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Daily activity patterns and relative abundance of medium and large mammals in a communal natural protected area on the central coast of Oaxaca, Mexico

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Anthropogenic disturbances cause direct and indirect effects on the global decline in biodiversity. For better planning strategies on the conservation of medium and large mammals in Oaxaca, we present an analysis of daily activity patterns of medium and large mammals and their relative abundance in a Communal Natural Protected Area (CNPA) on the central coast of Oaxaca, Mexico. Sampling was carried out between November 2014 and September 2015, during the dry season and the rainy season, using forty camera traps placed within the CNPA El Gavilán and installed along wildlife trails, especially on pathways with clear evidence of use by wildlife. Date records for 10 species of medium and large mammals, obtained with 12,160 day/camera traps. *Leopardus pardalis* was active during the night but exhibited diurnal and nocturnal tendencies. *Herpailurus yagouaroundi*, *Nasua narica*, *Dicotyles angulatus* and *O. virginianus* were defined as cathemeral species. The most abundant medium mammals were *Dasypus novemcinctus* (RAI= 1.23), *Didelphis virginiana* (RAI= 1.15) and *Nasua narica* (RAI= 1.05). Our results can provide insights for the conservation of species in the CNPA El Gavilan. We recommend the continuance of studies on the temporal and seasonal variations of the activity patterns in order to maintain mammalian species conservation.

Key words: Conservation, relative abundance, mammals, Oaxaca, patterns.

INTRODUCTION

Biodiversity is recognized as a living heritage common to all humanity (Manfo, 2013). In the past 30 years remarkable progress has been made towards understanding how the loss of biodiversity affects the functioning of ecosystems and thus affects society (Bradley et al., 2012; Baboo et al., 2017). Biodiversity

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loss might affect the dynamics and functioning of ecosystems (Bargali et al., 1992a, b), and the supply of goods and services migh grow dramatically (Gosain et al., 2015; Mourya et al., 2019).

Anthropogenic disturbances cause direct and indirect effects on the global decline in biodiversity (Cardinale et al., 2012). The direct effects manifest in obvious ways as habitat loss and declines in wildlife population, while the indirect effects present themselves as disruptions in species' behaviours and interspecific interactions (Frey et al., 2017). In this sense, a better understanding of these indirect impacts is needed, especially in those highly threatened ecosystems such as the tropical dry forests (TDF), which are threatened by high deforestation, forest fires, overhunting, wildlife trade, human population growth and tourism development (Ortiz-Pérez et al., 2004).

Camera trapping (CT) has been suggested as an emerging methodology for understanding the indirect impacts described above (Frey et al., 2017); however, this technique has been widely used in ecology and conservation for species' distribution, estimating population densities and inventorying biodiversity (O´Connell et al., 2011; Long et al., 2013). Tipically, CT has focused on the spatial and numerical aspects of species and population ecology (Karanth and Nichols, 1998; Tobler et al., 2008; Linkie and Ridout, 2011) and has less often been used to examine species' behaviours and interactions (Frey et al., 2017).

Daily activity patterns (DAP) of animals in the wild are the product of animals´ adaptations to periodic environmental change and involve anatomic, physiological and behavioral changes (Morgan, 2004). In addition, circadian rhythms allow animals to anticipate environmental changes, making use of the best time of day for certain activities (Kronfeld-Schor and Dayan, 2003). So, DAP can be subdivided in four chrono-ecotypes: diurnal, nocturnal, crepuscular and cathemeral (active behavior occurs equally at night and during the day). These types are not rigid among mammal species but can vary depending on need, as determined by environmental conditions (Erkert et al., 1976).

In Oaxaca State, Mexico, the TDF occupies 16% of its territory and exists as two types of forest: deciduous tropical forest and semi-deciduous tropical forest (Torres-Colín, 2004; Trejo, 2010). In this ecosystem, the animal diversity is high, and particularly in the Planicie Costera del Pacífico (central coast), the overall species' richness is the highest in the state (González-Pérez et al., 2004), and mammal species' richness represents 63.6 and 25.4% of the total species recorded in Oaxaca and Mexico respectively (Briones-Salas and Sánchez-Cordero, 2004). The species richness of mammals, excluding the species of the Chiroptera order, on the central coast of Oaxaca comprises a total of 49 species belonging to 10 families and eight orders (Briones-Salas et al., 2016). They represent one of the most important biological groups because they are involved in a large number of ecological processes within the ecosystems they inhabit (Gonzalez-Christen, 2010). Additionally, one of the strategies for biodiversity conservation is the creation of the Areas Destinadas Voluntariamente a la Conservación (Communal Natural Protected Areas), which operates as a mechanism for the conservation of biodiversity and local natural resources through the participation of local human communities (Rodríguez-Luna et al., 2011).

With the aim of contributing to better planning strategies for the conservation of medium and large mammals in Oaxaca, we present an analysis of daily activity patterns of medium and large mammals and their relative abundance in a Communal Natural Protected Area on the central coast of Oaxaca, Mexico.

