Diversity of large and medium mammals in Juchitan, Isthmus of Tehuantepec, Oaxaca, Mexico

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Abstract

Diversity of large and medium mammals in Juchitan, Isthmus of Tehuantepec, Oaxaca, Mexico.— The Isthmus of Tehuantepec in Oaxaca, Mexico, is one of the country's most important regions from a zoogeographical perspective due to the large number of endemic Neotropical species found there. Between September 2007 and August 2008, we sampled medium–sized and large mammals in the Juchitan municipality and compared their diversity in two areas with distinct levels of anthropogenic impact, defined according to estimates of human activities, livestock density and habitat degradation, We obtained 167 records of 18 species, with a 79% representation according to species accumulation models in both areas. The highest species richness and alpha diversity were recorded in the preserved area, whereas the disturbed area exhibited half the diversity found in the preserved area. A high interchange of species was also observed between zones. The two species with the largest number of records were *Urocyon cinereoargenteus* (n = 52) and *Didelphis virginiana* (n = 42). In both areas, the highest relative abundance occurred during the rainy season. Habitat degradation and human activities seem to affect the diversity of mammal species in the region.

Key words: Biodiversity, Conservation, Disturbance, Isthmus of Tehuantepec, Tropical deciduous forest.

Resumen

La diversidad de los mamíferos de talla grande y mediana en Juchitán, istmo de Tehuantepec, Oaxaca, México.— El istmo de Tehuantepec en Oaxaca, México, es una de las regiones más importantes del país desde el punto de vista zoogeográfico, ya que alberga una gran cantidad de especies endémicas neotropicales. Entre septiembre de 2007 y agosto de 2008, se realizó un muestreo de mamíferos de talla mediana y grande en el municipio de Juchitán, y comparamos su diversidad en dos zonas con distintos niveles de impacto antropogénico definido de acuerdo con las estimaciones de las actividades humanas, la densidad de ganado y la degradación del hábitat. Se obtuvieron 167 registros de 18 especies, con una representatividad del 79% según el modelo de acumulación de especies en ambas zonas. La mayor riqueza de especies y de diversidad alfa se registraron en la zona conservada, mientras que la zona perturbada presenta la mitad de la diversidad encontrada en la zona conservada. Se observó un fuerte intercambio de especies entre ambas zonas. Dos especies, *Urocyon cinereoargenteus* (n = 52) y *Didelphis virginiana* (n = 42), tuvieron el mayor número de registros. En ambas zonas, la mayor abundancia relativa se observó durante la época de lluvias. La degradación del hábitat y las actividades humanas al parecer afectan a la diversidad de especies de mamíferos en la región.

Palabras clave: Biodiversidad, Conservación, Perturbación, Istmo de Tehuantepec, Bosque deciduo tropical.

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Introduction

One of the issues of greatest interest in ecology is the relationship between habitat structure and the structure of animal communities. Habitat disturbance and habitat fragmentation influence both the original plant communities and the heterogeneity and complexity of the entire ecosystem. This, in turn, influences the availability of resources, and affects the birth and death rates of several species, thus affecting vertebrate diversity (August, 1983; Soule et al., 1992; Collins et al., 1995; Murcia, 1995; Zarza, 2001). Large and medium–sized mammals are particularly sensitive to habitat changes, and they are common victims of poaching and illegal trading (Michalski & Peres, 2005; Laurance et al., 2006). The functional significance of these species lies in their ecological roles, such as seed dispersal and predation on numerous plant species. These functional roles may change the structure and composition of the ecosystem. Moreover, these species influence the community structure and complexity on the trophic levels in which they are involved, due to their regulatory role as preys and predators (Roemer et al., 2009). The loss of these organisms could have devastating effects because they contribute in many ways to the functioning of the natural ecosystem (Alonso et al., 2001; Bolaños & Naranjo, 2001). Given the importance of these species, studies identifying and predicting the environmental changes that may affect their diversity are essential, and in such studies, relative abundance and species diversity are usually used as indicators (Carrillo et al., 2000).

