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Conservation

Baird´s tapir: predicting patterns of crop damage surrounding the Calakmul Biosphere Reserve, Campeche, Mexico

Tapir centroamericano: prediciendo patrones de daños a los cultivos alrededor de la Reserva de la Biosfera Calakmul, México

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Abstract

Baird´s tapir has been documented to cause little crop damage. However, the damage they do cause has led farmers to hunt them to prevent them from entering their fields. This study aims to identify damage caused by Baird´s tapir in crops in rural communities surrounding the Calakmul Biosphere Reserve, as well to analyze variables influencing crop damage. Ecological and agricultural variables, as well as those related to crop protection measures, were examined. In order to measure the ecological variables, habitat and availability of wild fruit were characterized along transects. Agricultural variables and crop protection measures were measured through a questionnaire. In all study communities, tapirs were found to damage crops (an average of 14% of all crops among the 4 communities). The variables "number of farmers who cultivate beans" and "number of farmers applying other protective measures"were positively correlated with "percentage of crop damage". Generalized linear models showed that "number of farmers who cultivate beans" was the variable that best explained crop damage by the tapir. This study addresses the interaction between farmers and tapirs, providing information that could help explain crop damage caused by this mammal surrounding the Calakmul Biosphere Reserve.

Keywords: Crop damage; Relative abundance; Generalized linear models; Crops; Ungulates

Resumen

Se ha documentado que el tapir centroamericano causa pocos daños a los cultivos, sin embargo, los tapires han sido cazados de manera preventiva antes de entrar a los cultivos. Consecuentemente, este estudio tiene como objetivo conocer el daño causado por tapires en cultivos alrededor de la Reserva de la Biosfera Calakmul, así como analizar variables que influyen en el daño a los cultivos. Se examinaron variables ecológicas, agrícolas y medidas de protección. Las variables ecológicas se obtuvieron recorriendo transectos en los cuales se caracterizó el hábitat y disponibilidad

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de frutos. Las variables agrícolas y medidas de protección se obtuvieron por medio de cuestionarios. En general, el promedio total de daño causado por el tapir en las cuatro comunidades fue de 14%. Los agricultores que cultivan frijol y los que aplican medidas de protección se correlacionaron positivamente con los daños a los cultivos. Los modelos lineales generalizados mostraron que la variable que explica mejor los daños a los cultivos por el tapir fueron los agricultores que cultivan frijol. Este estudio resalta la interacción entre los agricultores y el tapir aportando información de diversos patrones que podrían explicar los daños causados a la agricultura por este mamífero en Calakmul.

Palabras clave: Daños en los cultivos; Abundancia relativa; Modelos lineales generalizados; Cultivos; Ungulados

Introduction

A variety of wildlife species are responsible for crop damage in different parts of the world (Songhurst & Coulson, 2014). Threats to wildlife have increased as human settlements have increased in size and number near areas with populations of wildlife, many of which have been designated natural protected areas in recent decades (Hegel et al., 2009; Linnell et al., 1999; Sitati et al., 2003). As a result, farmers face the need to reduce crop damage caused by wildlife (Osborn & Hill, 2005).

Many wildlife species cause crop damage — particularly birds and mammals (González, 2003; Romero-Balderas et al., 2006; Songhurst & Coulson, 2014). Large mammals generally require extensive areas as they must consume large amounts of food and water in order to meet their physiological needs (Songhurst & Coulson, 2014; Sukumar, 1990).

Studies in Latin America have reported crop damage caused by medium-sized and large mammals such as the brown agouti (*Dasyprocta variegata*), the paca (*Cuniculus paca*), the tayra (*Eira barbara*), the capybara (*Hydrochaeris hydrochaeris*), tapirs (*Tapirus terrestris* and *T. bairdii*), and peccaries (*Tayassu pecari* and *Pecari tajacu*; Naugthon-Treves et al., 2003; Pérez & Pacheco, 2006; Waters, 2015).

In Mexico, studies have reported crop damage by wild vertebrates such as the peccary (*Pecari tajacu*), the raccoon (*Procyon lotor*), the white-tailed deer (*Odocoileus virginianus*), and the badger (*Nasua narica*; De la Cruz, 2003; Gallegos et al., 2004; Romero-Balderas et al., 2006). In the state of Campeche, tapirs have been hunted with the intention to prevent crop damage (Reyna-Hurtado & Tanner, 2007).

Tapirs have been reported to damage crops grown for family subsistence in many parts of their geographical range (Waters et al., 2006). For example, in Colombia mountain tapirs (*Tapirus pinchaque*) have been found to damage crops (Suárez & Lizcano, 2002). In the Peruvian Amazon the lowland tapir (*Tapirus terrestris*) has caused crop damage in rural communities surrounding a national park (Naughton-Treves et al., 2003). In Belize Baird´s tapir has been reported to cause crop damage (Waters, 2015) .