MATERIALS AND METHODS

Study area

Fieldwork was conducted in the Communal Natural Protected Area (CNPA) El Gavilán, located in the municipality of Santa María Tonameca on the Central Coast of Oaxaca, Mexico. This CNPA is located in the transition area between the coastal plain and Sierra Madre del Sur physiographic province (Figure 1). The climate is warm and sub-humid, with an annual mean temperature of 26.8°C, anual mean precipitation of 2245 mm (García, 1973) and a long period of drought from November to May (Trejo, 2010). Some tree species in this region are *Ceiba parvifolia* Rose, *Lysiloma divaricata* (Jacq.) JF Macbr, and *Plumeria rubra* L. (Torres-Colín, 2004). The basic forms in these forests are schrubs, vines and cacti (Trejo, 1998), with the predominant species being *Acacia cochliacantha* Willd., *A. farnesiana* (L.) Willd., *A. cornigera* (L) Willd., *A. Ziziphus* amole (Sessé and Moc.) MC Johnst, *Guaiacum coulteri* A. Gray., *Opuntia decumbens* Salm-Dyck, among others (Salas-Morales et al., 2003).

Data collection in the field

Sampling was carried out between November 2014 and September 2015, during the dry season (November-May) and the rainy season (June-September). Forty camera traps (20 Moultrie cameras, 10 Stealth cameras, and 10 Bushnell Trophy cameras) were used to record the activities of medium and large mammals with body mass greater than 1 kg (Chiarello, 2000; Marques and Fabián, 2018). The camera traps were placed in four groups (10 cameras per group) within the CNPA El Gavilán and installed in one-camera stations along wildlife trails, sidewalks and especially on pathways with clear evidence of use by wildlife (Gonthier and Castañeda, 2013). Each station was treated as an independent sampling location, and the distance between each station was 500 m. We set all cameras to a height of approximately 0.5 m above the ground (Botello et al., 2008; Buenrostro Silva et al., 2015). Camera traps were operational 24 h per day, and batteries were frequently replaced to guarantee the camera traps would continue working (Marques and Fabián, 2018).

Classification of chrono-ecotypes

Independent photographic records were classified and quantified

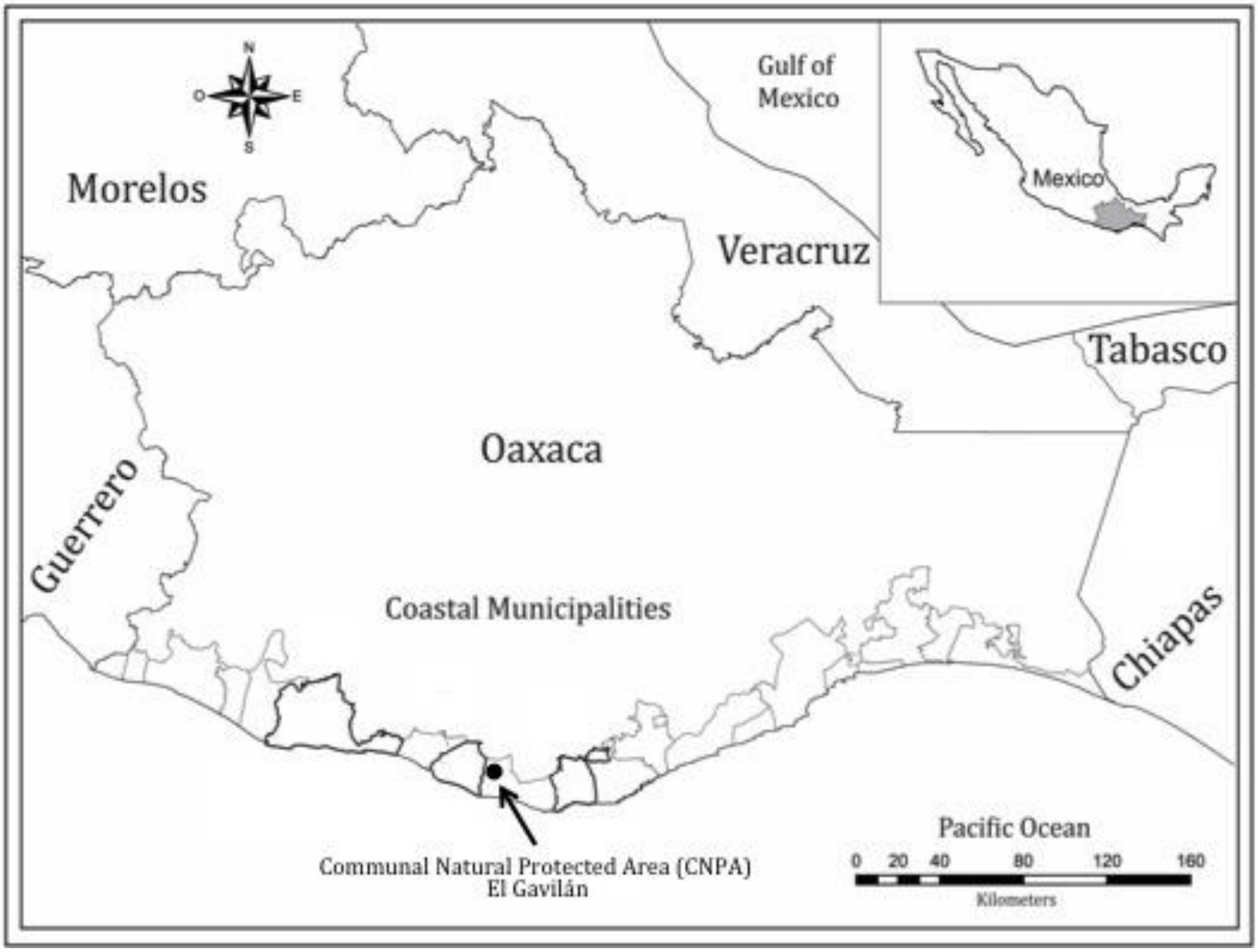

Figure 1. Geographical location of the Communal Natural Protected Area (CNPA) El Gavilán, Oaxaca, Mexico.

according to activity periods defined by Gódinez (2014). The crepuscular morning was considered between 06:00 to 08:00, and crepuscular evening was considered between 18:00 to 20:00. The intervals between these were considered to be diurnal and nocturnal.

