

Abundance, herd size, activity pattern and occupancy of ungulates in Southeastern Mexico

Gabriela Pérez-Irineo* and Antonio Santos-Moreno

Laboratorio de Ecología Animal, Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Unidad Oaxaca, Instituto Politécnico Nacional, Hornos 1003, Colonia La Noche Buena, Santa Cruz Xoxocotlán, Oaxaca 71230, México

Submitted: September 19, 2015. Final revision received: January 9, 2016.

Accepted: January 23, 2016

Abstract

This study provides information about relative abundance, herd size, activity pattern, and occupancy of ungulates at Los Chimalapas, southeastern Mexico, one of the last refuges inhabited by two conservation priority ungulate species: *Tapirus bairdii* and *Tayassu pecari*. For three years, four species of ungulates were recorded using camera traps: *T. bairdii*, *T. pecari*, *Mazama temama*, and *Tayassu tajacu*, involving an effort of 8529 trap-days and 839 records. *T. pecari* was found to be highest in relative abundance, while *T. tajacu*'s abundance was lowest. Populations were composed principally of adults, but there were records of offspring for all four species. The herd size was smaller compared to other populations of *T. tajacu* and *T. pecari*. Occupancy models were used to analyze the presence of the species in the region and showed that *M. temama* and *T. bairdii* had a high occupancy probability. In comparison, the occupancy probability of *T. pecari* was low. This study shows that ungulate populations are still breeding, and have higher possibility of permanence, in Los Chimalapas, Southeastern Mexico. The region is an important area for the conservation of *T. bairdii* and *T. pecari*, both disappeared from some other areas of the southeast.

Keywords

Chimalapas; *Mazama temama*; occupancy models; *Tapirus bairdii*; *Tayassu pecari*; tropical rain forest

Introduction

The ungulate group plays various important roles in the dynamics of a habitat, due to their feeding habits, they are herbivores, that include fruits and seeds. As a consequence, they are also seed dispersal agents and some plant species depend on these animals for the germination of their seeds (Bodmer, 1991). Ungulates also repre-

*) Corresponding author; e-mail: gabyirineo@yahoo.com.mx

sent an important biomass and are a food resource for predators (Nuñez et al., 2000; Mandujano, 2007) as well as for local human communities (due to the abundance of meat obtained when hunted; Naranjo et al., 2004; Santos-Fita et al., 2012).

However, for some of the species in this group, there is not enough basic information, and it is difficult to determine their size population and, hence, their state of conservation. In particular, the Central American red brocket (*Mazama temama*) is classified by IUCN under ‘insufficient data’ because there is very little information on the size of its populations (IUCN, 2014). Other species have been more widely studied, but they still show insufficient information, such as the genus *Tayassu* (Gallina & Mandujano, 2009). Ecological studies indicate that variations in abundance, activity or use of sites by ungulates are associated the seasons, the magnitude of human activity, the presence of other species of the same trophic guild, or the availability of resources (Keuroghlian et al., 2004; Di Bitetti et al., 2008; Pérez-Cortez et al., 2012; Reyna-Hurtado et al., 2012).

Camera traps have been used successfully to estimate the abundance of individually-marked species and species richness (Di Bitetti et al., 2008; Tobler et al., 2008). These devices are useful in areas with rugged topography or dense vegetation, and they allow detection of the rarest or nocturnal species, such as ungulates (Tobler et al., 2008). In recent years, camera traps have been used to study activity patterns, habitat-use, density and occupancy of ungulates (Reyna-Hurtado, 2007; Tobler et al., 2008; Rovero & Marshall, 2009; Carbajal-Borges et al., 2014).

Of the 11 ungulate species found in Mexico, six of them inhabit the southeastern region of the country: *M. temama*, the Yucatan brown brocket; *Mazama pandora*, the white tailed deer *Odocoileus virginianus*, the white-lipped peccary; *Tayassu pecari*, the collared peccary; *Tayassu tajacu*; and the Baird’s tapir *Tapirus bairdii* (Lorenzo et al., 2008). However, the forest cover in Southeastern Mexico has undergone major changes which have resulted in a significant reduction of the native species habitats, including that of ungulates (Gallina & Mandujano, 2009; Naranjo, 2009; Reyna-Hurtado, 2009; Carbajal-Borges et al., 2014). Thus, the original habitat of *T. pecari* is reduced by 80%, and populations remain in the states of Oaxaca, Chiapas, Campeche and Quintana Roo (Reyna-Hurtado et al., 2009). In the case of *T. bairdii*, the reduction has reached 50%, and it is present only in Veracruz, Campeche, Chiapas, Quintana Roo and Oaxaca (Naranjo, 2009). Furthermore, these species are subject to hunting in the regions where they are distributed, with the ensuing reduction of their populations (Naranjo, 2009; Reyna-Hurtado et al., 2009; Santos-Fita et al., 2012).

The Los Chimalapas region is located at the state of Oaxaca of Southeastern Mexico. Los Chimalapas form part of the Selva Zoque-La Sepultura Priority Terrestrial Region, together with El Ocote and La Sepultura in Chiapas and the Uxpanapa region in Veracruz (fig. 1). The original vegetation cover is present in nearly 90% of the territory, and shows a high level of conservation. Even though the deforestation rate is low in the region, the expansion of livestock areas and deforestation are increasing, mainly in the areas close to villages (Ortega del Valle et al., 2012).