Baird´s tapir —the largest land mammal in the Neotropics (Tobler, 2002)— is in danger of extinction throughout its distribution due to hunting and habitat loss (Semarnat, 2002; IUCN, 2010). High-quality habitat for tapirs is characterized by a high density of permanent water sources; dense, diverse understory which favors abundance of food; large areas of riparian vegetation; a low rate of wildfire occurrence; and little human presence (Muench, 2001; Naranjo, 2002, 2009; Tobler et al., 2006). Studies by Fragoso (1983, 1991) have reported that the tapir frequently visits and feeds on cornfields. While in most cases little crop damage has been reported (Naranjo, 2002, peasants often illegally hunt tapirs to prevent them from crop raiding (R. Reyna-Hurtado, M. San Vicente, N. Arias and S. Calme, personal communication).

Studies of wild animals that damage crops have allowed for identifying variables that may predict which crops will be damaged. The main predictive variables identified by previous studies are crop size and location in relation to water availability and protected natural areas, and densities of wildlife that cause crop damage (Hill, 2000; Karanth et al., 2013; Naughton-Treves, 1998; Osborn & Hill, 2005; Saj et al., 2001; Songhurst & Coulson, 2014). Other factors also influence the degree of crop damage, such as type of crop, its seasonality, level of maintenance, whether or not the crop is isolated from other crops, human density, and level of hunting (Hill, 2000; Naughton-Treves, 1998; Newmark et al., 1994; Songhurst & Coulson, 2014).

Given that threats to wildlife by farmers, and vice versa, is influenced by the landscape. It is important to investigate the location and geographic features surrounding the crops. For example, a study by Naughton-Treves (1998) in communities surrounding the Kibale National Park in Uganda found that the most vulnerable crops are those grown in smaller fields adjacent to forests, and those maintaining a narrow strip of a bait crop can absorb most damage caused by wildlife. This study recommends establishment of control measures such as crop surveillance and planting less palatable crops on the borders of the fields.

In the present research we evaluated perceived crop damage due to Baird´s tapir by applying questionnaires in 4 communities surrounding the Calakmul Biosphere Reserve (CBR) in 2016 and we estimated the relative abundance of tapirs by walking several transects. We also examined the way in which the ecological and agricultural variables, as well as the variables related to crop protection measures influence crop damage by Baird´s tapir. Less crop damage is expected when communities have a greater relative abundance of tapirs as well as well-preserved forests given availability of wild fruit.

Material and methods

The present study was conducted in the peasant communities 20 de Junio, Nuevo Becal, Zoh Lagoon, and 20 de Noviembre, bordering the CBR (Fig. 1). The village 20 de Junio has a population of 449 inhabitants, most of whom are originally from the state of Chiapas, and an area of 60 km^2 (INEGI, 2011). Nuevo Becal has a population of 420 inhabitants, mostly from Tabasco and Veracruz, and an area of 530 km^2 (INEGI, 2011). Zoh Lagoon has a population of 1,074 inhabitants originally from Chiapas and other municipalities of Campeche, and an area of 240 km^2 (INEGI, 2011). Finally, 20 de Noviembre has a population of 418 inhabitants, from the northern region of Campeche, and an area is 290 km^2 (INEGI, 2011). Most of the inhabitants from Chiapas and Campeche are of Mayan descent. Data was gathered from 4 study sites: the rural communities 20 de Junio, Nuevo Becal, Zoh Lagoon, and 20 de Noviembre. These sites were chosen based on *1)* evidence of crop damage by tapirs (R. Reyna-Hurtado, M. San Vicente, N. Arias and S. Calme, personal communication), *2)* existence of large areas of unfragmentated habitat, and *3)* proximity to the CBR.

Additionally, these communities were selected based on reports of tapirs causing crop damage, the practice of hunting wild animals for self-subsistence, and existence of relatively well-conserved forests (Reyna-Hurtado & Tanner, 2005; Santos-Fita et al., 2012). One or more of the following vegetation types are found in the study sites: *1)* medium semi-evergreen forest, consisting of trees measuring 15-25 m in height, 25% of which lose their leaves during the dry season; *2)* semi-evergreen flooded lowland forest, with the majority of trees measuring less than 15 m in height; *3)* low deciduous forest with trees less than 15 m in height, 75-100% of which lose their leaves during the dry season, and *4)* secondary vegetation, which results from original vegetation having been eliminated due to anthropogenic activities and/or natural phenomena (Pennington & Sarukhan, 1998).

The majority of residents of these communities are farmers who harvest corn, beans, sweet potatoes, and squash for family subsistence. Other economic activities include harvesting chilies and black pepper for sale, honey, wood, coal, and chewing gum (*Manilkara zapota*), and raising livestock. Some inhabitants provide transportation services (taxis), work as tour guides in the CBR, or own small grocery stores (Argüelles et al., 2009; Conafor, 2009). Other traditional activities are hunting and fishing, mainly for family subsistence (Escamilla et al., 2000; Reyna-Hurtado & Tanner, 2005; Reyna-Hurtado et al., 1999; Santos-Fita et al., 2012; Weber, 2000).