Data were analyzed with Oriana software version 4 (Kovach, 2011) for circular statistics using the Raleigh test of uniformity and Rao's spacing test, with the objective of examining data that are distributed in a circular manner, such as time (Lehner, 1996). Circular statistical analyses of 10 species were carried out following Marques and Fabián (2018) procedures; there was a minimun of 11 photo-captures, with the objective of determining the mean vectors of hours in activity, the circular standard deviation and variance and their respective 95% confidence intervals. The mean vector has two properties: mean angle (μ) and length (r). The first is expressed as the time of day angle that represents the mean time of each species' activities. The second property can vary from 0 to 1, with higher values indicating that observations are grouped around the mean, while smaller values indicate that observations are not concentrated (Marques and Fabián, 2018).

A Raleigh test of uniformity (Z) was performance to determine whether simple times were significantly different from what would be expected by chance. Higher values of Z indicate greater concentration of the data around the mean (lower probability that data are uniformly distributed). Probabilities below the significance level of 0.5 indicate that data are not distributed uniformly and are evidence of a trend. Rao's spacing test (U) assesses spacing between adjacent points around a circle. Small p values mean that spacing is not uniform (Marques and Fabián, 2018). The Mardia-Watson-Wheeler test (Zar 2010) was used separately for each of the 10 species recorded to investigate if there were significant differences in time of activity between both seasons (Vera and Fábian, 2018). The Kruskal-Wallis test (Zar, 2010) was used to verify whether there were differences in activity over the 24-h period for the medium and large mammals as a whole. The relative abundance index (RAI) was calculated based on the number of independent photographic records per 100 camera-trap days (sampling effort) with the formula RAI= n/days * 100, where n = number of photocaptures o independant photographic records, days = sampling effort and 100 = standard correction factor. The RAI was calculated for each species in both seasons (dry and rainy) and compared through a *t* test (Zar, 2010). Independent photographic records were considered when there were (1) consecutive photographs of individuals of different species, (2) consecutive photographs of individuals of the same species separated by more than 24 h or (3) non-consecutive photographs of individuals of the same species. In the case of photographs of gregarious species where more than one individual was observed, the number of independent records considered was the same as the number of individuals observed in the image (Monroy-Vilchis et

Table 1. Independent photocapture records (IPR) in Communal Natural Protected Area El gavilan, Oaxaca, Mexico.

Species	IPR	D(%)	C(%)	N(%)
Leopardus pardalis	105	8 (7.6)	0	97 (92.4)
L. wiedii	75	0	5 (6.6)	70 (93.4)
Herpailurus yagouaroundi	46	3 (6.5)	8 (17.4)	35 (76.2)
Nasua narica	128	35 (27.34)	27 (21.1)	66 (51.56)
Procyon lotor	58	0	0	58 (100)
Didelphis virginiana	191	0	68 (35.6)	123 (64.4)
Dasypus novemcinctus	150	0	85 (56.6)	65 (43.4)
Dicotyles angulatus	86	37 (43)	14 (16.3)	35 (40.7)
Odocoileus virginianus	95	23 (24.2)	35 (36.8)	37 (39)
Sciurus aureogaster	84	84 (100)	0	0

D= diurnal; C= crepuscular; N= nocturnal; Scientific names of mammals according to Wilson and Reeder (2005).

al., 2011; Buenrostro-Silva et al., 2015). The time for the first detection of each species was calculated as the number of days used between setting up the camera-traps and the first registration of each species captured (Monroy-Vilchis et al., 2011; Buenrostro-Silva et al., 2015). All statistical analyses were made with the XLStat ecology version (Addinsoft Co.).

RESULTS

The sampling effort expended in CNPA El Gavilan returned 1,018 independent photographic records with full time and date records for 10 species of medium and large mammals, obtained with 12,160 day/camera traps. The only species with diurnal tendency was *Sciurus aureogaster*. The nocturnal species was *Procyon lotor*, while *Leopardus wiedii*, *Didelphis virginiana*, and *Dasypus novemcinctus* exhibited nocturnal and crepuscular tendencies, but were also active during the night. *Leopardus pardalis* was active during the night but exhibited diurnal and nocturnal tendencies. *Herpailurus yagouaroundi*, *Nasua narica*, *Dicotyles angulatus* and *O. virginianus* were defined as cathemeral because they did not exhibit any particular tendency, with activities evenly distributed across all periods (Table 1 and Figure 2).

The majority of photocaptured species had activity concentrated in certain periods, principally nocturnal periods. Four species (*H. yagouaroundi*, *N. narica*, *D. angulatus* and *O. virginianus)* showed times of activity uniformly distributed across 24 h (Table 2). However, these four cathemeral species did not exhibit significant differences in activity between both seasons. Among the ten species photocaptured in both seasons, there were no significant differences in activity times (Table 3).