The Isthmus of Tehuantepec (Mexico) is one of most diverse regions within this country (Briones–Salas & Sánchez–Cordero, 2004; González et al., 2004). Furthermore, this area has a particular importance from a zoogeographical perspective because it lies in the zone where the Nearctic and Neotropical regions overlap. This important corridor between the Atlantic and costal Pacific plains represents a significant barrier for highland mammal species, and also favors a high degree of endemicity (Peterson et al., 1999; García–Trejo & Navarro, 2004; Barragan et al., 2010). However, this diversity may be declining dramatically, due to hunting and habitat modification derived from crops and livestock. Therefore, the aim of this study was to identify the differences in diversity, in terms of abundance and heterogeneity, of medium–sized and large mammals in two areas with differing degrees of anthropogenic disturbance. If anthropogenic environmental changes affect mammal communities, we hypothesized that the area with greater human disturbance would exhibit a lower diversity of medium and large mammals.

Methods

The study area is located in the coastal plain of Tehuantepec, northeast of the city of Juchitan, Oaxaca, Mexico, at 200 m a.s.l., within the coordinates 94° 55' to 94° 50' W, and 16° 38' to 16° 30' N (fig. 1). The climate is sub–humid and warm. There is a marked dry season from December to May, and a rainy season from June to November, with an average annual rainfall of 932.2 mm. The annual average temperature is 27.6°C (Garcia, 1988). The first sampling area was located on the hill of Tolistoque, northeast of Juchitan (16° 35' 5.91" N, 94° 52' 20.63" W) within an area —protected by the regional indigenous communities— known as Ojo de Agua Tolistoque Protected Communal Area (Ortega et al., 2010). The vegetation is tropical deciduous forest. The second sampling area was south of the Protected Communal Area northeast of Juchitan (16° 32' 12.95" N, 94° 50' 53.95" W), in an area of secondary vegetation. This area is dedicated to farming activities, with gallery forest areas around irrigation canals, and tropical deciduous forest remnants (fig. 1).

We applied an indirect sampling method. Such methods are sometimes the only option available to study the distribution and abundance of inaccessible vertebrates such as medium–sized and large mammals (Sutherland, 1996). These methods also have some advantages over direct methods as they are easier to implement and independent of the time of day, which is important when target species are nocturnal, cryptic and difficult to capture or recapture because their traces remain for long periods of time (Bilenca et al., 1999; Simoneti & Huareco, 1999; Aranda, 2000; Carrillo et al., 2000; Ojasti, 2000).

In both areas the level of disturbance was evaluated according to the index proposed by Peters & Martorell (2000) and Martorell & Peters (2005). In order to measure the contribution of different agents, we recorded 14 metrics at each site by means of two 50 m long transects at each site (table 1). Disturbance was measured on a scale of 0–100, where zero is the least disturbance. The values were calculated as follows:

$$\begin{aligned} \text{Disturbance} = {} & 3.41\ \text{Goat} - 1.37\ \text{Catt} + \\ & + 27.62\ \text{Brow} + 49.20\ \text{Ltra} - 1.03\ \text{Comp} + \\ & + 41.01\ \text{Fuel} + 0.12\ \text{Tran} + 24.17\ \text{Prox} + \\ & + 8.98\ \text{Core} + 8.98\ \text{Luse} - 0.49\ \text{Fire} + \\ & + 26.94\ \text{Eros} + 17.97\ \text{Isla} + 26.97\ \text{Toms} + 0.2 \end{aligned}$$

The medium and large mammals were classified using the system of Robinson & Redford (1986), who divided mammals into four categories based on a logarithmic scale of average weight: small < 100 g; medium > 100~ < 1,000 g; large > 1,000 g < 10,000 g; very large > l0,000 g. To search for traces of medium and large mammals, monthly samples were taken from September 2007 to August 2008. During each period, four transects (two in each zone) of 4.5 km each were sampled, resulting in a total sampling of 108 km walked in each zone.

We used a Mexican mammal field guide (Aranda, 2000) to identify tracks and feces, and compared these with the reference material on traces of mammals of Oaxaca, of the Collection of Mammalogy (OAX.MA.026.0497) at the Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR–Oaxaca), National Polytechnic Institute (IPN).

Ten camera traps (Cuddeback Expert ®) were also used for the last six sampling periods to confirm the presence of the species (five in each zone). These were placed at approximately 1.5 km from each other.