Initial contact was made with the "ejido" representative of each community, to whom the objectives of the study were explained, and consent was obtained to carry out participant observation and apply a questionnaire with the help of a Mayan translator, as some interviewees did not speak Spanish. Before beginning each questionnaire, the objectives of the study were explained and the person was asked whether he or she wished to collaborate. If they agreed, the 20-minute questionnaire was applied. From January to May, 2016, a total of 120 questionnaires were applied (30 in each community) randomly to men and women aged 15 to 85 who participate in agricultural activities.

The questionnaire consisted of 28 questions organized into 4 sections: *1)* personal data, *2)* economic activities carried out by the interviewee, *3)* information regarding the tapir and crops, and *4)* hunting (Appendix 1). Information was captured directly in the field using a laptop computer, in which responses to the questionnaires were captured using the Access program to capture information, following the methodology proposed by Gurri-García et al. (2015).

Relative abundance

Data was gathered from 4 study sites: the rural communities 20 de Junio, Nuevo Becal, Zoh Lagoon, and 20 de Noviembre. These sites were chosen based on evidence of crop damage by tapirs (R. Reyna-Hurtado, M. San Vicente, N. Arias and S. Calme, personal communication), existence of large areas of unfragmentated habitat, and proximity to the CBR.

Relative abundance was estimated based on the number of tapir footprints per kilometer observed in the linear transects. Transects in the 4 communities (Fig. 1) were randomly located in forested areas 1 - 8 km from the communities, with 0.5 - 1 km between transects (Reyna-Hurtado & Tanner, 2005). A total of 4 linear transects were established per community, ranging from 1.7 to 2 km in length, with the exception of Zoh Lagoon, in which one transect was eliminated due to difficult access.

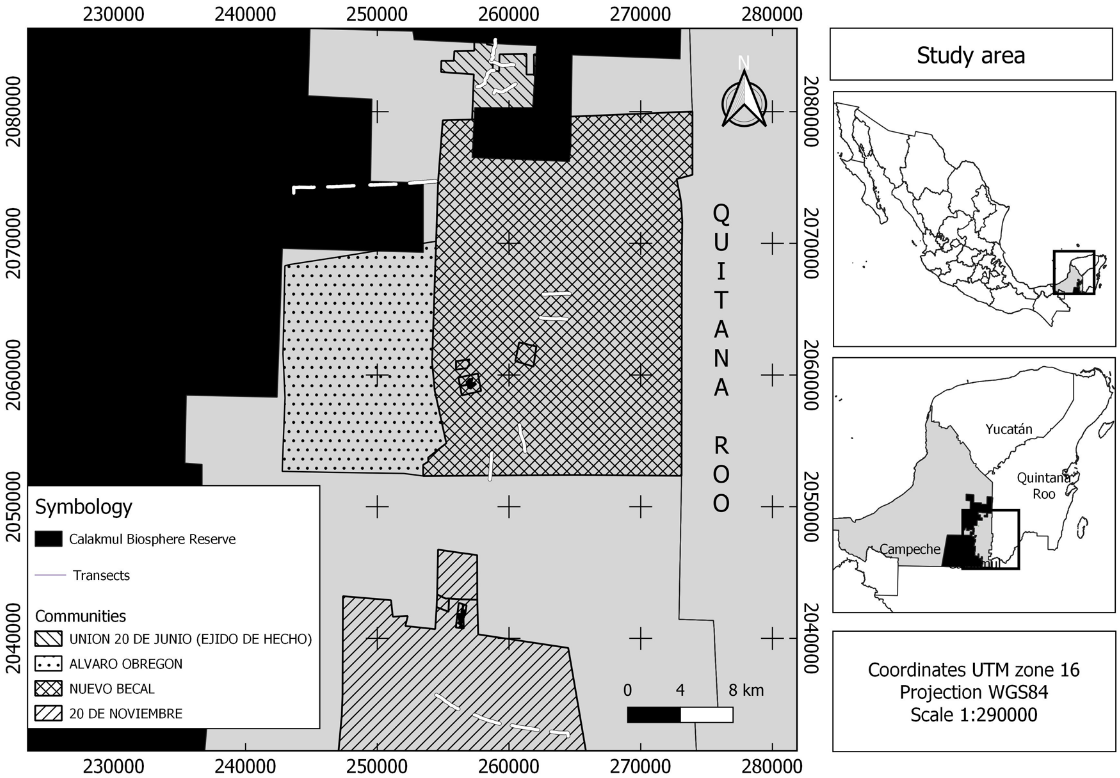

Figure 1. Map of study communities and transects walked in Calakmul, Campeche, Mexico

Footprints were recorded by walking 1 time per month the 15 transects at a constant velocity. We walked the transect 4 times (from February - May, 2016), exhaustively searching for tapir tracks within 1 m of the central line of the transect. Each footprint was considered to be a unique record, and all tracks found were recorded without considering any criteria of independence. In order to avoid double counting, all footprints found were erased after being recorded (Briceño-Méndez et al., 2014; Reyna-Hurtado & Tanner, 2005, 2007).

