THERYA, 2020, Vol. 11 (2): 213-220 DOI: 10.12933/therya-20-878 ISSN 2007-3364

Peccaries and their relationship with water availability and their predators in Calakmul, México

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A reduction in the frequency of rainfall and an increase in drought periods, as a consequence of climatic change, has caused the desiccation of water ponds (locally known as "aguadas") in the Calakmul region. The objective of this study was to determine if the abundance and distribution of the white-lipped peccary, *Tayassu pecari,* and the collared peccary, *Pecari tajacu,* in the ponds of the Calakmul Biosphere Reserve, a tropical forest in Southern México, are related to water availability and to the presence of their predators throughout five years of study. Using photo-trapping technique, 12 aguadas were monitored. The index of abundance of photographic records and the activity patterns were estimated, and the presence of both species of peccaries was related through linear and logarithmic regressions with the availability of water and their predators (pumas and jaguars). The abundance and presence of the white-lipped peccary and the jaguar were directly related to decreasing water availability, while water was not a determining factor for the presence of the collared peccary and the puma. The decrease in the availability of water in the aguadas of the reserve has become a serious threat to the white-lipped peccary, one that, when coupled with other threats such as hunting and fragmentation of their habitat in the communities surrounding the reserve, will increase the risk of extinction of these populations, that at least for the white-lipped peccary, is the most important in Mesoamerica.

La reducción en la precipitación y el aumento de los periodos de sequía, como consecuencia del cambio climático, ha ocasionado la desecación de las aguadas en la región de Calakmul. El objetivo de este estudio consistió en determinar cómo la abundancia y la distribución del pecarí de labio blanco *Tayassu pecari* y el pecarí de collar *Pecari tajacu* en las aguadas de la Reserva de la Biosfera Calakmul se relacionan con la disponibilidad de agua y con la presencia de sus depredadores a lo largo de cinco años de estudio. A través de la técnica de fototrampeo 12 aguadas fueron monitoreadas. Se estimó el índice de abundancia de registros fotográficos, los patrones de actividad y se relacionó a través de regresiones lineales y logarítmicas la presencia de ambas especies de pecaríes con la disponibilidad de agua y con sus depredadores (pumas y jaguares). La abundancia y presencia del pecarí de labio blanco y del jaguar, se relacionaron directamente con la disminución de la disponibilidad de agua, mientras que, para el pecarí de collar y el puma, el agua no fue un factor determinante para su presencia. La disminución en la disponibilidad de agua en las aguadas de la Reserva se ha convertido en una fuerte amenaza para el pecarí de labio blanco, aunado a otras amenazas como la cacería y la fragmentación de su hábitat en las comunidades aledañas a la reserva, que ponen en riesgo a esta población considerada la más importante de Mesoamérica.

Key words: climatic change; jaguars; photo-trapping; pumas; Tayassuidae.

Introduction

Calakmul Biosphere Reserve (CBR) located in southern México is the largest protected tropical forest in México (Garcia-Gil *et al.* 1999) and conserves a great diversity of wildlife, including more than 250 species of birds, 150 species of mammals, and 30 species of reptiles and amphibians (Galindo-Leal 1999). In the CBR there are not major water bodies, and all the water that falls by precipitation accumulates in some specific sites known locally as "aguadas." These sites are the only source of water for wildlife and human communities during the dry season (Reyna-Hurtado *et al.* 2010). In the last years, and as a consequence of climate change, the precipitation has reduced and the dry periods have extended, which has caused the desiccation and disappearing of several of these water bodies, especially in the south part of the CBR (Mardero *et al.* 2012; Zúñiga-Morales and Sima-Panti 2015).

This phenomenon may possibly be causing changes in the spatial and temporal patterns of the species associated with the ponds (Reyna-Hurtado *et al.* 2012). O'Farrill *et al.* (2014) estimated that a possible response of the animals to the pond disappearing phenomenon would be the migration to more humid areas, such as the communal forest adjacent to the protected area, which would reduce the conservation value of the CBR.

In the CBR there are two species of peccaries, the white-lipped peccary (*Tayassu pecari)* and the collared peccary (*Pecari tajacu*). For these species, the presence of water is an essential component of their habitat as they drink water and wallow in the mud as a heat refreshing strategy and to avoid ectoparasites (Sowls 1997; Reyna-Hurtado *et al.* 2014; Beck *et al.* 2017; Reyna-Hurtado *et al.* 2017). Water availability has been described as the most important element of the landscape for white-lipped peccary and is the

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axis of the group's movements in sites where water is not uniformly distributed in time and space (Reyna-Hurtado *et al.* 2009, 2012).