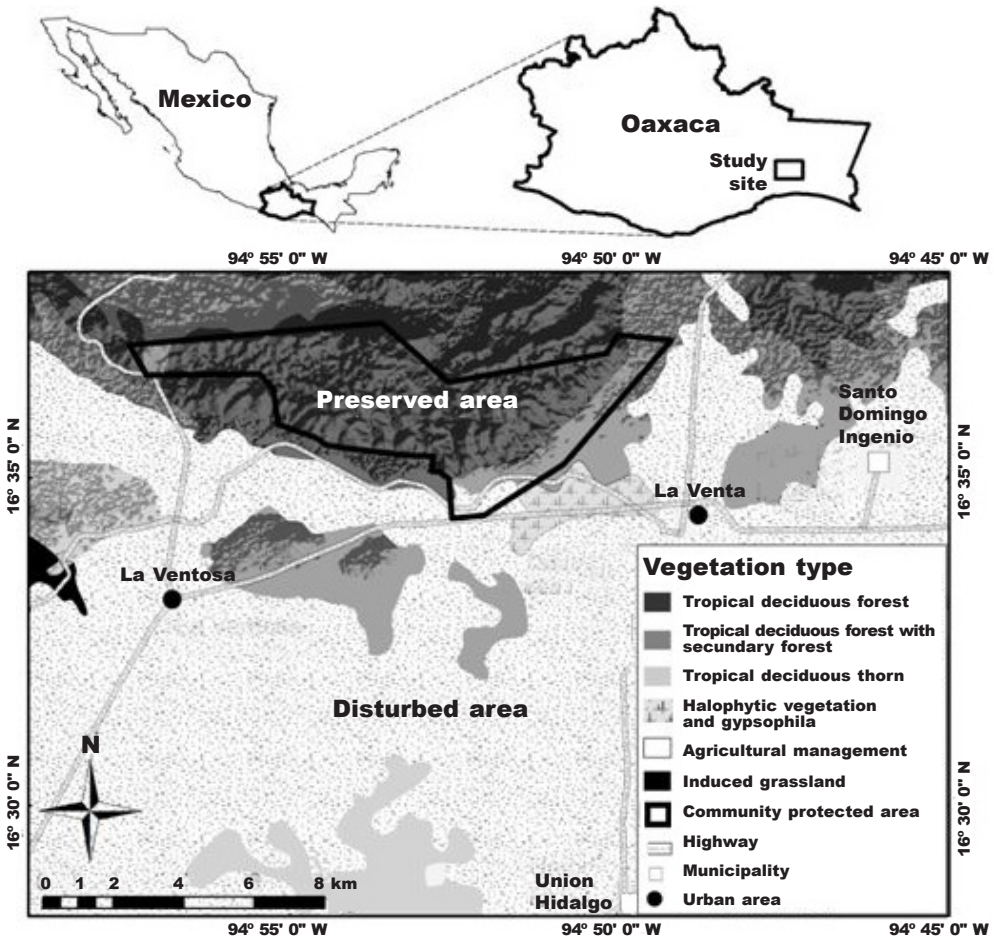

Fig. 1. Geographic location and vegetation types around the study area in the Isthmus of Tehuantepec, Oaxaca, Mexico.

Fig. 1. Ubicación geográfica y tipos de vegetación en el entorno de la zona de estudio en el istmo de Tehuantepec, Oaxaca, México.

Each camera trap was installed approximately 40–50 cm above ground level, depending on the topography and slope of the sampling area. The camera circuit was programmed to remain active for 24 hours, and the camera locations were geo–referenced with a GPS (Garmin Etrex®). Cameras were checked monthly. Photographic records were prepared according to Botello et al. (2007) and deposited in the Collection of Mammalogy (OAX. MA.026.0497) of CIIDIR–OAX.

Data analysis

Species inventories were evaluated using Clench's asymptotic models of species accumulation with the program Species Accumulation, for which the data were previously randomized 100 times with the EstimateS program, version 8.0 (Colwell, 2000). We also calculated the sampling effort required to include 95% of the species in the inventories.

The relative species abundance index for each area and season (dry and rainy) was calculated as the total number of signs found per species, divided by the distance sampled (Carrillo et al., 2000). A Mann–Whitney *U* test was applied to determine whether there were significant differences in relative abundance between areas and seasons (Zar, 1999).

The species diversity of each area and season was determined according to the Shannon–Wiener entropy index (*H'*). Dominance (*D*) was estimated with the Berger–Parker index (Whittaker, 1972), which is an indirect method to measure species diversity: The lower the dominance, the higher the species diversity, and vice versa. Pielou's eveness index (*J'*) was determined as the proportion of diversity observed in relation to the maximum diversity expected (Magurran, 1988). To compare the Shannon index between areas, we applied the Student's *t* test modified by Hutchenson (Magurran, 1988).