To estimate relative abundance, the Index of Relative Abundance of Footprints (IRAF) was calculated by dividing the total number of footprints found (NF) by the total number of kilometers (km) walked (Caughley, 1977). Thus, IRAF = NF/km.

Once the index was obtained, values were adjusted to a normal distribution using the Shapiro-Wilk goodness-of-fit test. To determine whether significant differences existed among the number of tapir records (IRAF) in the 4 communities, an analysis of variance (ANOVA) was applied and statistical analyses were performed using SPSS, version 21.0 (SPSS, 2012).

To know the proportion of available habitat type, every 100 m of km walked were established sampling points, in total 293 sampling points were located in all transects. At each sampling point, the tree species present were recorded and the vegetation type was identified. The vegetation sample obtained at each transect was considered representative of the vegetation present at each side. Therefore, these data were used to estimate the relative frequency of each vegetation type at each study site (Carrillo-Reyna et al., 2015). Furtemore to know the habitat preference, each time a footprint was found, the surrounding type of vegetation was classified. Data for vegetation was analyzed according to the criteria of Pennington and Sarukhan (1998), and the type of vegetation generally found along the transects was contrasted with the type of vegetation immediately surrounding tracks identified. A chi square analysis was performed using the number of tracks found and the relative frecuency of each vegetation type the amount of each vegetation type. Expected and observed frequency of tracks and Bonferroni intervals for each type of vegetation were calculated. With this analysis, the tapirs´ preference for each type of vegetation was evaluated. These analyses were performed using the HABUSE 4.0 program (Byers et al., 1984).

To estimate availability of wild fruit in each site, each type of fruit typically eaten by tapirs found in each transect was identified according to the literature (Cruz, 2001; Naranjo, 2009; Naranjo & Cruz, 1998; Rivadeneyra, 2007). The number of fruits falling from each tree was verified by drawing 2-1 m^2 quadrants next to the tree and counting the number of fruits inside the quadrants. To ensure that data was comparable between sites, the average was divided by the total distance covered in each site and multiplied by 100, to avoid using fractional numbers. With this data, the percentage of fruit were obtained in each site and each specie of tree (Carrillo-Reyna et al., 2015). A Spearman correlation was applied using the SPSS program, version 21.0 (SPSS, 2012) to confirm possible associations between availability of fruit in the transect and IRAF.

Density of the understory was calculated by photographing the transect using a Nikon 3300 digital camera. Photographs were taken of the vegetation on one side of each transect, placing the camera at a height of 1 m with no zoom (objective: 18-55 mm). Photographs were taken once a month at the beginning, middle (1 km), and end of each transect (2 km), and placed in a 10 x 10 template, and the number of squares containing vegetation was counted. In this manner, the percentage of understory density in each community was obtained. A Pearson correlation was performed using the SPSS program, version 21.0 (SPSS, 2012) to verify whether a relationship existed between understory density and IRAF.

In the present study, crop damage by the tapir was documented and 3 types of variables were analyzed: ecological and agricultural variables, and those related to crop protection measures. The sole ecological variable measured was "relative abundance of the tapir". Agricultural variables were "distance of the crop to the nearest community", "average crop area per farmer", "number of farmer who cultivate beans", and number of farmers who cultivate squash"; Dunn et al., 2012; Treves & Naughton-Treves, 2005; Waters, 2015). Variables related to crop protection measures were "number of farmers who hunt in their field" and "number of farmers applying other protective measures" (Hill, 2000; Naranjo et al., 2015; Reyna-Hurtado & Tanner, 2005, 2007).

The collected data (ecological variable, agricultural variables and crop protection measures carried out by the farmers) was converted to log 10. To determine distribution of the data, the Shapiro-Wilk test was used, and a Pearson correlation was subsequently applied to those variables with a normal distribution ("percentage of crop damage", "relative abundance of the tapir", "distance of the crop to the nearest community", "average crop area per farmer", "number of farmers who cultivate beans", "number of farmers who hunt in their field ", and "number of farmers applying other protective measures"). To determine whether significant differences existed among crop damage in the 4 communities, an analysis of variance (ANOVA) was applied and statistical analyses were performed using SPSS, version 21.0 (SPSS, 2012).

Variable associated with crop damage caused by the tapir were identified, and models relating these variables to each other were constructed. The a priori model was identified as that with the least number of variables that could explain crop damage. The model was determined based on the smallest Akaike´s information criterion (AIC) and the greatest Akaike´s weight (ωi; Burnham & Anderson, 2002). In determining models, each potential model should be compared with a "global model" which includes all potential variables. The best model (based on AIC) should include a subset of the "global model" variables, with an optimal equilibrium between model fit and parsimony (Burnham & Anderson, 2002).