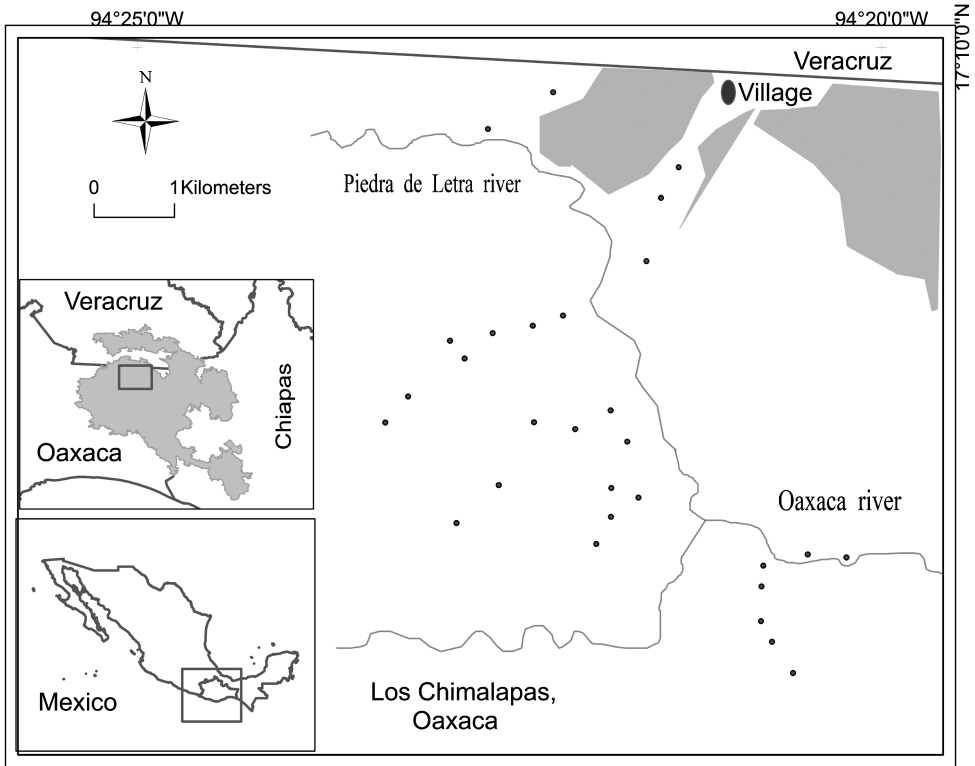


Figure 1. Study site at Los Chimalapas region in Southeastern Mexico. Points indicate the positions of the camera traps. Polygonal grey areas show livestock areas. The gray area in the upper inset shows the Selva Zoque-La Sepultura Priority Terrestrial Region between the states of Oaxaca, Veracruz, and Chiapas.

Four ungulate species inhabit this area, two of which are listed as endangered species and conservation priorities: *T. bairdii* and *T. pecari* (SEMARNAT, 2010). *O. virginianus* is considered relatively common in other regions, and *M. temama* has not been sufficiently studied. In this region, there are also other mammalian species considered conservation priorities, such as the jaguar *Panthera onca* and the spider monkey *Ateles geoffroyi* (Olgún et al., 2008). Notwithstanding this biodiversity, there is limited ecological data in the region, especially for *T. pecari* and *M. temama*. This study provides information on relative abundance, herd size, activity pattern, and occupancy (that is, the area occupied by the species) of ungulates at Los Chimalapas, one of the few refuges inhabited by two ungulate species considered a conservation priority.

Significant variations are expected to occur in terms of relative abundance and the activity pattern between the dry and rainy seasons, as has been observed in other regions (Keuroghlian et al., 2004; Pérez-Cortez et al., 2012). Also, it is expected that species occupancy will be higher in optimal regions, i.e., those located far from human activities and with a small abundance of other competitor species.

Methods

Study site

The study site is located in the northern region of Los Chimalapas in Southeastern Mexico. The sampling site is located in the vicinity of the rivers locally known as Piedra de Letra and Oaxaca, in addition to many other smaller streams (fig. 1). The tropical rain forest covers more than 46% of the region with species such as *Astrocaryum mexicanum*, *Desmoncus chinantlensis*, *Bactris mexicana*, *Chamaedorea* spp., and trees such as *Cordia*, *Spondias* and *Ficus* (Ortega del Valle et al., 2012). The climate is warm-humid with a monthly average temperature that ranges from 18 to 26°C. Average annual precipitation is 2000 mm (Salas et al., 2001). The topography of the region is irregular, with heights that range from 100 to 2550 meters above sea level.

Data analysis

A total of 29 sampling stations were installed from March 2011 to June 2013, covering an area of 22 km². Unbaited camera traps were placed at a height of 30 cm above ground. Three camera traps were placed in the rainforest next to rivers, four on trails, five in areas that were close to livestock, and the rest inside the forest. Because of the particular topographical conditions of Los Chimalapas, traps were spaced from 0.5 to 1.5 km apart. The models used were Wildgame IR4 4MP Digital Game Scouting Camera, ScoutGuard SG550/SG550V 5MP and Bushnell Trophy Cam 5MP. All traps were set to remain active for 24 h. The delay period between photographs varied from 3 seconds to 1 minute.