Table 1. Metrics of the disturbance index of livestock density variables, human activities variables and land degradation variables.

Tabla 1. Valores del índice de perturbación de las variables relativas a la densidad de ganado, las actividades humanas y la degradación del suelo.

Variable	Acronym	Description
Livestock density		
Goat droppings frequency	Goat	Computed from presence of goat dung in ten randomly chosen 1 m squares along the transect; frequency was defined as the fraction of squares with positive records.
Cattle droppings frequency	Catt	Bovine and equine dung, computed as for Goat.
Browsing	Brow	All shrubs and trees that were rooted within the transect were thoroughly examined for signs of browsing. The ratio of browsed to total plants was calculated as an index of browsing intensity.
Livestock trail density	Ltra	Livestock uses well–defined trails to move while browsing. The number of these per meter along the transect was recorded.
Soil compaction	Comp	The constant trampling of livestock along tracks causes soil compaction, which affects water infiltration. A cylinder of 10.4 cm of diameter was driven 4 cm into the ground in a randomly chosen trail. 250 ml of water were then poured into the cylinder, and the time needed for complete infiltration was recorded. This procedure was repeated on a spot with no evidence of trampling. The degree of soil compaction was calculated as the ratio of the time recorded on the trail and in the untrampled terrain.
Human activities		
Fuelwood extraction	Fuel	Peasants cut branches for fuel. This metric was measured as Brow, but taking machete cuts into account.
Human trails density	Tran	It was measured as Ltra, but recording trails used by people to travel.
Settlement proximity	Prox	Proximity was defined as the multiplicative inverse of the distance to the closest towns in km.
Contiguity to activity cores	Core	A core was defined as a place where human activities normally take place, such as houses, cornfields, mines and chapels. Contiguity was recorded at each transect if a core was less than 200 m away. The fraction of transects contiguous to a core was used as a metric.
Land use	Luse	In several studies the percent of land cover devoted to agriculture, cultivated or induced pastures, or urban areas is used as a measure of disturbance. Here, the fraction of the study area used for these purposes was visually estimated.
Evidence of fires	Fire	Most of these are initiated by people, either to clear an area, promote pasture growth for livestock, or accidentally. The presence or absence of evidence at a study site was recorded as one or zero.

Table 1. (Cont.)

Variable	Acronym	Description
Land degradation		
Erosion	Eros	Overgrazing and human activities increase erosion. We only considered spots where the soil showed tracks of strong and frequent removal of material by water (such as ravines) as unequivocal evidence of erosion. Twenty points were selected randomly along the transect for its estimation, and the fraction of eroded spots was recorded.
Presence of soil islands	Isla	When severe erosion takes place, soil is only held where large shrubs are rooted. As a result, a landscape of small mounds can be observed. The presence or absence of these "islands" was recorded either as one or zero.
Totally modified surfaces	Toms	Land may be so severely modified that measuring most of the previous metrics makes no sense, as it can happen on a paved road, a house, or on artificial water–ways. When the transect crossed such surfaces, their cover was measured by means of the line intercept method.

Furthermore, to analyze diversity more effectively, we calculated the effective number of species (true diversity) to know how much diversity was lost or gained between areas and between seasons. We used the exponential Shannon–Wiener index, in which all the species in the community are weighted in exact proportion to their abundance (Jost, 2006; Moreno et al., 2011).

Beta diversity (change in species composition) between areas was evaluated using the Whittaker index (Wilson & Schmida, 1984; Magurran, 1988), which in this case can have values between 1 and 2, and the degree of similarity between habitats was evaluated according to the Jaccard similarity index (Magurran, 1988).

Results

The least disturbed area was located on the Tolistoque hill, hereafter called the 'preserved area'. The area located southeast of La Venta was named the 'disturbed area', and it showed greater disturbance due to its proximity to centers of activity, changes in land use, and islands (table 2).

Clench's species accumulation model was the best choice for the data, although asymptote was not reached in the study area. The model predicted 23 species (a = 6,806 and b = 0.297), meaning that our mammal inventory was 79% complete. According to this model, a total of 63 months would be required to record 95% of the medium and large mammal species living in the study site.