Upon constructing potential models, variables correlated with each other are eliminated according to the Spearman coefficient, as suggested by Karanth et al. (2013). Variables with a correlation > 0.5 were eliminated. In general, the variable "number of farmers who hunt in their field" was eliminated due to its correlation with the variable "number of farmers applying other protective measures", and the variable "number of farmers who cultivate squash" was eliminated due to its correlation with the variable "number of farmers who cultivate beans". Crop damage was modeled according to agricultural variables ("distance of the crop to the nearest community", "average crop area per farmer", and "number of farmers who cultivate beans") and crop protection measures ("number of farmers applying other protective measures"). The variable "relative abundance of the tapir" was not considered as data was insufficient to carry out the analysis. For the global model "percentage of crop damage", 4 variables were selected. Models were also constructed for each community, eliminating those variables with high correlations between each other (> 0.5). The only correlation identified was between "number of farmers who cultivate beans" and "number of farmers who cultivate squash" in Zoh Lagoon, and therefore the latter variable was eliminated.

Akaike differences (AIC) and Akaike´s weight (ωi) were used to classify the models from those, which were most to least supported by the data. ΔAIC is the difference of AIC of each model between the models with the lowest AIC value. Where ωi is the weighted value for each model based on the sum of the total value of each model in which

ΔAIC is 1 (Burnham & Anderson, 2002). These values allowed for interpreting the probability of the data of the candidate models (Burnham & Anderson, 2002). These analyses were carried out using the R Studio V 1.0.136 program (RStudio Team, 2015).

Results

Of all farmers surveyed, 62% (N = 74) reported crop damage due to the tapir the previous year (N = 120); 33% (n = 40) reported the bean crop to have been the most affected. The greatest number of farmers reported damage in 20 de Junio (77% of farmers), followed by Nuevo Becal (67%), 20 de Noviembre (60%), and Zoh Lagoon (43%). The average estimated percentage of crop damage caused by the tapir was 14%. The communities with the most crop damage were 20 de Junio and Nuevo Becal – both with 19%, followed by 20 de Noviembre with 14%, and finally Zoh Lagoon with 6%. No significant differences were found among communities (ANOVA, F = 4.50, $p = 0.316$).

A positive Pearson correlation was found between "percentage of crop damage" and "number of farmers who cultivate beans" (rs = 0.97, $p = 0.02$), as well as between "percentage of crop damage" and "number of farmers applying other protective measures" (rs = 0.99, $p = 0.05$).

A total of 769 tracks (6.56 tracks/km) were recorded among all sites (117.2 km). The highest relative abundance was found in Nuevo Becal, with 8.81 tracks/km, followed by Zoh Lagoon (6.63 tracks/km), 20 de Noviembre (6.20 tracks/km), and 20 de Junio site (4.55 tracks/km). No significant differences were found among communities (ANOVA, F = 0.41, $p = 0.74$).

Four types of vegetation were recorded: medium semi-evergreen forest, semi-evergreen flooded lowland forest, low deciduous forest, and secondary vegetation. In general, medium semi-evergreen forest was the dominant habitat, present in 70.5% of all sampling points in 20 de Junio, 71.7% in Zoh Lagoon, 50% in Nuevo Becal, and 90.7% in 20 de Noviembre. Secondary vegetation was present in the fewest sampling points, with only 5.1% of sampling points in 20 de Junio. The only community with all 4 types of vegetation was 20 de Junio, while 20 de Noviembre had only 2 vegetation types (medium semi-evergreen forest and low deciduous forest).

The type of vegetation in which the most tapir tracks were found was medium semi-evergreen forest, with a total of 508, followed by low deciduous forest with 213, low deciduous forest with 48, and no tracks in secondary vegetation (Table 1). The Chi square analysis indicated a preference by the tapir of semi-evergreen flooded lowland forest, and to a lesser extent low deciduous forest. This species apparently avoided secondary vegetation and used the medium semi-evergreen forest because of its abundance rather than the fact that it preferred this habitat (N = 769, $X^2 = 53.38$, $p = 0.00$).

During the 4 months of sampling, which corresponded to the dry season, the community with the highest understory density was 20 de Noviembre (56%), while Zoh Lagoon had the lowest density (47.1%). Meanwhile 20 de Junio had a density of 53.7 and Nuevo Becal 52.8. The Pearson correlation did not show a significant relationship between percentage of understory density and IRAF (rs = 0.01, $p = 0.95$).

A total of 16 fruit species were found in the 117.2 km traveled, although only 10 of these had previously been reported as part of the tapir diet (Appendix 2). The fruit of the breadnut tree (*Brosimum alicastrum*) was the most abundant, present in 86% of the distance traveled, followed by "chicozapote zapote" (*Manilkara zapota*), present in 72% of the distance traveled. Both species were present in all communities during all sampling months. The community with the greatest abundance of fruit was Zoh Lagoon, which contained 36.1% of all fruits found in the 4 communities, followed by 20 de Noviembre which contained 30.3%, Nuevo Becal with 29.7%, and finally 20 de Junio with 3.9%. The Spearman correlation did not show a significant relationship between proportion of fruits and IRAF (rs = 0.16, $p = 0.54$).

In general, 2 models best explain the percentage of crop damage according to ΔAIC < 2. The most important predictor variables were "number of farmers who cultivate beans" and "average crop area per farmer" (Table 2). The global model was that with the highest values for AIC (1055.3) and ΔAIC (4.5).