The collared peccary is different than white-lipped peccary as it can also inhabit dry areas and has developed ecological strategies to cope with water scarcity (Sowls 1997; Reyna-Hurtado *et al.* 2014). However, in tropical forests, both collared peccary density and distribution have been related to the presence of water bodies, indicating the importance of these pieces of the landscape for peccary survival (Hernández 2013; García-Marmolejo *et al.* 2015).

Water is an essential component of the peccary habitat and is associated with their presence and abundance. It is probable that the reduction and disappearance of these water bodies in the CBR is having an impact on the distribution patterns of both species, as well as their relationships (increase in competition) and their interaction with predators. Peccaries are two of the more important preys species in the diet of jaguars (*Panthera onca*) and pumas (*Puma concolor*; Aranda 1994; Amín 2004; Moreno 2008). Therefore, the abundance of peccaries in ponds may also affect the presence and use of ponds by these felines.

Climate change scenarios for the Calakmul region predict an even larger reduction in precipitation in the coming years (Magrin *et al.* 2007). Therefore, to describe and understand the preset relationships among species in tropical forests and how they adapt to changes in the environment is essential to promote management of conservation actions. The objective of this study consisted of determining, over five years, the relationships among the abundance and spatial distribution of the two species of peccaries with variation in water availability in the ponds of the CBR and with the presence and abundance of their two main predators species. It is predicted that the white-lipped peccary will be more associated with the ponds than the collared peccary, and that a reduction of water availability will affect the abundance and visitation rate of the white-lipped peccary. It is also expected that white-lipped peccary will co-occur more frequently with jaguars than with pumas; while at the same time, puma and collared peccary will co-occur more often than jaguar – collared peccary (Aranda 1994; Aranda and Sanchez Cordero 1996; Foster *et al.* 2010).

Methods and Materials

Study Site. Calakmul Biosphere Reserve is located in the Calakmul municipality in Campeche State, Southern México. It is located between 18° 40' 7.7" N, -89° 12' 34.3" W (Figure 1). It was established in 1989 and protects the largest tropical forest in México with an area of 7,231 km^2 (Morales and Magaña 2001). The climate is calid sub-humid with an annual temperature of 24.6 ℃ and with an annual precipitation average between 1,200 to 2,000 mm (García 1988). In the last 50 years the annual precipitation has decreased 16 % and 30 % during the dry and wet season with respect to the average from 1980 to 1999 (Bárcena *et al.* 2010). In addition to this, the number of days without rain is longer in the region each time; since 1986 the rainy and very rainy years have become less frequent and the dry periods have increased in recent years (Mardero *et al.* 2012).

The area is flat with rolling hills and altitude is between 250 to 340 masl. The predominant vegetation type is tropical humid forest classified in 1) Medium sub-perennial forest, 2) Low-flooded forest, 3) Low-tropical forest, and 4) Secondary vegetation. (Pennington and Sarukhán 1998).

Data collection. From January 2014 to December 2018, 12 ponds were monitored with the technique of photo-trapping in the Southern zone of the CBR (Figure 1). Of these ponds only nine were monitored in 2014, 10 in 2015, and 12 from 2016 to 2018. The name of the ponds were: Aguada2, Aguada4, Baños, Bonfil, Calakmul, Corriente, Dos Aguadas, Griselda, Km20, Km46, Nico, and Verde. The distance among ponds varied between 0.7 to 3.7 km and in each pond a single camera was set (Reconyx PC600 and PC800). The cameras were attached to a tree near to the pond, at approximately 50 cm from the ground facing the ponds and they were active 24 hours. The cameras stayed there all year long and were only visited to change memory cards and batteries. The records were entered in a database where the following information was recorded: site, date, hour, time that the recording lasted (in minutes), and the number of individuals.