We obtained 167 records, of which 61% were traces and 28% were feces. Of all the records, 79 (47.30%) were found in the preserved area and 88 (52.70%) in the disturbed area (table 3). The records belonged to 18 species, 18 genera, 12 families and six orders of medium and large mammals (table 4). Through the use of camera traps, 82 photographs of mammals were obtained, confirming the presence of ten of the species recorded by indirect methods.

In terms of relative abundance, *Urocyon cinereoargenteus* was the species with the highest abundance in the preserved area (0.23/km), while in the disturbed area the most abundant species were *Didelphis virginiana* (0.29/km) and *U. cinereoargenteus* (0.25/km) (table 4). According to the Mann–Whitney test, significant differences were found between the relative abundance in the two study areas (N_1 = 79, N_2 = 88, U = 63.5, p = 0.032). *U. cinereoargenteus* and *D. virginiana* were the most abundant species during the two seasons. In both areas, the highest relative abundance of species was observed in the rainy season. However, the seasonal variation in relative abundance was not statistically significant (U = 72, p = 0.76, and U = 23.5, p = 0.72, in preserved and disturbed areas, respectively).

The preserved area exhibited the highest diversity (H' = 2.33) and evenness (J' = 0.82), and the lowest dominance (D = 30.86) (table 4). Significant differences were observed in the Shannon–Wiener index between the diversity of the preserved and disturbed areas (t = 4.9, d.f. = 160). The highest diversity was recorded during the rainy season in the preserved area

Table 2. Values obtained with the disturbance index in two areas with different levels of perturbation near the Isthmus of Tehuantepec, Oaxaca. (For the abbreviations of variables see table 1.)

Tabla 2. Valores obtenidos con el índice de perturbación en dos zonas con diferentes grados de perturbación en el istmo de Tehuantepec, Oaxaca. (Para las abreviaturas de las variables ver tabla 1.)

	Area	
	Preserved	Disturbed
Livestock density		
Goat	0.000	0.000
Catt	0.400	0.400
Fire	0.000	0.000
Brow	0.027	0.050
Ltra	0.020	0.020
Comp	0.185	0.260
Human activities		
Fuel	0.126	0.046
Fire	0.000	0.000
Tran	0.051	0.040
Prox	0.191	0.301
Core	0.000	1.000
Luse	0.000	1.000
Land degradation		
Eros	0.125	0.700
Isla	0.000	1.000
Toms	0.000	0.050
Total disturbance	14.339	67.074

(*H'* = 2.30). This area also showed lower dominance (*D* = 18.18) and higher evenness ($J^{'}$ = 0.92). No significant differences were found in the Shannon index between seasons for the preserved and disturbed areas (*t* = 1.40, g.l. = 80.56 and *t* = 1.68, g.l. = 73.60, respectively).

According to the measure of true diversity, the diversity of medium and large mammals in the preserved area was double that of the disturbed area. During the dry season, the diversity of mammal species was lower than during the rainy season in both the preserved (24%) and disturbed areas (28%).

Our data revealed a high turnover of species between zones (βw = 1.48). Of the 17 species recorded in this study, eight were found in both areas, while nine species were exclusively found in the preserved area. *Spilogale gracilis* was recorded only in the disturbed area. Finally, the two areas showed a similarity of 47% in species composition according to the Jaccard similarity index.

Discussion

The indirect method was an efficient way to study mammal diversity in this study. Using this method we recorded 18 species of medium–sized and large mammals, whereas the camera traps only recorded the presence of ten species. However, this sampling was not standardized, as camera trapping was only used during the last six months of sampling. Consequently, we recommend the use of complementary methods to record a greater number of species. Indirect methods could however underestimate species richness and abundance as they focused mainly on recording terrestrial species and can overlook tree–dwellers (Aranda, 2000). Combining various techniques also reduces the influence of environmental and methodological factors, providing a more reliable estimate of diversity and abundance in a particular study site (Botello et al., 2008). Zarco (2007) recorded the same number of species as in this study using camera traps in the same vegetation type. This technique facilitates the determination of species' activity patterns, but it is expensive to implement compared to indirect methods.

The species richness found in the area is equivalent to 34.62, 45.00, 57.89 and 66.67% of the total species, genera, families and orders of medium and large mammals present in Oaxaca. These values are higher than the 17 species reported by Santos–Moreno & Ruiz–Velásquez (2011) in the region of Isthmus of Tehuantepec in similar vegetation type, while Monroy–Vilchis et al. (2011) recorded 19 species with camera traps in an area where the main vegetation type, was tropical deciduous forest. These results show that the study area maintains a diverse community of medium and large mammals, despite the effects of disturbance (habitat deterioration and a high presence of human activities) in the south of the Protected Communal Area.