Table 1

Baird´s tapir footprints recorded in different types of vegetation according to the method by Byers et al. (1984) in 4 communities surrounding the Calakmul Biosphere Reserve, January-May, 2016.

Forest types	Observed	Expected	X^2
Medium semi-evergreen	508 (=)	541	
Semi-evergreen flooded lowland	213 (+)	145	$p = 0.00$
Low deciduous	48 (–)	74	
Secondary vegetation	0 (–)	10	

The symbols (=), (+), and (–) next to the observed values, indicate that those values are the results according to Bonferroni intervals using the HABUSE Program (Byers el at., 1984) in equal, greater, or lesser availability than the respective expected values.

In 20 de Junio, "the number of farmers who cultivate beans" and "distance of crop to the nearest community" were the predictor variables. In Nuevo Becal, the predictor variables were "number of farmers who hunt in their field" and "distance of crop to the nearest community". In Zoh Lagoon, the predictor variables were "number of farmers applying other protective measures" and "number of farmers who cultivate beans". Finally, in 20 de Noviembre, the predictor variables were "number of farmers who cultivate beans" and "distance of crop to the nearest community" (Table 2).

Discussion

Sixty-seven percent of farmers interviewed reported crop damage by the tapir, and 33% reported the most damaged crop to be beans. This is likely due to the fact that —as suggested by Naughton-Treves et al. (2003)— the tapir is a large mammal capable of destroying the crop by trampling it as well as feeding on its shoots and soft leaves. A study by Waters (2015) in Belize coincides with this study, finding that beans was the crop most affected by tapirs, having been reported by 60% of farmers. In Honduras, the tapir has also been observed to damage the bean crop (Dunn et al., 2012).

In the present study, a positive correlation was found between the variables "percentage of crop damage" and "the number of farmers who cultivate beans" (rs = 0.97; $p = 0.02$), indicating that where a greater number of farmers grow beans, crop damage increases. This is consistent with that observed in previous studies (Dunn et al., 2012; Waters, 2015), and appears to partly be because as beans are a vine crop, the tangled vines are easily broken when tapirs walk through them. Another possible explanation is that tapirs prefer soft shoots and leaves, such as those of beans. A positive association was also detected between

Table 2

Selection of models according to Akaike´s information criterion to identify variables that influence crop damage in 4 communities surrounding the Calakmul Reserve Biosphere, Mexico, January - May, 2016. In bold = the models that best explain the percentage of crop damage according to ΔAIC.

Communities	Model	AIC	ΔAIC	*Ωi*	Variables included
All	GLOB	1055.3	4.5	0.04	DISTCO, CROP, ME, B
	DISTCO	1053.4	2.6	0.12	HCUL, ME, B
	ME	1052	**1.2**	**0.27**	HCUL, B
	B	**1050.8**	**0**	**0.55**	**B**
20 de Junio	GLOB	277.72	5.63	0.011	DISTCO, CROP, ME, HUNT, B, S
	HUNT	275.72	3.63	0.054	DISTCO, HUNT, B
	DISTCO	273.88	**1.79**	**0.211**	DISTCO, B
	B	**272.09**	**0**	**0.724**	**B**
Nuevo Becal	GLOB	280.8	2.46	0.08	DISTCO, CROP, ME, HUNT, B, S
	DISTCO	279.31	**0.92**	**0.28**	DISTCO, HUNT
	HUNT	**278.34**	**0**	**0.64**	**HUNT**
Zoh Lagoon	GLOB	242.98	5.01	0.014	DISTCO, CROP, ME, HUNT, B
	DISTCO	241	3.03	0.067	DISTCO, ME, B
	ESTR	239.35	**1.38**	**0.241**	ME, B
	B	**237.97**	**0**	**0.677**	**ME**
20 de Noviembre	GLOB	258.29	5.1	0.014	DISTCO, CROP, ME, HUNT, B, S
	HCUL	256.49	3.3	0.062	DISTCO, CROP, B
	DISTCO	254.83	**1.64**	**0.22**	DISTCO, B
	B	**253.19**	**0**	**0.704**	**B**

Ωi: Model weight, GLO: global model, DISTCO: distance of crop to the nearest community, CROP: average crop area per farmer, ME: number of farmers applying other protective measures, HUNT: number of farmers who hunt in their field, B: number of farmers who cultivate beans, S: number of farmers who cultivate squash.

the variables "percentage of crop damage" and "number of farmers applying other protective measures" (rs = 0.99; p = 0.05), which indicates that as crop damage increases, farmers carry out more measures to protect their crops. In Uganda, Naughton-Treves (1998) found that farmers had increased measures to reduce damage caused by large mammals, including planting less palatable crops alongside the threatened crops, setting traps in the field, using poison, and hunting.