In order to ensure that all events were independent and to avoid pseudoreplication (Tobler *et al.*, 2008), for each species all photographs taken by each sampling station within a one hour span were considered as single records. In the case of gregarious species each observed individual was considered as a single record. The relative abundance was quantified as the number of single records during 100 days-trap. Variations in the relative abundance between the dry and rainy seasons were assessed by means of the Mann-Whitney *U* test (Zar, 1999).

In order to measure the size of the herd, the maximum number of individuals observed in each photograph was quantified. Also, the presence of offspring and young animals was recorded. Depending on the species, offspring were defined as those individuals of smaller size than adults, with clear pelage or with white dorsal spots. Young animals were those with sizes in-between adults and offspring (Mayer & Wetzel, 1987; March, 2005; March & Mandujano, 2005; March & Naranjo, 2005).

Occupancy models were used to analyze the proportion of area occupied by the species (Mackenzie et al., 2006). These models were developed taking into account that the presence of other species and the environmental conditions may have an influence on the probability of ungulates occupying the area. The models evaluated

were those in which the occupancy probability (ψ) is affected by 1) the proximity to the nearest village ($\psi_{\text{village } p}$), 2) livestock areas ($\psi_{\text{livestock } p}$), 3) bodies of water ($\psi_{\text{water } p}$), 4) the presence of another ungulate species capable of competing ($\psi_{\text{species } p}$), and 5) none of the evaluated factors having an influence (ψp) (see results). The effect of these variables on the occupancy probability was measured through a regression model with regression coefficient (beta). In all cases, the detection probability (p) was considered constant. Occupancy was considered closed to changes during the sampling period. Because the region shows a similar canopy cover in the whole area under study, and there is scarce human activity, these variables were not included. The proximity between the trap and the nearest body of water varied from 0.1 to 3 km, and between the trap and the nearest village it ranged from 0.3 to 8.2 km, while the proximity between the trap and the livestock areas varied from 0.2 to 3.1 km. In order to evaluate the impact of the presence of other species, the number of single records of each species in each camera trap site was used. Environmental variable values were calculated with the ArcGis software, version 9.3 (Esri, 2008), and each value was standardized and expressed as the difference between each value in relation to the variable mean, divided by its standard deviation. Analyses were carried out for each species and, the Presence software, version 7.5 was used for the construction and evaluation of the models (Hines, 2006). The best candidate model was selected according to the Akaike Information Criterion modified for small samples (AICc; Burnham & Anderson, 2004).

To analyze the activity pattern of each species, the 24 h period was divided into hour-long segments, and each independent record was classified within those intervals. To avoid an overestimate of activity in the case of gregarious species, a single record was the herd. For example, if the herd was formed by 10 individuals, herd was considered a single record regardless of the number of individuals in the group. Species were classified as diurnal, nocturnal or crepuscular according to their period of greater activity (i.e., higher frequency of records). The activity pattern was compared between seasons (dry and rainy), using the non-parametric Mardia-Watson-Wheeler W test. When the sample size was less than 10, the Watson U^2 test was used. The Oriana software, version 4, was used for statistical tests (Kovach Computing Services, 2011). Tests were considered significant with $p \leq 0.05$.

Results

Four species of ungulates were recorded: *M. temama*, *T. pecari*, *T. tajacu* and *T. bairdii* with an effort of 8529 days-trap, and 839 single records. Additionally, three predators were recorded (*P. onca*, puma *Puma concolor*, and ocelot *Leopardus pardalis*) and other species recorded were paca (*Cuniculus paca*), agouti (*Dasyprocta mexicana*), or tayra (*Eira barbara*). *T. pecari* obtained the highest relative abundance ($R.A. = 4.97$ records in 100 days-trap) followed by *T. bairdii* (1.71), *M. temama* (1.69) and *T. tajacu* (1.47; table 1). Within each season, the difference in the abundance of species between one year and the next was not significant in

Table 1.

Number of single records (photographic records obtained within a 1 h span per trap), relative abundance (RA, number of single records in 100 days-trap) and state of conservation of ungulates at Los Chimalapas in Southeastern Mexico, according to Norma Oficial Mexicana-059-SEMARNAT-2010, and IUCN.

Species	Records	RA	SEMARNAT	IUCN
<i>Mazama temama</i>	144	1.69	–	–
<i>Tayassu tajacu</i>	107	1.25	–	–
<i>Tayassu pecari</i>	291	3.41	endangered	vulnerable
<i>Tapirus bairdii</i>	143	1.68	endangered	endangered

the dry season: 2011-2012 ($U = 2.0$, $P = 0.08$), 2011-2013 ($U = 6.0$, $P = 0.56$), and 2012-2013 ($U = 6.0$, $P = 0.56$); nor in the rainy season: 2011-2012 ($U = 6.0$, $P = 0.56$). Given these results, all the data corresponding to each season was used to make the final comparisons, but the difference in the abundance pattern between each season was not significant ($U = 5.5$, $P = 0.38$).

T. bairdii and *M. temama* were registered as solitary animals in most of the records (>90%). Also, 60% of the *T. tajacu* records showed one individual and 40% were groups of between 2 and 5 animals (mean = 2.72 ± 0.20 , $N = 23$ records). In the case of *T. pecari*, 15% of the records showed one individual and 85% were groups of between 2 and 34 individuals (mean = 7.25 ± 1.01 , $N = 55$).