The species richness found at the site, however seems low compared to the study by Cervantes & Yepez (1995) around Salina Cruz, in the coastal plain of Tehuantepec, Oaxaca. In their study, the authors recorded 30 species of medium–sized and large mammals. This difference may be due to the fact that Cervantes & Yepez (1995) conducted their study in tropical deciduous forest, mangrove forest, thorn scrub and dune vegetation, so a greater number of species occupying different ecological niches and ecosystems was recorded. This was seen in the case of *Lontra longicaudis,* for example, which is located only in aquatic environments.

The number of species found in our study was similar to that reported by Lavariega et al. (2012) in the municipality of Santiago Camotlán. However, their study was conducted in cloud forest, oak forest, evergreen forest, crop fields and coffee plantations. Species typical of highly conserved sites, such as *Panthera onca* and *Tamandua mexicana*, are reported in some of these habitats. They are also recorded in association with cattle in disturbed areas, but in a lower proportion (Treves & Karanth, 2003).

According to the Clench model, the species inventory is not fully represented, and it is likely that more species are still to be found in the area. We

Table 3. Number of records of medium and large mammals recorded in La Venta, Juchitan. Record types: F. Footprint; f. Feces; Sr. Skeletal remains; S. Sighting.

Tabla 3. Número de registros de especies de mamíferos de talla mediana y grande registrados en La Venta, Juchitán. Tipos de registros: F. Huella; f. Excrementos; Sr. Restos óseos; S. Avistamiento.

	Preserved area					Disturbed area				
	F	f	Sr	S	Total	F	f	Sr	S	Total
Canis latrans	1	4	–	–	5	–	–	–	–	–
Coendou mexicanus	–	–	3	–	3	–	–	–	–	–
Conepatus leuconotus	3	–	–	–	3	–	–	–		–
Dasypus novemcinctus	1	–	2	–	3	12	–	1	–	13
Didelphis virginiana	9	–	1	–	10	32	–	–	–	32
Herpailurus yagouaroundi	1	–	–	–	1	1	–	–	–	1
Leopardus pardalis	2	–	–	–	2	–	–	–	–	–
Mustela frenata	1	–	–	–	1	–	–	–	–	–
Nasua narica	1	–	–	–	1	1	–	–	–	1
Odocoileus virginianus	9	1	1	–	11	–	–	–	–	–
Pecari tajacu	–	–	3	–	3	–	–	–	–	–
Philander opossum	1	–	–	–	1	1	–	–	–	1
Procyon lotor	1	–	–	–	1	7	–	–	–	7
Puma concolor	2	1	–	–	3	–	–	–	–	–
Spilogale putorius	–	–	–	–	–	3	–	–	–	3
Sciurus aureogaster	–	–	–	3	3	–	–	–	–	–
Sylvilagus floridanus	2	–	–	1	3	2	1	–	–	3
Urocyon cinereoargenteus	6	–	18	1	25	8	18	–	1	27

recorded the presence of *Ateles geoffroyi* at the north of the Tolistoque hill on April 2007 (16° 35' 52.97" N / 94° 52' 35.56" W), although its presence had not been reported by Ortiz–Martinez et al. (2008) in a study on the distribution of *Alouatta palliata* and *A. geoffroyi*. We did not include this latest species in our analysis given that we saw it only once, several months before the present study, in the north of the preserved area. By including *A. geoffroyi*, our inventory would reach 83% of completeness, and we would be missing only three species.

One factor that could affect estimates of the relative abundance of species is the difference in the detectability of their traces, which is related to the size of the species (Litvaitis et al., 1994), their habits, their inclination while walking, and the type of substrate. It is therefore more likely to find tracks of *D. virginiana* because their weight facilitates track impressions and makes them easier to detect. On the contrary, the genus *Sciurus* may be more abundant than deer *Odocoileus* sp., but their habits are primarily arboreal, making track observations more difficult. It is noteworthy that the rainy season facilitated the record of tracks, mainly in areas of flooding, and at this season we recorded the greatest abundance of species.