The estimated relative abundance of tapir footprints in this study (6.56 tracks/km) was above the range of abundances estimated in previous studies in Mexico (0.005 - .81 tracks/ km) (Lira-Torres et al., 2004; Naranjo, 2009; Naranjo & Bodmer, 2002; Naranjo & Cruz, 1998; Naranjo et al., 2015; Reyna-Hurtado & Tanner, 2007; Tejeda-Cruz et al., 2009). This was probably due to the effect of the locations selected to record tracks and the methodology used, such as the width of the transect, sampling season, and having counted footprints without criteria of independence. Nuevo Becal had a greater relative abundance (8.81 tracks/ km) than other contributions for the same site (0.42 tracks/ km; Reyna-Hurtado & Tanner, 2007). This difference was probably because that tracks were sought in the community´s conservation area and/or an increase in the tapir population, both of which should be examined in future studies. No significant differences were found in relative abundances among the 4 sites, which could be by the fact that these sites have permanent water sources; a dense, diverse understory which favors abundance of food; riparian vegetation, and low rate of forest fires, all of which favor conservation of this species (Muench, 2001; Naranjo, 2002, 2009; Tobler et al., 2006).

The tapir's preference for semi-evergreen lowland flooded forest that we documented is known in the area (Reyna-Hurtado & Tanner, 2005), this is surely because of the animals preference for sites with abundant available water such as "aguadas" and semi-perennial flooded lowlands that hold water, and therefore this type of habitat is more favorable, and even essential for the survival of this species (Lira-Torres et al., 2014; Reyna-Hurtado & Tanner, 2007). In addition, these areas where we find the greates abundance coincide with sites rarely frequented by hunters (Reyna-Hurtado & Tanner 2005).

In the communities included in this study, as well as in Mayan communities in the state of Quintana Roo, tapirs are not preferred game due to the taste of their meat and the difficulty of hunting and transporting them (Jorgenson, 2000; Reyna-Hurtado & Tanner, 2007). However, in this study 2 cases of hunting tapirs in crops had previously been recorded (in 20 de Junio and 20 de Noviembre), and a previous study had recorded hunting of a tapir that caused crop damage in Nuevo Becal (Reyna-Hurtado & Tanner, 2007). A study by Dunn et al. (2012) in Honduras, documented that farmers considered that the tapir damages their bean crops —which coincides with that observed in the present study, and for this reason, they had hunted 8 tapirs near their crop fields.

The generalized linear models (global model) for all communities indicated that the predictor variables —those that principally influenced crop damage— were "number of farmers who cultivate beans" and "average crop area per farmer". Thus, the tapir principally harms bean crops in our study area. This concords with that observed in previous studies (Dunn et al., 2012; Naughton-Treves et al., 2003; Waters, 2015), with possible explanations being those mentioned above. Another variable that could contribute to explaining the percentage of damage is that the greater the number of hectares cultivated per farmer, the greater the crop loss. However, in Calakmul, farmers do not cultivate very large areas, but rather typically have several small fields (1 ha). This could indicate that the greater the change in land use from forest to crops, the greater the crop loss due to wildlife (Lee et al., 1986; Treves & Naughton-Treves, 2005).

In this study, Nuevo Becal was the only community with a different predictor variable in the generalized linear models: "number of farmers who hunt in their field". In the questionnaires, the farmers of this community stated that hunting is common and that they hunt to protect their crops and obtain meat. However, they indicated that the tapir is not their favored prey, as they do not like the taste. This opinion coincides with that found by Reyna-Hurtado and Tanner (2007) in the same community. Nonetheless, during the time of our fieldwork, a farmer in 20 de Junio and another in 20 de Noviembre killed a tapir that was causing crop damage.

We found that "distance of the crop to the nearest community" was a predictor variable for 3 communities, which could indicate that the tapir does not typically travel long distances from forests to the communities. Thus, when a crop is farther from a community, the tapir is more likely to cause damage. This is similar to that recorded in Tambopata, Peru by Naughton-Treves et al. (2003), who documented that large mammals —capybara, tapirs, and white-lipped peccaries— appeared only in farms which were relatively far from villages. In the present study, the variables "distance of the crop to water bodies" and "type of forest near crops" were not analyzed, since the tapir requires access to water (Pérez-Cortés et al., 2012). Nevertheless, other variables that were not evaluated may predict crop damage by the tapir - for example "type of forest near crops", as conserved forest serves the function of a wildlife corridor.

Finally, no correlation was found between "percentage of crop damage" and "relative abundance of the tapir" (rs = -0.08, p = 0.91), which indicates that abundance in this study does not influence crop damage. "Relative abundance of the tapir" was not correlated with the availability of wild fruits (Carrillo-Reyna et al., 2015), given that regardless of the availability of wild fruit in the forest, tapirs cause crop damage. Nevertheless, our hypothesis was accepted, Zoh Lagoon had the least percentage of damage (6%), the greatest relative abundance of tapirs (6.63 tracks/km), and the greatest availability of fruit (36.1%). These results could indicate that a well-conserved forest with availability of food could reduce crop damage due to the tapir.

