyzes revealed reduced annual precipitation during 1951–2019, but especially since the 1990's, coinciding with reports from the Economic Commission for


**Figure 8.** Different species recorded by camera traps during the dry seasons at the apiary of the ejido "Union 20 de Junio", Calakmul, Campeche, Mexico: A) Baird's tapir (*Tapirus bairdii*) B) ocelot (*Leopardus pardalis*) C) coati (*Nasua narica*) and D) armed people recorded working at the apiary.


**Figure 9.** Camera trap photographic records from an artificial waterhole (jagüey) at the ejido "Unión 20 de Junio", Calakmul, Campeche, Mexico: A) Baird's tapir at the beginning of the dry season (jagüey is almost full) B) probably the same tapir a month later, the water has started to decrease C) 23 days after picture B people with domestic animals visiting the jagüey and D) six days after picture C at the end of the dry season a tapir passes through the jagüey which is completely dry.

Latin America and the Caribbean (CEPAL 2015), and the IPCC (2013). Dow and Downing (2016) and Bouroncle et al. (2017) reported that more variable precipitation and droughts will likely happen in Central America, including the Mayan lowlands of Mexico. The Yucatan Peninsula, including the Calakmul region, has a long record of periodic droughts, which scholars believe contributed to the collapse of Mayan civilization (Haug et al. 2003; Douglas et al. 2015).

During our study period (2008–2019) rainfall had not significantly decreased despite the widespread perception of the inhabitants and local media (Chim 2017) that Calakmul has experienced its worst drought in recent years. This could be due to the fact that, according to some scholars, investigations of changing precipitation patterns require at least a 30-year data series, given temporal climate oscillations (Onyutha et al. 2016), especially in trend detection (Camberlin 2009; Di Baldassarre et al. 2011).

Another reason could be that, even if the total annual precipitation may not be decreasing significantly, recent studies (Mardero et al. 2019) have shown changes in the distribution and intensity of precipitation in the area, with rainfall concentrating on fewer events, longer periods of drought between them, and with frequent late starts of the rainy season. If precipitation variability in Calakmul keeps intensifying and the rains during the wet season are not enough to replenish the aguadas, animals may broaden their migratory ranges to survive the dry season, increasing the risk of hunting and the risk of conflicts with rural communities.

## Human-tapir conflicts

Although we did not detect a statistical relationship in the Calakmul region between precipitation trends and tapir sightings, water scarcity has resulted in more tapir sightings near or within human settlements, and those tapirs sighted presented poor body condition and symptoms of dehydration. The number of sightings in the municipality of Calakmul have increased in the last five years. The highest recorded observations were associated with the intense and prolonged drought of 2019.

It has been previously documented that in Calakmul, white-lipped peccaries (*Tayassu pecari*) and tapirs increase or decrease their movements depending on water availability (Reyna-Hurtado et al. 2012; 2016). Water scarcity is leading to tapirs approaching human settlements and visiting jagüeyes and apiaries more frequently until the water runs out or when people and jaguars scare them off. With this in mind, we believe that the search and need for water associated with the increase in frequency and intensity of droughts could increase the number of cases of HTCs in the Calakmul region (Fig. 10).

Increasing conflicts between humans and wildlife is one of the main threats to the long-term survival of many species in the world (Nyhus 2016). Armillas et al. (2020) reported that areas adjacent to the CBR were the least studied in terms of HWC. This does not mean that there are fewer negative events in these areas, but on the contrary, it is evident that this theme has been ignored by researchers (Armillas et al. 2020).


**Figure 10.** Sightings of Baird's tapirs (*Tapirus bairdii*) in different ejidos of Calakmul, Campeche, Mexico: A) tapir searching for water in a jagüey B) tapir tied by local people who offered water in a bucket C) carcass of a tapir shot at the edge of a waterhole and D) female and offspring covered with mud as a consequence of water scarcity in waterholes.