The most abundant medium mammals were *D. novemcinctus* (RAI= 1.23), *D.virginiana* (RAI= 1.15) and *Nasua narica* (RAI= 1.05). *Procyon lotor* (RAI= 0.47) and *Herpailurus yagouaroundi* (RAI= 0.378) were less abundant (Table 4). The time of the first detection of each species ocurred between three and 43 days (Figure 3).

DISCUSSION

The relationship between the movement activity of animals and the time they spend at rest is one of the most important characteristics it shares with other members of its own species (Marques, 2004), and all this depends on a number of factors. For example, daily activity is determined both by external environmental factor (light, temperature, weather, precipitation, etc.) and the endogenous factors (physiological state) of the animals themselves (Ogurtsov et al., 2018). The types of activities are determined by a combination of conditions that generally ensure a relatively safe existence for the species (safety of obtaining food, survival of young animals, etc.) (Ogurtsov et al., 2018).

In this study, the majority of these species had predominantly nocturnal activities with a tendency to use the first half of the night most intensely in both seasons, whereas the diurnal species (*Sciurus auregaster*) tended to use the beginning of the day. The behaviour of nocturnal species may reflect a quest for thermal comfort during the earlier hours of the night when the temperature has not yet reached its lowest point (Marques and Fabián, 2018), or it could be a strategy to minimize predation (Van Schaik and Griffiths, 1996; Heurich et al., 2014). On the other hand, the activity of the diurnal species intensifies at the beggining of the day as they search for food when the temperature has not yet reached its highest point. Valdéz and Téllez (2005) mention that *S. aureogaster* has two peaks of activity during the day, in the morning (07:00 to 09:00) and in the afternoon (15:00 to 17:00), and it matches one of the peaks of activity with our records.

D. virginiana, *D. novemcinctus* and *L. wiedii* were species with nocturnal and twilight activity patterns,

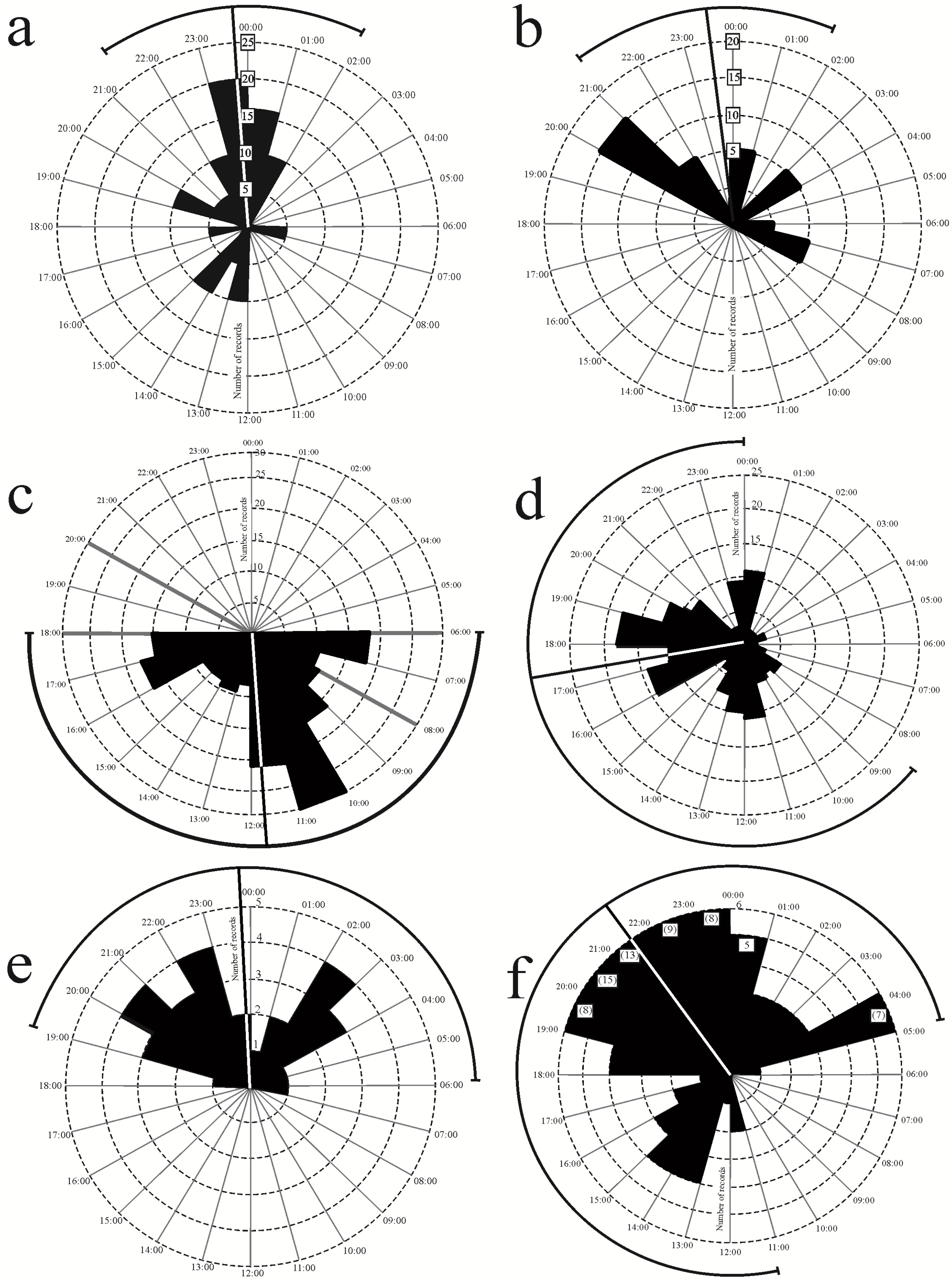

Figure 2. Activity patterns of six species of medium and large mammals in the Communal Natural Protected Area of El Gavilan, Oaxaca, México. The numbers around the edges of circles indicate time of day. The circular concetric dashes lines and numbers in black boxes indicates the number of records; the radius line indicate the mean vector; the external curved line represents the confidence interval for the mean. a= *Leopardus wieii*, b= *Procyon lotor*, c= *Nasua narica*, d= *Dicotyles angulatus*, e= *Didelphis virginiana*, f= *Dasypus novemcinctus*.