Offspring of *T. tajacu* and *M. temama* were recorded during the rainy season. Young *M. temama* were only recorded in the dry season (January, April and May; $N = 4$). Offspring and young *T. pecari* were recorded in both seasons (February-April, June, August-November). The herds showed records of maximum four offspring ($N = 16$) and four young animals ($N = 16$). Offspring and young *T. bairdii* were recorded in the dry season (May, $N = 3$).

In view of the few records, data was grouped in one-month blocks, which allowed us to obtain 27 sampling occasions. Models linking the occupancy probability to an environmental variable presented high AICc values compared to those related to the presence of other species (table 2). The occupancy probability of *M. temama* was higher in places far away from villages (beta = -1.169 , S.E. = 0.78), while that of *T. bairdii* was positively related to the proximity of water (beta = 3.001 , S.E. = 1.92). The occupancy probability of *T. tajacu* was negatively related to the presence of *T. bairdii* (beta = -1.082 , S.E. = 0.56). The occupancy probability of *T. pecari* was not related to any of the variables under analysis. *M. temama* and *T. bairdii* showed a high occupancy probability ($\psi > 0.8$), followed by *T. tajacu* ($\psi = 0.59$). The detection probabilities were low for all species ($p < 0.11$; table 2).

Two species were mainly diurnal: *T. tajacu* (95% of the records, $N = 73$) and *T. pecari* (73%, $N = 64$). The highest activity levels of *T. tajacu* occurred between 08:00 and 10:00, while those of *T. pecari* were from 16:00 to 20:00. *T. bairdii* was mainly nocturnal (74%, $N = 143$), with maximum levels of activity were from

Table 2.

Occupancy models for the four species of ungulates present at Los Chimalapas, Southeastern Mexico, with values of the coefficient variable (β), occupancy and detection probabilities for each species in the best selected model.

Species	Model	AICc	AICc weight	Beta (S.E.)	Sites with detections (%)	ψ (S.E.)	p (S.E.)
<i>M. temama</i>	$\psi_{\text{village}}P$	461.77	0.39	-1.169 (0.78)	76	0.82 (0.08)	0.11 (0.01)
	$\psi_{\text{livestock}}P$	462.93	0.22	-0.86 (0.64)			
	ψ_p	464.07	0.12				
	$\psi_{\text{water}}P$	464.80	0.08	-0.34 (0.48)			
	$\psi_{T. tajacu}P$	464.83	0.08	-0.33 (0.46)			
	$\psi_{T. bairdii}P$	465.10	0.07	0.26 (0.63)			
<i>T. bairdii</i>	$\psi_{\text{water}}P$	503.39	0.29	3.001 (1.92)	76	0.81 (0.08)	0.11 (0.01)
	$\psi_{\text{village}}P$	503.87	0.23	0.71 (0.50)			
	$\psi_{\text{livestock}}P$	504.53	0.16	0.64 (0.54)			
	ψ_p	504.92	0.13				
	$\psi_{T. tajacu}P$	505.64	0.09	4.97 (4.79)			
	$\psi_{M. temama}P$	506.11	0.07	-0.04 (0.46)			
<i>T. tajacu</i>	$\psi_{T. bairdii}P$	324.98	0.62	-1.082 (0.56)	53	0.59 (0.10)	0.09 (0.01)
	ψ_p	328.64	0.10				
	$\psi_{\text{village}}P$	328.71	0.09	-0.44 (0.42)			
	$\psi_{T. pecari}P$	329.51	0.06	0.24 (0.43)			
	$\psi_{\text{livestock}}P$	329.70	0.05	-0.16 (0.40)			
	$\psi_{\text{water}}P$	329.83	0.05	0.08 (0.40)			
<i>T. pecari</i>	ψ_p	229.39	0.26		30	0.32 (0.08)	0.13 (0.02)
	$\psi_{\text{livestock}}P$	230.09	0.18	-1.87 (0.19)			
	$\psi_{\text{village}}P$	229.99	0.19	0.53 (0.44)			
	$\psi_{T. bairdii}P$	231.29	0.09	-0.22 (0.44)			
	$\psi_{M. temama}P$	231.44	0.09	-0.15 (0.45)			
	$\psi_{T. tajacu}P$	231.49	0.09	-0.11 (0.42)			
	$\psi_{\text{water}}P$	231.56	0.09	0.03 (0.40)			

AICc, Akaike Information Criterion, modified for small samples; AICc weight, relative contribution of each model in relation to all the models; ψ , occupancy probability; p , detection probability; S.E., standard error of the parameter.

03:00 to 04:00, and from 18:00 to 21:00. *M. temama* showed cathemeral activity pattern (fig. 2).

The difference in the activity pattern between one year and the next was not significant for the dry season ($P > 0.1$) or the rainy season ($P > 0.29$). Therefore, the data was combined for the final analyses. The difference of activity pattern between dry and rainy seasons was not significant for any of the species under study: *T. tajacu* ($W = 4.67$, $P = 0.09$), *T. pecari* ($W = 0.89$, $P = 0.64$), *M. temama* ($W = 4.42$, $P = 0.10$) and *T. bairdii* ($W = 3.51$, $P = 0.17$).