The relative abundance of *Dasypus novemcinctus* was lower than that reported by Navarro (2005) in secondary forest and oak forest, as this author reported densities of 0.2 individuals/km at each vegetation type. Likewise, Perez–Irineo & Santos–Moreno (2012) reported an even higher relative abundance for the same species (0.07 individuals/km) in a deciduous forest in northeastern Oaxaca. In our study, particularly the disturbed area is affected by strong human intervention, which may explain the low observed abundance of this species. Hunting may also contribute to decrease the abundance and increase the secretive and evasive behavior of some species. It is well known that medium and large sized mammal species are the most affected by hunting. In our study area local inhabitants and people from the surroundings were observed hunting. The most hunted species for meat consumption are armadillos *D. novemcinctus*, squirrels *Sciurus aureogaster* and rabbits *Silvilagus floridanus*.

The high abundance of *U. cinereoargenteus* and *D. virginiana* corresponds with the findings of Orjuela & Jimenez (2004) and Luna (2005), who report that the fox has the highest relative abundance values. These high values of abundance may be related to

Table 4. List of species of medium and large mammals recorded in La Venta, Juchitan, following the taxonomic arrangement proposed by Ramirez et al. (2005) and including the number of records (n) and relative abundance (Rel ab) in each of the areas and seasons. Index of diversity *α* and *β*. Status conservation NOM 059 (* Threatened, ** Endangered). (For the abbreviations of record types, Rec, see table 3.)

Tabla 4. Lista de las especies de mamíferos de talla mediana y grande registradas en La Venta, Juchitán, siguiendo la taxonomía propuesta por Ramírez et al. (2005) e incluyendo el número de registros (n) y la abundancia relativa (Rel ab) en cada zona y temporada. Índices de diversidad α *y* β*. Estado de conservación NOM 059 (* Amenazada, ** En peligro). (Para las abreviaturas de los tipos de registro, Rec, véase la tabla 3.)*

		Preserved area						Disturbed area					
		Rainy		Dry		Total		Rainy		Dry		Total	
Taxonomic list	Rec	n	Rel ab	n	Rel ab	n	Rel ab	n	Rel ab	n	Rel ab	n	Rel ab
O. Didelphimorphia / F. Didelphidae													
Didelphis virginiana	F, P	3	0.0556	7	0.1296	10	0.0926	21	0.3889	11	0.2037	32	0.2963
Philander oposum	F	1	0.0185	0	0.0000	1	0.0093	1	0.0185	0	0.0000	1	0.0093
O. Cingulata / F. Dasypodidae													
Dasypus novemcinctus	F, Sr, P	3	0.0556	0	0.0000	3	0.0278	11	0.2037	2	0.0370	13	0.1204
O. Canivora / F. Canidae													
Canis latrans	F, f, P	3	0.0556	2	0.0370	5	0.0463		–		–	0	0.0000
Urocyon cinereoargenteus	F, f, S, P	6	0.1111	19	0.3519	25	0.2315	11	0.2037	16	0.2963	27	0.2500
O. Canivora / F. Felidae													
*Herpailurus yagouaroundi**	F	0	0.0000	1	0.0185	1	0.0093	1	0.0185	0	0.0000	1	0.0093
Puma concolor	F	1	0.0185	2	0.0741	3	0.0463		–		–	0	0.0000
*Leopardus pardalis***	F, P	0	0.0000	2	0.03704	2	0.0185					0	
O. Canivora / F. Mustelidae													
Mustela frenata	F	0	0.0000	1	0.0185	1	0.0093		–		–	0	0.0000
O. Carnivora / F. Mephitidae													
Conepatus leuconotus	F, P	1	0.0185	2	0.0370	3	0.0278		–		–	0	0.0000
Spilogale putorius	F, P					0	0.0000	1	0.0185	2	0.0370	3	0.0278
O. Carnivora / F. Procyonidae													
Nasua narica	F	0	0.0000	1	0.0185	1	0.0093	1	0.0185	0	0.0000	1	0.0093
Procyon lotor	F, P	0	0.0000	1	0.0185	1	0.0093	5	0.0926	2	0.0370	7	0.0648
O. Artiodactyla / F. Tayassuidae													
Pecari tajacu	Sr	3	0.0556	0	0.0000	3	0.0278		–		–	0	0.0000
O. Artiodactyla / F. Cervidae													
Odocoileus virginianus	F, f, Sr, P	6	0.1111	5	0.0926	11	0.1019		–		–	0	0.0000
O. Rodentia / F. Sciuridae													
Sciurus aureogaster	F, S	1	0.0185	2	0.0370	3	0.0278		–		–	0	0.0000
O. Rodentia / F. Erethizontidae													
*Coendou mexicanus**	Sr	3	0.0556	0	0.0000	3	0.0278		–		–	0	0.0000
O. Lagomorpha / F. Leporidae													
Sylvilagus floridanus	F, S, P	2	0.0370	1	0.0185	3	0.0278	2	0.0370	1	0.0185	3	0.0278
Total records		33		46		79		54		34		88	
Total species						17						9	

Table 4. (Cont.)