Table 2. Circular statistics analysis of times of activity of medium and large mammals in Communal Natural Protected Area El Gavilan, Oaxaca, Mexico.

Species	r	Mean vector	Circular variance	Circular standard deviation	95% Confidence Interval	Z	U (µ)
Leopardus pardalis	0.473	23:47	0.275	04:07	21:32; 02:02	82.153 (p<1E-11)	213.017 (p<0.01)
L. wiedii	0.271	23:28	0.342	05:40	21:53; 02:03	67.261 (p<1E-12)	204.862) (p<0.01)
Herpailurus yagouaroundi	0.157	21:32	0.291	03:23	18:28; 00:42	56.572 (p=1.85)	142.581 (0.5>p>0.1)
Nasua narica	0.667	22:56	0.483	06:38	20:16; 00:36	35.694 (p<1E-1)	198.573 (p<0.01)
Procyon lotor	0.350	01:17	0.352	04:13	23:42; 02:52	4.683 (p=3.31-12	162.3 (0.5>p>0.1)
Didelphis virginiana	0.549	03:29	0.185	03:52	00:09; 06:49	6.731 (p=0.031)	196.752 (p<0.01)
Dasypus novemcinctus	0.362	00:38	0.404	04:18	00:02; 03:14	3.635 (p=0.031)	148.083 (p<0.01)
Dicotyles angulatus	0.275	11:23	0.193	07:43	08:08; 02:38	4.295 (p<1E-11)	142.759 (p<0.01)
Odocoileus virginianus	0.684	22:06	0.274	03:48	18:51; 02:21	7.631 (p=0.007)	196.714 (p<0.01)
Sciurus aureogaster	0.012	09:35	0.382	01:37	08:39; 10:31	0.017 (p=0.892)	124.865 (p<0.05)

r= Properties of mean vector; Z= Rayleigh tests of uniformity; U= Rao´s spacing test.

possibly due to the predatory-prey relationship. In the Isthmus of Tehuantepec, Oaxaca, similar results were found for these species (Cortés-Marcial and Briones-Salas, 2014). The assemblage of felids in the NPA El Gavilan includes three medium-sized species (*L. pardalis*, *L. wiedii* and *H. yagouaroundi*). *L. pardalis* and *L. wiedii* are primarily nocturnal species (de Oliveira, 1998; Sunquist and Sunquist, 2002; Pérez-Irineo and Santos-Moreno, 2016), but in this study *L. wiedii* exhibited twilight and nocturnal activity while *L. pardalis* had diurnal and nocturnal activity. Our results are in part to the point of Los Chimalapas region, where Pérez-Irineo and Santos-Moreno (2016) found diurnal and nocturnal activity patterns in *L. pardalis* and *L. wiedii*. Our study provides similar evidence that *L. wiedii* coexists with *L. pardalis.* Altought *H. yagouaroundi* is a poorly studied species, there are records of it in all the neotropics region (Carvajal-Villarreal et al., 2012; Valenzuela-Galván et al., 2013; Cortés-Marcial and Briones-Salas, 2014; Buenrostro-Silva et al., 2015; Briones-Salas et al., 2016; Pérez-Irineo and Santos-Moreno, 2016). Aranda (2005) mentions that this species has daytime habits, but here we documented it as exhibiting cathemeral activity with a major nocturnal tendency.

The rest of the cathemeral species recorded in this study shows similarities with those reported by Cortés-Marcial and Briones-Salas (2014). *Nasua narica, Dicotyles angulatus* and *Odocoileus virginianus* showed broad activity patterns, probably related to their feeding habits, and their body size allows them to forage them both day and night (Van Schaik and Griffiths, 1996). *O. virginianus* has been recorded with cathemeral patterns in arid environments in the Tehuacan-Cuicatlan Biosphere Reserve, Oaxaca, with a tendency of use between 06:00 and 12:00 (Mandujano and Hernández, 2019); however, in the northeast of Mexico, it was found to have nocturnal tendencies (Gallina and Bello, 2014).

The most abundant medium mammals in our study were *D. novemcinctus*, *D. virginiana* and *N. narica*, and it is possible that their abundances are related to their alimentary habits (Pina et al., 2004; Mesa-Zavala et al., 2012). Our results match with reported by Monroy-Vilchis et al. (2011), Pérez-Irineo and Santos Moreno (2012), and Cortés-Marcial and Briones-Salas (2014). The absence of arboreal species may be related to the sampling design used, due to this one is being searched to the records of terrestrial mammals, and not for species with arboreal habits (Aranda, 2012). Although there were records of other mammals, it was not possible to analyse their acitivity patterns due to low registration rate. For example, *Puma concolor* is a territorial species and requires large field extensions to be able to realize its activities (Bustamante, 2008; Monroy-Vilchis et al., 2011). In our study there was only one record of this species.