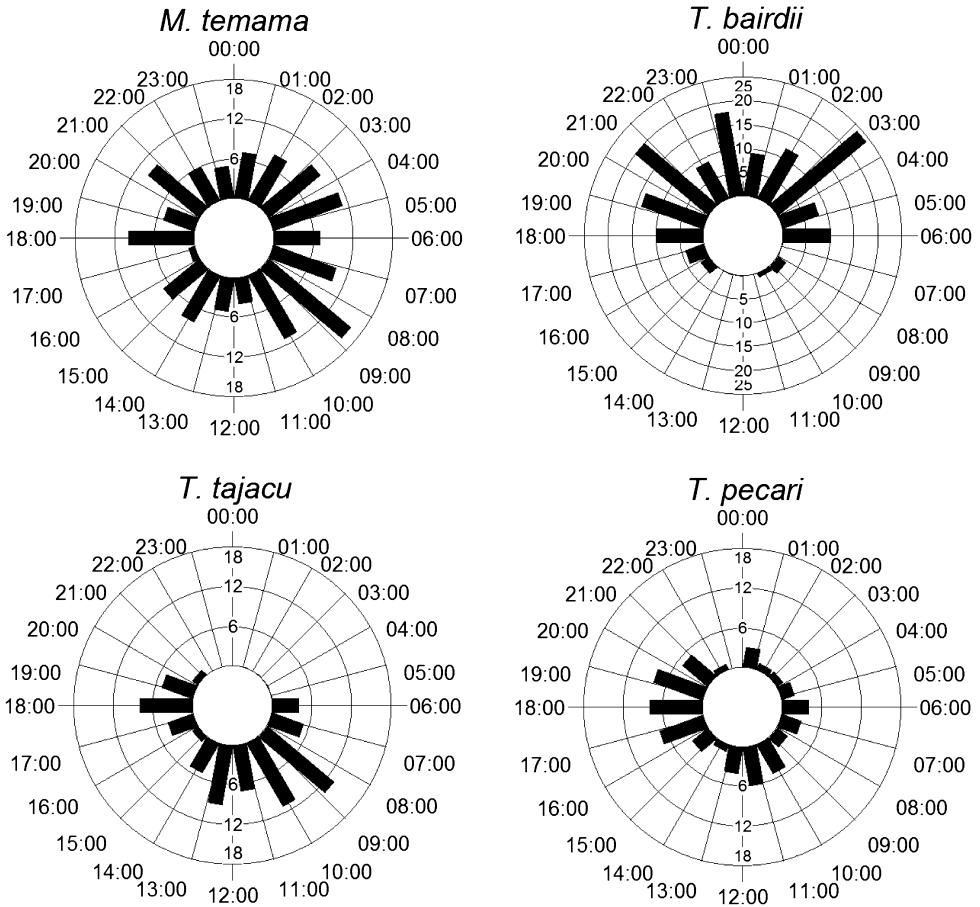


Figure 2. Activity pattern of the four ungulate species present at Los Chimalapas in Southeastern Mexico. The black bar indicates the frequency of records in each time period. For each species all the photographic records obtained within a 1 h span per trap were considered a single record. The records corresponding to herds were considered as a single record: *M. temama* = 142 records, *T. tajacu* = 73, *T. pecari* = 64, *T. bairdii* = 142.

Discussion

Five species of ungulates inhabit Los Chimalapas, and four of them were recorded in this study. *O. virginianus* was not recorded although it has been recorded in the southern region (Olguín et al., 2008). This can be compared to other areas in Mexico. Studies have shown variability in the richness, species composition and abundance of ungulates communities. The region with higher richness was Calakmul, Campeche with five species and *M. temama* and *T. pecari* showed higher abundance (Reyna-Hurtado, 2002). In the case of El Edén Ecological Reserve at Quintana Roo, there is four species, and *O. virginianus* and *T. tajacu* showed higher abundance (González et al., 2008). In the Lacandona rainforest, Chiapas, inhabit

five species. *M. temama*, *T. tajacu* and *T. pecari* were abundant (Naranjo & Bodmer, 2007; Tejeda-Cruz et al., 2009). In other regions the abundance, richness and species composition were different in the ungulates ensembles too (Bodmer, 1989; Weber & González, 2003; Tobler et al., 2008). These differences might possibly be due to environmental heterogeneity, availability of resources and the degree of conservation (Weber & González, 2003; Naranjo, 2009; Reyna-Hurtado et al., 2012).

Some authors consider that *T. pecari* and *T. tajacu* do not have a specific breeding season (March, 2005; March & Mandujano, 2005). However, others state that breeding is seasonal and is possibly related to the periods with higher food availability in each region (Altrichter et al., 2001; Reyna-Hurtado et al., 2009). Offspring and young animals were recorded in both seasons for all the ungulates species at Los Chimalapas. *T. pecari* and *T. tajacu* offspring and young animals were present in two periods of the year. *M. temama* offspring were only recorded during the rainy season and young animals during the dry season. In the case of *T. bairdii* offspring and young animals were recorded during the dry season. The scarcity of records of offspring and young animals for *T. bairdii* and *M. temama* was possibly due to long gestation periods (240 days in the case of *T. temama* and 400 days for *T. bairdii*), a long rearing period (one year) and few offspring – normally one per birth (Pukazhenthil et al., 2013). Thus, these individuals are difficult to record.