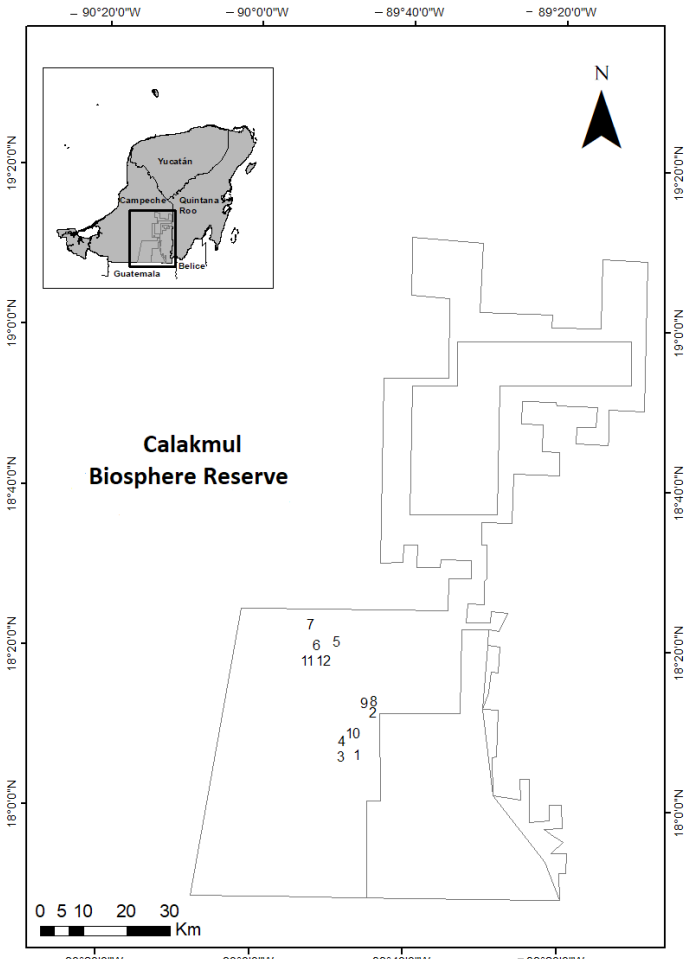

Figure 1. Map of ponds monitored in Calakmul Biosphere Reserve: 1. Baños; 2. Bonfil; 3. Calakmul; 4. Corriente; 5. Dos Aguadas; 6. Griselda; 7. Km 20; 8. Km 46; 9. Nico; 10. Verde; 11. Aguada4 y 12. Aguada2.

Pond visitation records. An abundance index (AI) of photographic records was estimated for the two species with the following equation: AI = N / SE * 1000 trap-days. Where N = Records number, SE = Sampling efforts (number of cameras deployed by the days the cameras were working in the field) multiplied by 1,000 (standard units). Given that peccaries visited and spent time in the ponds (Reyna-Hurtado *et al.* 2009), a one-hour filter was considered among consecutive sequences of photos of a group of peccaries to consider a record independent. This index was used to compare frequency of visits between the two species and among years, seasons (rainy and dry), and ponds.

For each species we ran non-parametric Kruskal Wallis tests followed by a Dunn post-hoc test to compare AI among ponds and years. Mann-Whitney non-parametric tests were also applied to compare abundance between the two seasons (Rohlf and Sokal 1981).

Activity patterns. To estimate activity patterns (AP) of the white-lipped peccary and collared peccary, the records were grouped per species and per two-hour intervals. These intervals were represented in a circular scale where the average angle and the dispersion of the values were estimated through the software Oriana 4.01 (Kovach 1994). Using Kernel estimators the proportion of overlap of activity patterns between the two species was also estimated (overlap coefficient) for the five year period with the tool "Overlap" in R (R Core Team 2018, R Studio ver. 1.1.463). The estimator *Δ4* was used as it is recommend for samples > 75 (Meredith and Rideout 2016). The interval of confidence (CI) between the upper and lower 95 % limit of the overlap estimation of the activity of the two species was calculated through percentages based in 1000 samples (Ridout and Linkie 2009).

Occurrence and Co-occurrence between peccaries and their predators. To test the occurrence and co-occurrence between the two peccaries and then with their predators, the independent records of the species were used. The percentage of occurrence in each pond and each year of each pair of species were calculated. Then, as a more detailed way to estimate co-occurrence, all records of co-occurrence of any pair of species in intervals of 1, 12, and 24 hours were recorded. Additionally, linear regression analyses were performed between the number of visits of the two species of peccaries and the number of visits of jaguars and pumas to test if the presence of peccaries was related to the presence of predators in the ponds.