Conclusions

This study documents the daily activity patterns of

Table 3. Differences in activity times between cathemeral species in both seasons in Communal Natural Protected Area El Gavilan, Oaxaca, Mexico.

Group of species	Dry vs. Rain
3 crepuscular-nocturnal species	W= 5.972; p = 0.673
Leopardus pardalis	W= 2.638; p= 0.371
L. wiedii	W= 4.229; p= 0.176
Herpailurus yagouaroundi	W= 11.1; p= 0.004 *
Nasua narica	W= 2.497; p= 0.287
Procyon lotor	W= 0.716; p= 0.699
Didelphis virginiana	W= 2.243; p= 0.326
Dasypus novemcinctus	W= 2.487; p= 0.287
Dicotyles angulatus	W= 2.683; p= 0.261
Odocoileus virginianus	W= 0.824; p= 0.662
Sciurus aureogaster	W= 1.188; p= 0.552

*Significative difference.

Table 4. Relative abundance index (RAI) of medium and large mammals in the Communal Natural Protected Area El Gavilan, Oaxaca, Mexico.

Especie	IPR	RAI	IPR (n)	RAI/ Dry	IPR (n)	RAI/ Rain
Leopardus pardalis	105	0.86	72	0.99	33	0.67
Leopardus wiedii	75	0.616	39	0.53	36	0.73
Herpailurus yagouaroundi	46	0.378	27	0.37	19	0.39
Nasua narica	128	1.05	76	1.04	52	1.06
Procyon lotor	58	0.47	36	0.49	22	0.44
Didelphis virginiana	191	1.15	93	1.28	98	1.99
Dasypus novemcinctus	150	1.23	82	1.13	68	1.38
Dicotyles angulatus	86	0.707	49	0.67	37	0.75
Odocoileus virginianus	95	0.78	53	0.73	42	0.85
Sciurus aureogaster	84	0.69	62	0.85	22	0.45

IPR= Independant photographic record; RAI= Relative Abundance Index.

some medium and large mammals in the tropical dry forest on the central coast of Oaxaca, but very few similar studies in the Mexican neotropics exist to make comparisons. Additionally, our results on relative abundance show the more abundants species and its importance for monitoring and maintaining mammalian biodiversity. Our results can provide insights into the conservation of species in the CNPA El Gavilan.

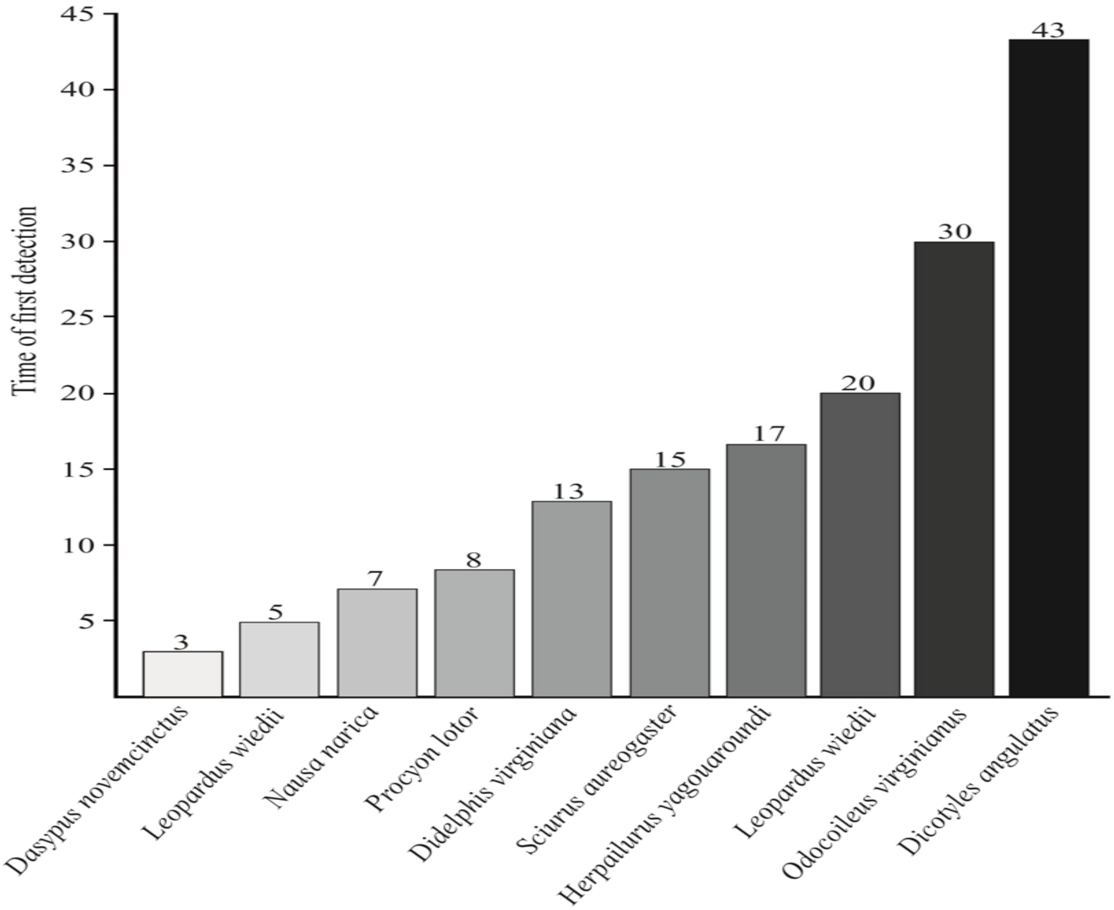

Figure 3. Time of first detection of medium an large mammals in the Communal Natural Protected Area El Gavilan, Oaxaca, México. The numbers above the bars indicate the time of first detection by this specific species.