Droughts are considered one of the principal factors for increasing HWCs in some developing countries in Africa and Asia (Saberwal et al. 1994; Dapash 2002, Lee and Graham 2006; Lamarque et al. 2009; Gemeda and Meles 2018). In those countries, an increase in livestock predation, attacks on humans by other animals, crop raiding, and destruction of water pipes during droughts have been documented (Gemeda and Meles 2018; Mukeka et al. 2019).

## Potential areas of human-tapir conflicts during droughts

Based on records obtained from local monitoring conducted at U20J, we identified potential areas that could increase human-tapir conflicts. Crop raiding is the most studied human-tapir conflict in Mesoamerica (Koster 2006; Waters et al. 2006; Waters 2015; Serrano-MacGregor 2017). In some ejidos of Calakmul there is a certain animosity towards tapirs, because people believe tapirs cause greater loss or damage to crops (tapirs eat between 12–15 kg daily) than small animals (López-Cen pers. obs.). This could have a negative effect on tapir's population, as they could become more susceptible to hunting or other methods of lethal control when the conflicts arise between tapirs and rural producers (Naranjo 2019). To date we do not have sufficient data to know how many tapirs have been killed in retaliation, but in several ejidos we have found tapir skulls with bullet remains (22 skulls in four years; Pérez-Flores pers. obs.). This suggests that there is still high hunting pressure on this species in the region, although it is not known whether it is for retaliation or for consumption.

Similar to the studies of Waters (2015) and Serrano-MacGregor (2017), we observed that tapirs are not the principal crop-raiders, but several farmers mentioned that tapirs fed and stepped on the crops of beans, corn and squash. Crop raiding by large herbivores increases with decreased natural forage during droughts (Weinman 2018). Crop raiding behavior exhibited by some tapirs might be related to the palatability of certain foods (e.g., beans, cabbage [*Brassica* spp.], corn, pineapple [*Ananas comosus*], plantain [*Musa paradisiaca*], potatoes [*Solanum* spp.], squash, watermelon [*Citrullus lanatus*] and yam [*Dioscorea* spp.]) rather than to a necessity to consume more nutritious forage, as we have observed that in Calakmul there is availability of different food items throughout the year (Pérez-Flores pers. obs.).

In recent years, and as a consequence of droughts, (less water for agriculture and livestock) apiculture has gained popularity in several of Calakmul's ejidos resulting in greater economic and ecological benefits. However, this activity could increase negative interactions between humans and tapirs, especially during the dry season when the highest honey production is reported (Coh-Martínez et al. 2019). This is because tapirs and other species drink the water that beekeepers place near the hives in buckets or plastic/iron drums and because they break and drop the wooden hives. For beekeepers, this represents an economic loss, which can result in beekeepers persecuting or even killing some tapirs (Pérez-Flores pers. obs.). The demand for honey in the state of Campeche (Mexico´s top ranked state for honey production; SEMARNATCAM 2013) could have serious consequences for tapir populations not only in Calakmul, but also in other municipalities (Hecelchakán, Hopelchén and Tenabo) where large quantities of honey are produced and where the presence of tapirs has been recorded (Contreras-Moreno et al. 2013; Carrillo-Reyna et al. 2015; Naranjo et al. 2015). Therefore, it is necessary to create a strategy for the adequate management of aguadas and jagüeyes that allow wildlife to always have access to water.