	Preserved area			Disturbed area		
Diversity *α*	Rainy	Dry	Total	Rainy	Dry	Total
Shannon–Wiener	2.304	2.023	2.331	1.653	1.324	1.597
Evenness (*J'*)	0.927	0.789	0.823	0.752	0.739	0.727
Dominance	0.181	0.395	0.308	0.388	0.470	0.363
Effectivenes diversity	10.010	7.563	10.289	5.225	3.757	4.939
% Diversity loss / areas	52.00					
% Loss / seasons	24.449			28.099		

Diversity *β*	
Whittaker	1.48
Jaccard	47%

the characteristics of the species; as omnivores, they are more likely to find food. Consequently, its presence is favored on disturbed areas, or in crops such as sorghum, one of the crops found in the region. We found evidence of sorghum consumption by foxes.

The diversity values recorded for both the preserved and the disturbed areas are lower than those reported by Cueva et al. (2010) (*H'* = 2.4). However, their study area represents a very well preserved area with a greater extension, since it belongs to a biological reserve of about 730 ha in the reserve community Santa Lucía (Ecuador). Contrary, the mammal diversity in our study area is higher than that reported by Perez–Irineo & Santos–Moreno (2012) in a deciduous forest in Oaxaca (*H'* = 0.89). Therefore, our results are significant because this index is usually between 1.5 and 3.5 (Magurran, 1988). It also has been observed that *H'* decreases as disturbance increases, varying from 0.98 to 2.16 according to the degree of the environmental disturbance. The results obtained in this study show that the preserved area is the most diverse, since in this area we found the lowest dominance and the highest evenness.

The total values of diversity indexes in both areas of study show that the populations of medium–sized and large mammals respond to anthropogenic factors, which is reflected in a decrease in their diversity. The preserved area offers the best conditions under which species can develop their activities: find shelter, search for food, and reproduce. The greatest diversity in the preserved area may be due to the greater vegetation richness and greater canopy height, which increases the potential niches and provides more food resources, shelter, protection and escape opportunities to mammals (Gallina et al., 2007). In this area we also found species such as *Puma concolor*, *Leopardus pardalis* and *Pecari tajacu*, which can be considered indicators of well–preserved environments (Cruz–Lara et al., 2004).

The disturbed area may present lower diversity due to several processes found in the area. Human activities such as deforestation, the opening of roads, and noise pollution, affect the habitat directly and indirectly, and modify wildlife activity (Herrera–Flores et al., 2002). Nevertheless, this area still maintains moderate diversity because of the fast–growing vegetation used as habitat and a food source for mammals (Soto & Herrera–Flores, 2003). The presence of water bodies near the site also attracts some mammal species that can find food, water and shelter in the surrounding vegetation (Guzmán–Lenis & Camargo–Sanabria, 2004).

Species diversity can change or remain stable in response to disturbances in the forest. Certain groups of animals, such as foxes, can increase their abundance. Thus, some species may increase their dominance, while the community species richness remains constant in the area. A change like this may decrease the diversity in the area. According to Rocha & Dalponte (2006), the absence of deer and puma in the disturbed area may be because the site does not meet the needs of a predator at on the top of the food chain, such as *P. concolor*, and does not provide a suitable habitat for the occurrence of *O. virginianus*.

The values of beta diversity and similarity suggest a high species turnover. The medium and large mammals found in both areas are considered different communities according to the proposal of Sanchez & Lopez (1988), who propose that for two communities to be similar they should have a similarity of above 66.6%. The high species turnover may be mainly due to the fragmentation of local populations throughout the environment, derived from disturbances such as the presence of the Panamerican Highway 185, which separates the two areas and thus creates a barrier that limits the movement of organisms between areas. Also, the isolation of populations may cause local extinctions due to lack of genetic exchange with other

individuals from different populations (Arroyave et al., 2006). In this way the presence of human activity can have also an adverse effect on the dispersion pattern of animals.

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