We recommend the continuance of studies on the temporal and seasonal variations of the activity patterns in order to maintain mammalian species conservation.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Aranda M (2005). *Leopardus pardalis*. In: Ceballos G, Oliva G (eds.), Los mamíferos silvestres de México. México, DF: Fondo de Cultura Económica, Comisión Nacional para el Conocimiento y uso de la Biodiversidad. pp. 359-361.

Aranda M (2012). Manual for tracking wild mammals in Mexico. National Commission for the Knowledge and Use of Biodiversity (CONABIO). Mexico DF.

Baboo B, Sagar R, Bargali SS, Verma H (2017). Tree species composition, regeneration and diversity within the protected area of Indian dry tropical forest. Tropical Ecology 58(3):409-423.

Bargali SS, Singh RP, Singh SP (1992b). Structure and function of an age series of eucalypt plantations in Central Himalaya, II. Nutrient dynamics. Annals of Botany 69:413-421.

Bargali SS, Singh SP, Singh RP (1992a). Structure and function of an age series of eucalypt plantations in Central Himalaya, I. Dry matter dynamics. Annals of Botany 69:405-411.

Botello F, Sánchez-Cordero V, Ceballos G (2008). Diversidad de carnívoros en Santa Catarina Ixtepeji, Sierra Madre de Oaxaca, México. In. Lorenzo CE, Espinoza J, Ortega J (eds), Avances en el estudio de los mamíferos de México II. México, DF: Asociación Mexicana de Mastozoología, A. C., pp. 335-354.

Bradley J, Cardinale J, Emmett D, Gonzalez A, Hooper DU., Perrings C, Venail P, Narwani A, Mace GM, Tilmanx D, Wardle DA, Kinzig AP, Daily G, Loreau M, Grace JB, Larigauderie A, Srivastava DS, Naeem S (2012). Biodiversity loss and its impact on humanity. Nature

7401:59-67. Briones-Salas MA, Martín-Regalado N, Lavariega MC (2016). Mammals in tropical dry forest on the central coast of Oaxaca, Mexico. Check List 12(2):1862. Available at: http://doi.org/10.15560/12.2.1862

Briones-Salas MA, Sánchez-Cordero V (2004). Mamíferos. In. García Mendoza AJ, Ordoñez MJ, Briones-Salas MA (eds.), Biodiversidad de Oaxaca. México, DF: Instituto de Biología, UNAM, Fondo Oaxaqueño para la Conservación de la Naturaleza-World Wildlife Fund, México, pp. 423-447.

Buenrostro Silva A, Sigüenza Pérez D, García Grajales J (2015). Mamíferos carnívoros del Parque Nacional de Chacahua, Oaxaca: Riqueza, abundancia y patrones de actividad. Revista Mexicana de Mastozoología Nueva Época 5(2):39-54.

Bustamante A (2008). Densidad y uso de hábitat por los felinos en la parte sureste del área de amortiguamiento del Parque Nacional Corcovado, Península de Osa, Costa Rica. Tesis de maestría. Instituto Internacional en Conservación y Manejo de Vida Silvestre, Universidad Nacional, Costa Rica.

Cardinale BJ, Duffy EJ, Gonzalez A, Hooper D, Perrings C, Venail P, Narwani A, Mace G, Tilman D, Wardle DA, Kinzig A, Daily GC, Loreau M, Grace JB, Larigauderie A, Srivastava DS, Naeem S (2012). Biodiversity loss and its impact on humanity. Nature 486:59-67.

Carvajal-Villarreal S, Caso A, Downey P, Moreno A, Tewes ME, Gassman LI (2012). Spatial patterns of the margay (*Leopardus wiedii*, Falidae, Carnivora) at El Cielo Biosphere Reserve, Tamaulipas, Mexico. Mammalia 76:237-244.

Cortés-Marcial M, Briones-Salas MA (2014). Diversidad, abundancia relativa y patrones de actividad de mamíferos medianos y grandes en una selva seca del Istmo de Tehuantepec, Oaxaca, México. Revista de Biología Tropical 62(4):1433-1448.

Chiarello AG (2000). Density znd population size of mammals in remants of Brazilian Atlantic Forest. Conservation Biology 14(6):1469-1657.

De Oliveira TG (1998). *Leopardus wiedii*. Mammalian Species 579:1-6.

Erkert HG, Bay FA, Kracht S (1976). Zeitgeber induced modulation of activity patterns in nocturnal mammals (Chiroptera). Experientia 32(5):560-562.

Frey S, Fisher JT, Burton AC, Volpe JP (2017). Investigating animal activity and temporal niche partitioning using camera-trap data: Challenges and opportunities. Remote Sensing in Ecology and Conservation 3(3):123-132.

Gallina S, Bello J (2014). Patrones de actividad del venado cola blanca en el noreste de México. Therya 5(2):423-436.

García E (1973). Los climas de México. México, DF: Instituto de Geografía, Universidad Nacional Autónoma de México.