Relationships between water availability and peccaries and their predators presence. Logistical regressions were performed to relate water availability (presence/absence) and its variation along the five years with the presence of the four species. Presence/absence of water was recorded using the photographic records and visits to change memories and batteries, and a matrix was built of each pond's water availability and the number of records obtained monthly of each species. The linear simple regression analyses and logistical regression analyses were done in R (R Core Team 2018; R Studio ver. 1.1.463) and were considered significant with a $P < 0.05$.

Results

Pond visitation abundance index. In total, the sampling effort was 13,744 camera-trap days. The AI for white-lipped peccary was 20.51 records/1,000 trap-days. The abundance during the dry season (22.88 records/1,000 trap-days) was higher than in the rainy season (18.35 records/1,000 trap-days) but the difference was not significant (W = 66.5, P = 0.77). However, when comparing AI across years there were statistically significant differences (H = 22.53, P = < 0.01). In 2018 there were no records of the species at all, making this year different from the rest of the years (2014, 2015, 2016 and 2017; P = < 0.05). The AI of the white-lipped peccary among ponds was also different and the differences were significant (H = 19.35, P = 0.04). The 67.73 % of the records of white-lipped peccary occurred in four ponds: Aguada4, Corriente, Calakmul, and Griselda, and the AI of these were different than the AI from Baños, Bonfil, Dos Aguadas, and Km46 (P < 0.05; Figure 2a). The ponds most visited by white-lipped peccary in 2014 were Calakmul and Griselda, in 2015 Corriente and Km20, in 2016 Calakmul and Griselda, and in 2017 Aguada4 and Corriente.

For the collared peccary the AI was 32.15 (records/1,000 trap-days), and in the dry season of 31.27 (records/1,000 trap days) that was very similar to the rainy season AI of 32.96 (records/1,000 trap-days) with no statistically significant differences (W = 64, P = 0.67). Similarly, there were no differences in the AI among years for collared peccary (H = 1.98, P = 0.73). However, when comparing AI of ponds, there were significant differences (H = 29.23, P = 0.002), with 69.45 % of the collared peccary records occurring in the following ponds: Baños, Dos Aguadas, Km20, and Verde, which had a statistically significant difference from Aguada4, Bonfil, Corriente, Calakmul, and Griselda (P < 0.05; Figure 2b). The most visited ponds for the collared peccary were Dos Aguadas in 2014; Baños in 2015; Baños and Km20 in 2016; Baños and Km20 in 2017; and Dos Aguadas in 2018.

Activity patterns. The white-lipped peccary and collared peccary were mainly diurnal species when visiting the ponds (6:00 to 18:00 h). The WLP concentrate their activity between 10:00 and 12:00 h (μ: 11.06), while collared peccary were more active from 6:00 to 10:00 h (μ = 9.17) and decrease their activity considerably after midday. However, a great degree of overlap was obtained among the activity patterns between the two species during the five years of study Δ = 0.79 (CI 95 % 0.69 to 0.83; Figure 3).

Occurrence and Co-occurrence among peccaries and their predators. The white-lipped peccary and collared peccary were recorded in all ponds sampled, however, their presence varied with the years, with the CP being higher than the white-lipped peccary in four of the five years of study. The rate of co-occurrence varied among years as well. Considering only the ponds and the times where the white-lipped peccary were present, the co-occurrence was higher than in ponds where the collared peccary was only present (Table 1). Ten records of co-occurrence were obtained between the two species in a period of time less than 24