The higher percentage of adults in the populations of ungulates at Los Chimalapas matches that of other studies undertaken by means of direct observation or other techniques. For instance, at the Lacandona rainforest, the populations of five ungulates are composed of 54–95% adults (Naranjo & Bodmer, 2007), while the population of *T. pecari* (Reyna-Hurtado et al., 2009) and *T. bairdii* are integrated by 90% adults in Calakmul, Mexico (Pérez-Cortés et al., 2012).

As in other regions, the herd size of *T. pecari* was larger than that of *T. tajacu* at Los Chimalapas. However, for both species the herd size was smaller than that reported for other areas: in the case of *T. pecari*, the variation is 15–31 individuals at the Calakmul region in Mexico (Reyna-Hurtado, 2007), or 15–70 individuals at South America (Peres, 1996; Altrichter & Boaglio, 2004; Keuroghlian et al., 2004). In the case of *T. tajacu*, the species generally show a small herd size: 4–10 individuals at El Edén Ecological Reserve, in Mexico (González et al., 2008), or 2–10 individuals in South America (Peres, 1996; Altrichter & Boaglio, 2004; Keuroghlian et al., 2004). It is possible that this difference is due, on the one hand, to the environmental variability, and on the other hand, to the difficulty to register each member of a herd with camera traps. So it could be that herds were not fully recorded because animals usually move in a row. Consequently, it remains possible that the herd size at Los Chimalapas is similar to that in the above mentioned areas.

Occupancy probability of *M. temama* showed a negative relation with the distance to the village, while *T. bairdii* had a positive relation regarding the distance to bodies of water. In the other regions, the occupancy of species is related to environmental variables too, such as areas near a body of water (Reyna-Hurtado, 2007; Pérez-Cortés et al., 2012; Reyna-Hurtado et al., 2012) or protected areas (Di Bitetti

et al., 2008). A low probability of detection presented in all species may be a consequence of their cryptic behavior and, in the case of *T. pecari*, to its nomad behavior (Mayer & Wetzel, 1987; Keuroghlian et al., 2004).

At Los Chimalapas, *T. pecari* and *T. tajacu* were recorded in the same sites, although at a different time. In the Atlantic Forest of Brazil, both species have been observed occupying the same sites. However, *T. pecari* have home range nine times larger than that of *T. tajacu*. Additionally, *T. pecari* stays only for a few days in an area and presents a greater nomad behavior, while *T. tajacu* forages for longer periods in each site (Keuroghlian et al., 2004). It is possible that the behavioral difference was a factor that determined the lower probability of occupancy of *T. pecari* in the area under study.

The general activity pattern of ungulates at Los Chimalapas was similar to other regions (Keuroghlian et al., 2004; Reyna-Hurtado, 2007; Carbajal-Borges et al., 2014), and there were no records of variations in the diurnal and nocturnal activity throughout the year. This activity may possibly be related to the high degree of conservation that allows species to be active during the day. Additionally, the differences in the time of maximum levels of activity might have contributed to the co-existence of the species, mainly between *T. pecari* and *T. tajacu*.

Other studies show that hunting pressure may affect abundance and daily activity patterns of ungulates (Di Bitetti et al., 2008; Reyna-Hurtado et al., 2009). Poaching in the study site is low and is concentrated mainly in *C. paca* and great curassow (*Crax rubra*). However, in areas near large villages the number of hunted species increases, as well as hunting purposes (i.e., for sale or as pets; Salas et al., 2001). Possibly, hunting pressure still has no impact on the activity and abundance of ungulates in the study site. However the loss of the forest may be the main problem faced by these species at Los Chimalapas, especially in areas that are near to villages.

Conservation implications

At Los Chimalapas, there are still five species of ungulates, four of which are analyzed in this study. This region is located in the Mesoamerican Biological Corridor. However, recent studies indicate that there is limited connectivity between the states of Oaxaca and Chiapas, at Southeastern Mexico. This generates isolation and difficult the dispersion of individuals, as indicated for *T. bairdii* in the region (Mendoza et al., 2013), and possibly for *T. pecari* too. The loss of connectivity between Los Chimalapas and other sites where both species are distributed may result in the isolation of populations. *T. pecari* and *T. bairdii* disappeared from some areas of the southeast (Naranjo, 2009; Reyna-Hurtado et al., 2009). Los Chimalapas is one of the last refuges where these priority species are found; the region is still well preserved, but it is not included in any governmental conservation program. As documented in this study, Los Chimalapas shelters reproductive populations of *T. bairdii* and *T. pecari*, the former falling in the endangered category, and the latter

considered a vulnerable species at the international level (IUCN, 2014). It is therefore necessary to undertake effective actions in order to ensure, in the first place, their permanence in the region, and in the second place, to reestablish the connectivity with other regions where these species are distributed.