The variables best correlated with crop damage were "number of farmers applying other protective measures", "number of farmers who cultivate beans", and "number of farmers who hunt in their field". Thus, it follows that farmers respond to crop damage by hunting and carrying out other crop protection measures, such as watching over the crop, scaring the animals, or even poisoning them, and that the bean crop is the most affected by the tapir.

The communities surrounding the CBR are well-preserved communal forests, which is why some authors —such as Reyna-Hurtado and Tanner (2007)— mention the need to protect tapir populations outside the CBR more than those within the reserve. Our results suggest that tapirs face the threat of hunting by farmers in communities surrounding the CBR, which could result in a decrease in the abundance of this species near these communities. However, no previous studies on the tapir have addressed crop damage in CBR. There is a need for research that actively involves farmers to identify environmental, economic, and crop protection variables and develop and test strategies to protect crops that do not affect the abundance of the tapir but rather contribute to its conservation in the region of the Calakmul Biosphere Reserve.

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Appendix 1. Questionaire regarding interactions between tapirs and peasants incommunities surrounding the calakmul biosphere reserve

Baird´s Tapir: Predicting patterns of crop damage surrounding the Calakmul Biosphere Reserve, Campeche, Mexico

Biology: Isabel Serrano Mac-Gregor 01/2016

ECOSUR

This questionnaire is voluntary, lasting a maximum of 20 minutes, and you may remain anonymous if you wish.

Location: Date:

Interviewer: Interview number:

Part 1. Personal information

1. Name: 2. Gender: (M) (F)

3. - Age: a) (<20) b) (20-29) c) (30-39) d) (40-49) e) (50-59) f) (>59)

4. -Schooling completed: a) Primary b) Junior high c) High school d) Undergraduate e) No formal schooling

5. Years of residence in the community: (<1) (1-10) (11-20) (>20)

6. Birthplace: a) In the community b) Another community c) Another state d) Another country e) Another municipality

7. Where were you born?

Part 2. Activities

1.What activities do you carry out? a) None b) Agriculture c) Forestry d) Hunting e) Cattle raising f) Wage labor g) Housework h) Beekeeping i) Other

2.What do you grow?

Appendix 1. Continued

Part 3. Data regarding tapirs and crops

1. Have you ever seen a tapir in your community? a) Yes b) No

2. How many times? 3. Where and in what year did you see tapirs?

4. How many did you see? 5. What age tapirs did you see? a) Adult b) Cub

6. What did you do when you saw the tapir/s?

7. What was the tapir doing? a) Nothing b) Eating c) Walking d) Swimming e) Other

8. Where did you see it? a) Crop field b) Lagoons c) Forest d) Other

9. Do you consider that tapirs have affected your crops? a) Yes b) No

10. Which crops have tapirs most affected?

11. Which part of the crop do tapirs most affect? a) Mature leaves b) Tender leaves c) Stems d) Roots e) Fruits

12. During which season/s do tapirs most affect the crops? a) Dry b) Rainy c) Both seasons d) Neither

13.How much damage did tapirs cause to your crops last year: a) None (0%) b) Very little (<5%) c) Little (10%) d) Moderate (20%) e) Half of my crops (50%) f) Almost all of my crops (>50%)

14. How far are your crops from the community? a) <1km b) 1-5km c) 5-10km d) >15km

15. Approximately how much land do you cultivate? a) <1 ha b) 1-5 ha c) 5-10 ha d) >10 ha

Part 4. Hunting

1. Did you hunt tapirs last year because they damaged your crops? a) Yes b) No

2. Did you hunt any other wild animal last year because it damaged your crops? a) Yes b) No

3. Would you like to know about other solutions to the problem of tapirs affecting your crops? a) Yes b) No c) I don't care

4. – (If not:) a) Why not? b) I am not interested c) I don't have time d) Other

THAT IS THE END OF THE INTERVIEW. THANK YOU FOR YOUR TIME AND INFORMATION

Appendix 2. Percentage of fruits known to be part of the tapir´s diet found in the 4 sampling communities bordering the Calakmul Biosphere Reserve from February to May, 2017. Sources: 1 = Naranjo and Cruz (1998); 2 = Cruz (2001); 3 = Rivadeneyda (2007); 4 = E. J. Naranjo (2009).

Scientific name	Common English name from Missouri Botanical Garden	Common Spanish or Mayan name	Percentage (%)	Source
Brosimum alicastrum	Breadnut	Ramón	86.04	1, 2, 3, 4
Manilkara zapota	Chicozapote	Zapote	7.19	1, 2, 3, 4
Pouteria reticulata	Wildcherry	Zapotillo	2.47	4
Cryosophila sp.		Guano kum	2.10	3, 4
Coccoloba sp.	Papalón	Uvero	0.79	2, 5
Pithecellobium insigne		Limoncillo	0.61	2
Ficus sp.		Ficus	0.37	1, 2, 3
Pouteria amygdalina	Silly young	Zapote faisan	0.23	4
Pouteria campechiana	Egg-fruit-tree	Kaniste	0.14	4
Vitex sp.		Ya´axnik	0.05	1, 2

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