Historically, natural waterholes (aguadas) have represented a fundamental resource for the survival of wildlife in Calakmul (Reyna-Hurtado et al. 2010; O'Farrill et al. 2014), and in the last decades the creation of artificial water bodies in some ejidos has provided wildlife with an alternate source of water (Fig. 10A). Both types of waterbodies are sensitive to the duration of the dry season, and if climate change predictions of severe droughts persist for Yucatan Peninsula (IPCC 2007), the incidences of conflicts between humans and tapirs will become more frequent and intense as a result of competition for water. Water scarcity leads to increased incidences of ambush for tapirs and other species (e.g., peccaries *T. pecari* and *Pecari tajacu*; deer *M. pandora*, *M. temama* and *Odocoileus virginianus*; and turtles *Trachemys venusta*, *Kinosternon* spp.) (Fig. 10B). Hunters wait for their prey at the edge of waterbodies (Reyna-Hurtado et al. 2010). In some of Calakmul's ejidos there is a high hunting pressure on tapirs (Fig. 10C) and water scarcity could favor their hunting. In addition, during droughts, the size of waterholes shrinks and some of them become muddy (Fig. 10D), which could turn them into a potential health threat not only for tapirs but also for humans and other wild and domestic animals that become entrapped in them. These waterbodies are the only source of water for the local communities during the dry season (Reyna-Hurtado et al. 2010); some of the inhabitants' wash their clothes, drink, bathe at these places; and, most of the time they bring their domestic animals along (e.g., cows [*Bos taurus* × *indicus*], dogs [*Canis lupus familiaris*], goats [*Capra aegagrus*], horses [*Equus ferus caballus*], sheep [*Ovis aries*]) which generally presents additional health problems (e.g., malnutrition, ecto and endoparasites, abscesses, wounds, tumors; Pérez-Flores pers. obs.). Although there are no studies in Calakmul that demonstrate the transmission of diseases between tapirs and humans/domestic animals or vice versa, we must remember that sometimes tapirs defecate and urinate into the water. Therefore, we must be careful, since potential zoonotic diseases (leptospirosis, linguatulosis) and vector arthropods (ticks and fleas) have been documented in tapirs in this region (Pérez-Flores and González-Solís 2018; Pérez-Flores et al. 2019).

Even though road-kill is one of the main threats to tapir populations worldwide (Medici 2010), few cases of road-killed tapirs have been recorded in the last ten years in the Yucatan Peninsula (approximately 15 cases; Contreras-Moreno et al. 2013, Pérez-Flores et al. 2019). The number of road-killed tapirs may be underestimated because some cases are not reported, and people from nearby villages pick them up and eat them (Contreras-Moreno and Pérez-Flores pers. obs.). These events could increase as a result of droughts, as several of the tapirs observed during 2019 have been close to roads, probably trying to cross roads in search of sources of water.

## Strategies to cope with water scarcity

The installation of artificial troughs for wildlife has been a strategy used for many years in arid sites (Epaphras et al. 2008; Hayward and Hayward 2012). Since 2015, the Mexican National Commission of Natural Protected Areas strategically installed five artificial troughs in the CBR to cope with water shortage during the dry seasons. Further in 2018, as part of the GEF Species at Risk Project, 10 more artificial troughs were installed; and in 2019, the number of artificial troughs increased to 30 (Fig. 11A and B).

Camera-traps were placed near the drinking troughs to record the species that visited them. Several species of cryptic mammals were recorded, including tapirs, which were frequently recorded during this last dry season (2019) (Fig. 11C and D). Water is a very important issue since the lack of it, due to a decrease in rainfall, can cause death by dehydration of animals with large bodies such as jaguars, tapirs, and white-lipped peccaries (Gandiwa et al. 2016). Therefore, the use of artificial drinking troughs is a good alternative to guarantee the availability of water in the dry season (Mandujano-Rodríguez and Hernández 2019). It should be noted that water supply for wildlife is important to reduce the problem of water scarcity (Epaphras


**Figure 11.** Installation of artificial troughs in different points of the Calakmul Biosphere Reserve (CBR), Campeche, Mexico: A) digging to install the artificial trough in the CBR B) filling them manually with water C) female Baird's tapir (*Tapirus bairdii*) and calf recorded with camera trap drinking water from the trough in the CBR and D) jaguar (*Panthera onca*) recorded with camera trap drinking water on a different trough in the CBR.

et al. 2008). Because of this, artificial water sources are a good tool to address the problems brought on by droughts that affect native fauna so much. In addition to allowing some individuals to obtain water, drinking fountains make it possible for individuals from various populations to interact with each other, which could be considered a site for socialization. This strategy is currently being adopted by the ejidos, as well as NGO's working locally, so that soon, community establishment of artificial troughs can be generalized to all Calakmul, allowing wildlife access to water during the dry season.