Acknowledgements

The authors thank the San Antonio Nuevo Paraíso community in Mexico for the facilities granted; IDEAWILD for the donated materials; the Laboratorio de Análisis Geoespacial, CIIDIR-IPN Unidad Oaxaca for support on geographical information; Consejo Nacional de Ciencia y Tecnología of Mexico for a scholarship provided to the first author; and Instituto Politécnico Nacional of Mexico for funding (Projects SIP-20110395, SIP20120962, and SIP-20131154 to A. Santos-Moreno). We thank those persons that collaborated with field work and R. del Castillo, M. García, G. Ramos, R. Solano, and two anonymous reviewers for comments and suggestions.

References

- Altrichter, M., Drews, C., Carrillo, E. & Sáenz, J. (2001) Sex ratio and breeding of white-lipped peccaries *Tayassu pecari* (Artiodactyla: Tayassuidae) in a Costa Rican rain forest. *Rev. Biol. Trop.*, 49, 383-389.
- Altrichter, M. & Boaglio, G.I. (2004) Distribution and relative abundance of peccaries in the Argentine Chaco: associations with human factors. *Biol. Conserv.*, 116, 217-225.
- Bodmer, R.E. (1989) Ungulate biomass in relation to feeding strategy within Amazonian forests. *Oecologia*, 81, 547-550.
- Bodmer, R.E. (1991) Strategies of seed dispersal and seed predation in Amazonian ungulates. *Biotropica*, 23, 255-261.
- Burnham, K. & Anderson, D. (2004) Multimodel inference. Understanding AIC and BIC in model selection. *Sociol. Method. Res.*, 33, 261-304.
- Carbajal-Borges, J.P., Godínez-Gómez, O. & Mendoza, E. (2014) Density, abundance and activity patterns of the endangered *Tapirus bairdii* in one of its last strongholds in southern Mexico. *Trop. Conserv. Sci.*, 7, 100-114.
- Di Bitetti, M.S., Paviolo, A., Ferrari, C.A., De Angelo, C. & Di Blanco, Y. (2008) Differential responses to hunting in two sympatric species of brocket deer (*Mazama americana* and *M. nana*). *Biotropica*, 40, 636-645.
- Esri (2008) *ArcGis version 9.3*. Available at <http://www.esri.com/software/arcgis>.
- Gallina, S. & Mandujano, S. (2009) Investigaciones sobre ecología, conservación y manejo de ungulados silvestres en México. *Trop. Conserv. Sci.*, 2, 128-139.
- González, R.M., Gallina, S., Mandujano, S. & Weber, M. (2008) Densidad y distribución de ungulados silvestres en la Reserva Ecológica El Edén, Quintana Roo, México. *Acta Zool. Mex. (n.s.)*, 24, 73-93.
- Hines, J.E. (2006) *PRESENCE. Software to estimate patch occupancy and related parameters*. Available at <http://www.mbr-pwrc.usgs.gov/software.html>.
- IUCN (2014) *The IUCN Red List of threatened species. Version 2014.2*. Available at www.iucnredlist.org. Downloaded on 24 October 2014.

- Keuroghlian, A., Eston, D.P. & Longland, W.S. (2004) Area use by white-lipped and collared peccaries (*Tayassu pecari* and *Tayassu tajacu*) in a tropical forest fragment. *Biol. Conserv.*, 120, 411–425.
- Kovach Computing Services (2001) *Software Oriana version 4*. Available at <http://www.kovcomp.co.uk/oriana/oribroc.html>.
- Lorenzo, C., Espinoza, E.E., Naranjo, E.J. & Bolaños, J.E. (2008) Mamíferos terrestres de la frontera sur de México. In: C. Lorenzo, E. Espinoza & J. Ortega (Eds.) *Avances en el estudio de los mamíferos de México, Vol. II*, pp. 147–164. Asociación Mexicana de Mastozoología, A.C., Chiapas.
- Mackenzie, D.I., Nichols, J.D., Royle, J.A., Pollock, K.H., Bailey, L.L. & Hines, J.E. (2006) *Occupancy Estimation and Modeling. Inferring Patterns and Dynamics of Species Occurrence*. Elsevier, California.
- Mandujano, S. (2007) Carrying capacity and potential production of ungulates for human use in a Mexican tropical dry forest. *Biotropica*, 39, 519–524.
- March, I.J. (2005) *Tayassu pecari*. In: G. Ceballos & G. Oliva (Eds.) *Los mamíferos silvestres de México*, pp. 512–513. Conabio & Fondo de Cultura Económica, Ciudad de México.
- March, I.J. & Mandujano, S. (2005) *Tayassu tajacu*. In: G. Ceballos & G. Oliva (Eds.) *Los mamíferos silvestres de México*, pp. 512–513. Conabio & Fondo de Cultura Económica, Ciudad de México.
- March, I.J. & Naranjo, E. (2005) *Tapirus bairdii*. In: G. Ceballos & G. Oliva (Eds.) *Los mamíferos silvestres de México*, pp. 512–513. Conabio & Fondo de Cultura Económica, Ciudad de México.
- Mayer, J.J. & Wetzel, R.M. (1987) *Tayassu pecari*. *Mammalian Species*, 293, 1–7.
- Mendoza, E., Fuller, T.L., Thomassen, H.A., Buermann, W., Ramírez-Mejía, D. & Smith, T.B. (2013) An assessment of the effectiveness of the Mesoamerican Biological Corridor for protection potential baird's tapir (*Tapirus bairdii*) habitat in southern Mexico. *Integrative Zool.*, 8, 34–46.
- Naranjo, E.J. (2009) Ecology and conservation of baird's tapir in Mexico. *Trop. Conserv. Sci.*, 2, 140–158.
- Naranjo, E.J. & Bodmer, R.E. (2007) Source-sink systems and conservation of hunted ungulates in the Lacandon forest, Mexico. *Biol. Conserv.*, 138, 412–420.
- Naranjo, E.J., Guerra, M.M., Bodmer, R.E. & Bolaños, J.E. (2004) Subsistence hunting by three ethnic groups of the Lacandon forest, Mexico. *J. Ethnobiol.*, 24, 233–253.
- Núñez, R., Miller, B. & Lindzey, F. (2000) Food habits of jaguar and pumas in Jalisco, Mexico. *J. Zool. London*, 252, 373–379.
- Olgún, H.C., León, L., Melo, U. & Sánchez-Cordero, V. (2008) Mastofauna de la región de Los Chimalapas, Oaxaca, México. In: C. Lorenzo, E. Espinoza & J. Ortega (Eds.) *Avances en el estudio de los mamíferos de México, Vol. II*, pp. 165–216. Asociación Mexicana de Mastozoología, A.C., Chiapas.
- Ortega del Valle, D., Carranza, T. & Martínez, J. (2012) *Una mirada desde el corazón de la jícara de oro. Experiencias de conservación en la Selva Zoque de Los Chimalapas*. WWF-México, Oaxaca.
- Peres, C.A. (1996) Population status of white-lipped *Tayassu pecari* and collared peccaries *T. tajacu* in hunted and un hunted Amazonian forests. *Biol. Conserv.*, 77, 115–123.
- Pérez-Cortes, S., Enríquez, P.L., Sima-Panti, D., Reyna-Hurtado, R. & Naranjo, E.J. (2012) Influencia de la disponibilidad de agua en la presencia y abundancia de *Tapirus bairdii* en la selva de Calakmul, Campeche, México. *Rev. Mex. Biodiv.*, 83, 753–761.
- Pukazhenthii, B., Quse, V., Hoyer, M., van Engeldorp, H., Sanjur, O. & Brown, J.L. (2013) A review of the reproductive biology and breeding management of tapirs. *Integrative Zool.*, 8, 18–34.
- Reyna-Hurtado, R. (2007) *Social ecology of the white-lipped peccary (Tayassu pecari) in the Calakmul forest, Campeche, Mexico*. Ph.D. Thesis, Florida University.