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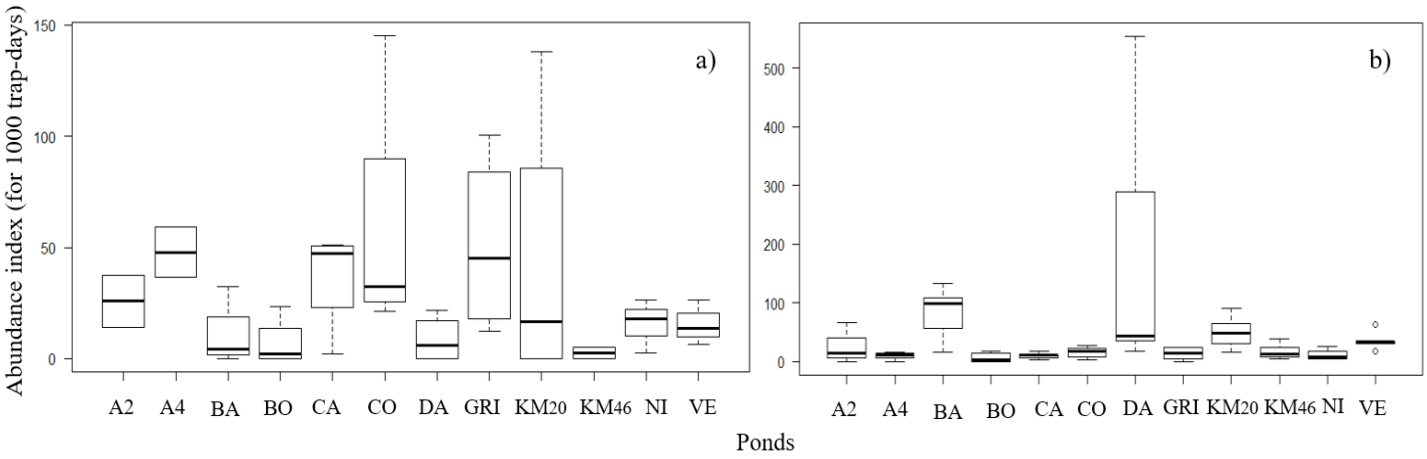

Figure 2. Pond visitation abundance index of *Tayassu pecari* a) and *Pecari tajacu* b) in Calakmul Biosphere Reserve (2014-2018): Baños (Ba); Bonfil (Bo); Calakmul (Ca); Corriente (Co); Dos Aguadas (DA); Griselda (Gri); Km 20; Km 46; Nico (Ni); Verde (Ve); Aguada4 (A4) and Aguada2 (A2).

hours and in all cases the white-lipped peccary preceded the collared peccary.

Peccaries and jaguar. The co-occurrence in ponds between jaguar and white-lipped peccary was higher in general than between jaguar and collared peccary, except for 2018 where there were not records of white-lipped peccary and the co-occurrence between jaguar and collared peccary increased (Table 2). In the same way, the percentage of occurrence in jaguars in ponds with only white-lipped peccary presence were higher in four years of sampling than in ponds with only collared peccary presence. Nineteen records of co-occurrence between jaguar and white-lipped peccary within 24 hours periods were recorded and in 13 of these cases the jaguar preceded white-lipped peccary and in six cases the white-lipped peccary preceded jaguar. The higher numbers of records were obtained in 2014 and 2015. Between jaguar and collared peccary, 12 records of co-occurrence were obtained and in seven of these cases the jaguar preceded collared peccary and in five the collared peccary preceded jaguars. The regression analyses indicated a significant relationship between jaguar and white-lipped peccary along all years (t = 2.594, P = 0.0106) but not between jaguar and the collared peccary (t = -0.467, P = 0.6451).

Peccaries-Puma. The percentage of co-occurrence between puma and collared peccary was higher than between puma and white-lipped peccary for all years and the same as in ponds with only records of one species of peccaries (Table 3). Ten records of co-occurrence within 24 hours between puma and white-lipped peccary were obtained and in seven the puma preceded white-lipped peccary and in five white-lipped peccary preceded puma. For 44 records of co-occurrence among puma and collared peccary, in 19 the puma preceded collared peccary and in 25 collared peccary preceded puma. Linear regression analyses showed a significant relationship between CP and puma presence in the ponds (t = 3.002, P = 0.003), but not between puma and white-lipped peccary (t = -0.45, P = 0.9643).

Relationship between water availability and peccaries and their predators presence. Water availability varied significantly among the five years of study. In 2014, 90 % of the ponds presented water in the dry season. In 2015 only 30 % of them had water in the dry season and in 2016 and 2017 only 25 % had water. In 2018, 50 % of the ponds had water during the dry season. However, in August 2018 all ponds were dry and remained dry to the end of the study in December 2018.

Table 1. Occurrence and co-occurrence of *Tayassu pecari* (WLP) and *Pecari tajacu* (CP) in the ponds of Calakmul Biosphere Reserve.