## Human-tapir coexistence

Some ejidos have implemented lethal and non-lethal methods to mitigate HWC. Among the lethal methods are hunting with gunfire and dogs in aguadas and milpas, and poison (carbofuran and glyphosate on seeds or fruits) for birds and small mammals, methods that are extensively used in southeast Mexico (Rodríguez-Calderón et al. 2018). On the other hand, non-lethal methods used include the construction of barriers (wire fences in milpas), increased vigilance of crops and waterholes, placement of water containers (plastic or iron drums) on the periphery of the production areas (apiaries and jagüeyes), and some people spread urine or feces from different animals (carnivores) and even of themselves to scare off raiders. We do not recommend the use of lethal methods, as we believe in the balance between protection of endangered species and the needs of local communities.

## Conclusions

Human-wildlife conflicts have not been recognized as one of the main threats to Baird's tapir populations in Mesoamerica. Our proposal has a multidisciplinary vision, as the region of Calakmul has a wide diversity of customs and cultures.

We propose: **Intensified surveillance in apiaries and milpas:** this is the most successful method to reduce HWC, especially in species that fear humans (Lamarque et al. 2009). The use of watchtowers around cultivated fields has been shown to be effective with some species in Africa (Lamarque et al. 2009). A rotating guard system for patrolling at night or the use of simple alarm systems with bells or tins full of stones can also be effective (Lamarque et al. 2009). **The establishment of buffer zones around crops:** where farmers plant palatable species for wildlife consumption, thus preventing tapirs and other species from damaging or destroying fewer crops, as well as the placement of water containers around apiaries during the dry season, since these strategies will reduce damage to crops and prevent tapirs from drinking the water placed near the hives or from breaking the wooden hives. **Implementation of an advisory program** between those responsible for monitoring (NGOs, biologists, researchers, and government institutions) and the beekeepers that will allow for peaceful coexistence between tapirs and apiculturists (e. g., improvement of facilities, strategies to cope with water shortage). **A community-based strategy** in which ejidos establish voluntary conservation areas for tapirs and other species, and one which alternative economic activities such as ecotourism and scientific tourism are implemented. **Development of hunting and management agreements with local communities:** these participatory agreements will consist of prohibiting or restricting tapir hunting, especially in ejidos where hunting pressure is high. The implementation of these agreements will raise awareness among the population and allow for a gradual cultural, economic and legislative change in the long term (Oliveira and Calouro 2019). **Development and implementation of an environmental education program** in communities, schools, governmental and non-governmental institutions, and other key actors, focused on promoting knowledge about the ecological importance of tapirs, and the coexistence between tapirs and humans. **Implementation of a monitoring program of economically productive areas, natural and artificial water bodies** to establish a calendar for placing artificial troughs in the ejidos and the CBR to cope with water scarcity. **Design,**

**implement and evaluate an emergency protocol for the management, care and rehabilitation of tapirs** (healthy and unhealthy) that wander into ejidos, roads and other economically productive areas. **Implementation of routine health surveillance strategy** that includes humans, domestic and wild animals in the region so as to identify potential infectious diseases.

## Acknowledgements

For his invaluable help in the field, we thank C. López-Díaz. Special thanks to SEYBA AC, N. Arias-Domínguez, E. Hernández-Pérez, M. Álvaro-Méndez, J. Figueroa-Nahuath for sharing photographic material. We are very grateful to the authorities of Union 20 de Junio and authorities of the Calakmul Biosphere Reserve for their support in this research. Thanks to project 00092169 "Fortalecimiento del manejo del Sistema de Áreas Protegidas para mejorar la conservación de especies en riesgo y sus hábitats ", implemented by the United Nations Development Program (UNDP), executed by the National Commission of Protected Natural Areas and financed by the Global Environment Facility. Special thanks to the WWF's Project "Salvando al jaguar: embajador de América" for the contribution of data collected in the study area. The map was produced by H. Weissenberger. JPF was supported by a scholarship (361517) granted by the Mexican government through CONACYT.

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