- Reyna-Hurtado, R. (2009) Conservation status of the white-lipped peccary (*Tayassu pecari*) outside the Calakmul Biosphere Reserve in Campeche, Mexico: a synthesis. *Trop. Conserv. Sci.*, 2, 159-172.
- Reyna-Hurtado, R., Chapman, C.A., Calme, S. & Pedersen, E.J. (2012) Searching in heterogeneous and limiting environments: foraging strategies of white-lipped peccaries (*Tayassu pecari*). *J. Mamm.*, 93, 124-133.
- Reyna-Hurtado, R., Naranjo, E., Chapman, C.A. & Tanner, G.W. (2009) Hunting and the conservation of a social ungulates: the white-lipped peccary *Tayassu pecari* in Calakmul, Mexico. *Oryx*, 44, 89-96.
- Reyna-Hurtado, R.A. (2002) *Hunting effects on the ungulate species in Calakmul forest, Mexico*. Mc. Thesis, Florida University.
- Rovero, F. & Marshall, A.R. (2009) Camera trapping photographic rate as an index of density in forest ungulates. *J. Appl. Ecol.*, 46, 1011-1017.
- Salas, S.H., Schibli, L. & Torres, E. (2001) La importancia ecológica y biológica. In: A. Aparicio Cid (Ed.) *Chimalapas, la última oportunidad*, pp. 29-47. Word Wildlife Found & Secretaria del medio Ambiente, Recursos Naturales y Pesca, Ciudad de México.
- Santos-Fita, D., Naranjo, E.J. & Rangel-Salazar, J.L. (2012) Wildlife uses and hunting patterns in rural communities of the Yucatan Peninsula, Mexico. *J. Ethnobiol. Ethnomed.*, 8, 1-38.
- SEMARNAT (2010) *Norma Oficial Mexicana NOM-059-SEMARNAT-2010. Protección ambiental-Especies nativas de México de flora y fauna silvestres-Categorías de riesgo y especificaciones para su inclusión. Exclusión o cambio-Lista de especies en riesgo*. Diario Oficial, 2010.
- Tejeda-Cruz, C., Naranjo, E.J., Cuarón, A.D., Perales, H. & Cruz-Burguete, J.L. (2009) Habitat use of wild ungulates in fragmented landscapes of the Lacandon forest, southern Mexico. *Mammalia*, 73, 211-219.
- Tobler, M.W., Carrillo-Percegué, S.E., Leite, R., Marea, R. & Powell, G. (2008) An evaluation of camera traps for inventorying large- and medium-sized terrestrial rainforest mammals. *Anim. Conserv.*, 11, 169-178.
- Weber, M. & González, S. (2003) Latin American deer diversity and conservation: a review of status and distribution. *Ecoscience*, 10, 443-454.
- Zar, J.H. (1999) *Biostatistical Analysis*. Prentice Hall, Nueva Jersey.