Year	WLP Occurrence rate	CP Occurrence rate	Global Co-occurrence	Ponds with WLP presence	Ponds with CP presence
2014	88.9 %	100 %	88.8 %	100 %	88.8 %
2015	88.9 %	100 %	80.0 %	100 %	80.0 %
2016	83.3 %	75 %	58.3 %	70 %	77.7 %
2017	67.0 %	100 %	66.6 %	100 %	66.6 %
2018	0 %	83.3 %	-	-	-

Global co-occurrence (% of ponds where both species were present). Co-occurrence only in ponds where WLP was present. Co-occurrence only in ponds where CP was present.

Table 2. Co-occurrence of *Panthera onca* (jaguar) and *Tayassu pecari* (WLP) / *Pecari tajacu* (CP) on the ponds of Calakmul Biosphere Reserve.

Year	WLP Global Co-occurrence	CP Global Co-occurrence	Ponds only with WLP presence	Ponds only with CP presence
2014	77.7 %	77.7 %	87.5 %	77.7 %
2015	90.0 %	90.0 %	100 %	90.0 %
2016	91.6 %	66.6 %	100 %	88.8 %
2017	83.3 %	66.6 %	87.5 %	66.6 %
2018	-	83.3 %	-	90.0 %

Global co-occurrence (% of co-occurrence in ponds where both species were present). Co-occurrence only in ponds where WLP was present. Co-occurrence only in ponds where CP was present.

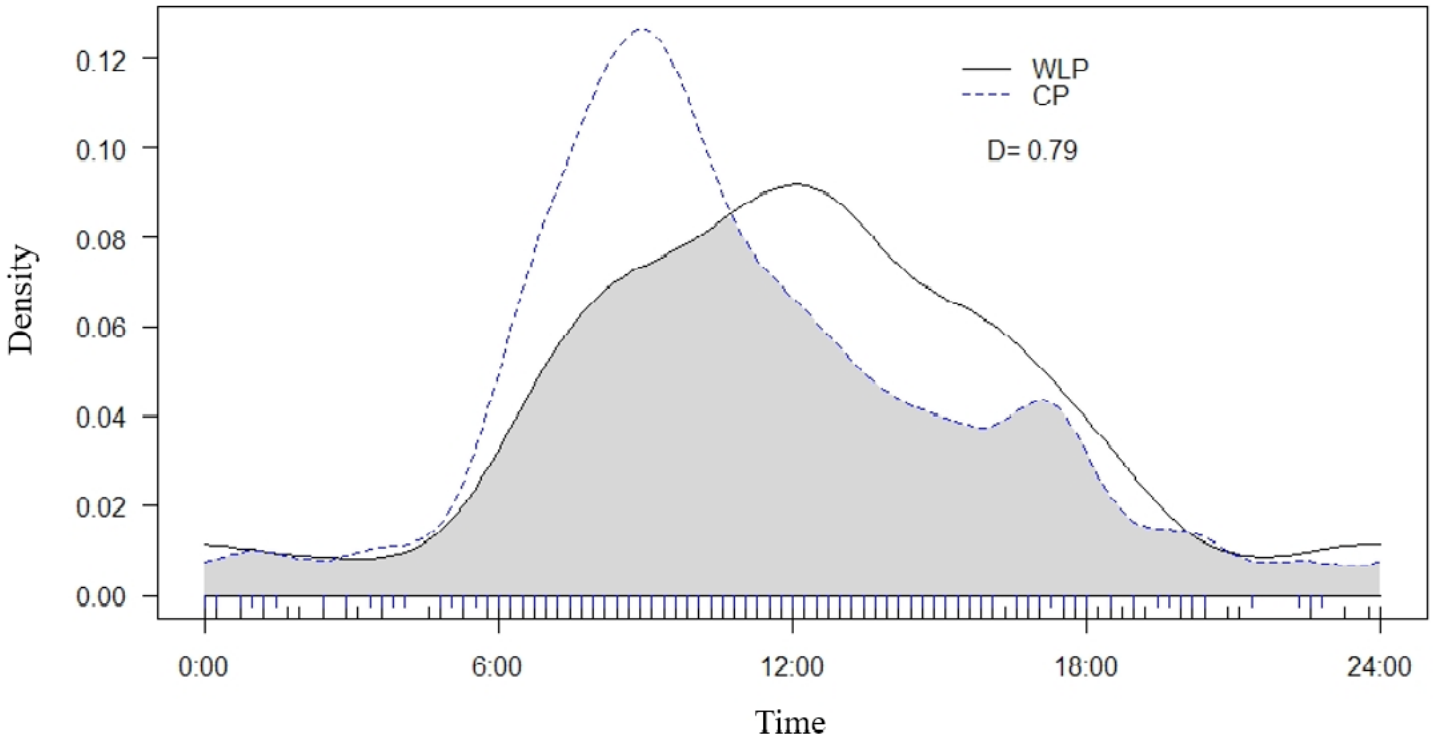

Figure 3. Proportion of overlap (D: overlap coefficient) between the activity patterns of *Tayassu pecari* (WLP, solid line) y *Pecari tajacu* (CP, pointed line) on Calakmul Biosphere Reserve.

Logistic regression analyses indicated a significant relationship between white-lipped peccary and water availability ($z = 2.817$, $P = 0.004$) as well as jaguar and water availability ($z = 2.504$, $P = 0.0123$) while a negative relationship was found among puma and water availability ($z = -3.457$ $P = > 0.001$), and for the collared peccary the water availability was not a factor that determined its presence ($z = 1.152$, $P = 0.249$).

Discussion

Use of ponds. The reduction of water availability and, consequently, desiccation of water bodies in CBR during the five years of study was directly related to the abundance and distribution of white-lipped peccary. In the first year of study the highest abundance of white-lipped peccary was obtained and the activity was centered around the ponds that conserved water. It has been reported through radiotelemetry studies that white-lipped peccary concentrate their home ranges during the dry season around water bodies, while during the rainy season they are more mobile and move long distances (Fragoso 1998; Reyna-Hurtado *et al.* 2009). In 2017 when the rainy season started, all ponds were dry due to a previous bad season, and that was the last time that white-lipped peccary was recorded in ponds. In 2018, there was not a single record of the species in any pond. White-lipped peccary have the ability to move long distances in a single day, making it probable that the species moved to wetter areas looking for water, even leaving the protected areas. This has been described previously for groups followed by radiotelemetry in the same study area (Reyna-Hurtado *et al.* 2009).

Table 3. Co-occurrence of *Puma concolor* (puma) and *Tayassu pecari* (WLP)/ *Pecari tajacu* (CP) on the ponds of Calakmul Biosphere Reserve .

Year	WLP Global Co-occurrence	CP Global Co-occurrence	Ponds with WLP presence	Ponds with CP presence
2014	77.7 %	88.8 %	87.5 %	88.8 %
2015	80.0 %	100 %	100 %	100 %
2016	83.3 %	83.3 %	88.8 %	88.8 %
2017	41.6 %	91.6 %	87.5 %	91.6 %
2018	-	91.6 %	-	100 %

Global co-occurrence (% of ponds where both species were present). Co-occurrence only in ponds where WLP was present. Co-occurrence only in ponds where CP was present.

For the collared peccary, water availability did not have a significant effect on its presence or abundance. This species concentrated its activity in four specific ponds, which remained dry most of the time and were less visited by the white-lipped peccary. The occurrence rate and abundance of the species in these ponds were higher for CP than white-lipped peccary in these ponds. Collared peccary was present in all ponds in three out of five years of study, while the white-lipped peccary showed a decreasing trend through the years. However, the abundance of collared peccary in ponds where the white-lipped peccary was present was very low and most of the visits occurred when white-lipped peccary were absent. In the co-occurrence events that took place within 12 and 24 hours in these ponds the white-lipped peccary always preceded the collared peccary. However, when white-lipped peccary arrived at some ponds, collared peccary did not visit these sites again. In 2017

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and 2018 the records of white-lipped peccary decreased or even disappeared, then CP increased its records even in ponds with water that were not used when white-lipped peccary was present. All these facts suggest a possible differentiation in the use of ponds by the two species and a dominance of white-lipped peccary over collared peccary when both species co-occur as it has been described before (Sowls 1997; Fragoso 1999; Keuroghlian *et al.* 2004).

Due to the increase of the dry periods in the Calakmul region and the consequent decrease of water availability, it is highly probable that the competition between the two species of peccaries will increase (Abrams and Chen 2002). Given the large body of the white-lipped peccary and the fact that it forms larger groups than collared peccary, white-lipped peccary it is a dominant species. Therefore, it is probable that the differential use by the two species as described in this study is a behavior to avoid coinciding in the ponds. The CP avoid some ponds, and the white-lipped peccary, as the dominant species, decreased the collared peccary access to the water forcing them to use ponds with less water or no water at all. In a study among elephants and other herbivores, access to water bodies a similar behavior was observed where elephant's presence and distribution affected the presence and distribution of other species (Valeix *et al.* 2007). Despite the strategies that peccaries have developed to coexist, water availability may be a resource that is causing temporal competition among white-lipped peccary and collared peccary (Sowls 1997).

The white-lipped peccary and collared peccary visited the ponds mostly during the day and there were very few nocturnal records. The same pattern has been reported in Mirador-Río Azul National Park in Guatemala (Moreira-Ramírez *et al.* 20155) and Laguna del Tigre National Park (Moreira-Ramírez *et al.* 2016) and in the Calakmul region (Briceño-Méndez *et al.* 2016). A large degree of overlap was detected between the two species, although the activity peak time was not the same (white-lipped peccary: 10:00 to14:00 h; collared peccary: 6:00 to10:00 h). The difference may have occurred because white-lipped peccary used ponds with water during the hottest hour of the day to refresh and drink (Sowls 1997). Conversely, collared peccary visited ponds with less water or no water at all and not during the hottest time of the day. These findings coincide with the fact that collared peccary is a common inhabitant of arid zones such as Texas or New México in the USA and have physiological characteristics that favor the heat dissipation and prevent dehydration as reducing water by evotranspiration or reducing urine disposal (Zervanos and Day 1977; Hellgren and Bissonette 1984; Sowls 1997).

Occurrence and co-occurrence among peccaries and their predators. When the presence of the four species (collared peccary, white-lipped peccary, jaguar and puma) were analyzed, it was found that the jaguar significantly associated with white-lipped peccary, which is considered one of the jaguar's main prey (Aranda 1994; Hernández 2008). It is highly probable that jaguars use these sites as a hunting grounds due to the frequency of visits by white-lipped peccary. Despite these significant relationships, when the co-occurrence events were analyzed, the majority of these occurred within one month and very few within a 24-hour period. Therefore, it is probable that the presence of both species is due to the fact that there is water in the ponds and that there may be more prey diversity and abundance around the ponds, among them the white-lipped peccary (Martínez-Ku *et al.* 2008).

To the contrary, puma presence was associated to collared peccary. Previous studies indicate that in places where jaguars and pumas co-exist there is an evolutionary advantage of jaguars and the two species segregated to coexist (Foster *et al.* 2013). Puma is a more adaptable species than jaguars and can survive in dry areas. Therefore, water availability is not a determining factor for its presence, rather prey availability and distribution. The ponds where collared peccary distributed are dry ponds that are also visited frequently by deer (Ramírez-Ortiz 2016). The puma presence in these ponds could be also a consequence of deer presence as well as collared peccary in these ponds. Both are highly prized preys of pumas (Aranda and Sanchez Cordero 1996; Hernández 2008).

This study demonstrated that peccaries are sensible to water availability variation, to the presence of the other species, and to the presence of their predators in Calakmul region. The disappearance of white-lipped peccary in the 2017 rainy season and all of 2018 indicate that the groups displaced to wet areas as predicted before by O'Farrill *et al.* (2014), or there was a massive mortality as it was evidenced in 2017 when several individuals of the species were found dead in less than one month in the study site (Reyna-Hurtado pers. obs.). Due to the rapid effects of climate change and the prediction of more dry periods (IPCC 2007) it is possible that species such as white-lipped peccary or jaguar will move to the reserve borders or even leave the protected area. Therefore, it is crucial to continue monitoring the species and its response to elaborate conservation strategies that conserve the two peccaries species and their predators of this changing ecosystem of Calakmul Biosphere Reserve.

Acknowledgements

We appreciate the resources of El Colegio de la Frontera Sur (ECOSUR) Campeche, and a grant to KSP number 470731 form CONACYT (Mexican National Council of Science for its Spanish initials). To the Calakmul Biosphere Reserve authority by al, the help provided in the field. We appreciate the essential help and knowledge provided by N. Arias in the field. This study was funded by a grant to RRH (182386 CONACYT Ciencia Básica 2012).

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Associated editor: Robert Owen
Submitted: July 18, 2019; Reviewed: August 15, 2019;
Accepted: January 22, 2020; Published on line: April 7, 2020.