Gódinez GA (2014). Patrones de actividad espacio-temporal de ungulados de la Rserva de la Biósfera El Triunfo, Chiapas, México. Tesis de licenciatura, Universidad Michoacana de San Nicolás de Hidalgo, Michoacán, México.

Gonthier DJ, Castañeda FE (2013). Large and medium sized mammal survey using camera traps in the Sikre River in the Río Plátano Biosphere Reserve, Honduras. Tropical Conservation Science 6(4):584-591.

Gonzalez-Christen A (2010). Los mamíferos de Veracruz: Distribución, endemismo y estado de conservación. México, DF: Comisión Nacional para el Conocimiento y Uso de la Biodioversidad (CONABIO), Gobierno del Estado de Veracruz, Universidad Veracruzana, Instituto de Ecología, A. C.

González-Pérez G, Briones Salas MA, Alfaro AM (2004). Integración del conocimiento faunístico de Oaxaca. In: García Mendoza AJ, Ordóñez MJ, Briones Salas MA (eds.), Biodiversidad de Oaxaca. México, DF: Instituto de Biología, Universidad Nacional Autónoma de México, Fondo Oaxaqueño para la Conservación de la Naturaleza, World Wildlife Fund, México, pp. 449-466.

Gosain BG, Negi GCS, Dhyani PP, Bargali SS, Saxena R (2015). Ecosystem services of forests: Carbon Stock in vegetation and soil components in a watershed of Kumaun Himalaya, India. International Journal of Ecology and Environmental Science 41(3-4):177-188.

Heurich M, Hilger A, Küchenhoff H, Andrén H, Bufka L, Krofel M, Mattison J, Persson J, Rauset GR, Scmidt K, Linell JDC (2014). Activity patterns of Eurasian lynx are modulated by light regime and individual traits over a wide latitudinal range. PLoS ONE 9(12):e114143.

Karanth K, Nichols D (1998). Estimation of tiger densities in India using photographic captures and recaptures. Ecology 79:2852-2862.

Kovach WL (2011). Oriana-Circular Statistics for Windows. V4. Kovach Computing Services, Pentraeth, Wales, U.K. Available at: http://www.kovcomp.com/oriana/index.html

Kronfeld-Schor N, Dayan T (2003). Partitioning of time as an ecological resource. Annual Review of Ecology, Evolution and Systematics 34:153-181.

Lehner PN (1996). Handbook of ethological methods. Second edition, Cambridge, United Kingdon: Cambdridge University Press.

Linkie M, Ridout MS (2011). Assessing tiger-prey interactions in Sumatran rainforests. Journal of Zoology 284(3):224-229.

Long ES, Nelson TC, Steensma KMM (2013). Conditional daily and seasonal movement strategies of male Columbia black-tailed deer (*Odocoileus hemionus columbianus*). Canadian Journal of Zoology 91:679-688.

Mandujano S, Hernández C (2019). Use of water developments by White-tailed deer in an extensive AHU in the biosphere reserve Tehucan-Cuicatlan, Mexico. Agroproductividad 12(6):37-42. Available at: http://www.doi.org/10.32854/agrop.v0i0.1406

Manfo DA (2013). Agroforestry and dynamics of floristic biodiversity and the agricultural landscape in the forest-savanna transition zone: the case of Obala region, Center-Cameroon. Master thesis in Geography, University of Yaoundé.

Marques MD (2004). Rhythms and ecology- do chronobiologists still remember nature? Biological Rhythm Research 35:1-2.

Marques RV, Fabián ME (2018). Daily activity patterns of medium and large neotropical mammals in an area of Atlantic rain forest at altitude. Revista Brasileira de Zoociências 19(3):38-64.

Mesa-Zavala E, Álvarez-Cárdenas S, Gallina-Tessaro P, Troyo-Diéguez E, Guerrero-Cárdenas I (2012). Vertebrados terrestres registrados mediante fototrampeo en arroyos estacionales y cañadas con agua superficial en un hábitat semiárido de Baja California Sur, México. Revista Mexicana de Biodiversidad 83(1):235-245.

Monroy-Vilchis O, Zarco-González M, Rodríguez-Soto L, Urios V (2011). Fototrampeo de mamíferos en la Sierra de Nanchititla, México: abundancia relativa y patrón de actividad. Revista de Biología Tropical 59:373-383.

Morgan E (2004). Ecological significance of biological clocks. Biological Rhythm Research 35(1/2):3-12.

Mourya NR, Bargali K, Bargali SS (2019). Effect of *Coriaria nepalensis* Wall. colonization in a mixed conifer forest of Indian Central Himalaya. Journal of Forestry Research 30(1):305-317.

O´Connell AF, Nichols JD, Karanth KU (2011). Camera traps in animal ecology: methods and analyses. Tokyo, Japan: Springer Press.

Ogurtsov S, Zheltukhin A, Kotlov IP (2018). Daily activity patterns of large and medium mammals based on camera traps data in the Central Forest Nature Reserve, Valdai Upland, Russia. Nature Conservation Research 3(2):68-88.

Ortiz-Pérez MA, Hernández JR, Figueroa JM (2004). Reconocimiento fisiográfico y geomorfológico. In: García Mendoza AJ, Ordóñez MJ, Briones Salas MA (eds.), Biodiversidad de Oaxaca. México, DF: Instituto de Biología, Universidad Nacional Autónoma de México, Fondo Oaxaqueño para la Conservación de la Naturaleza. World Wildlife Fund. pp. 43-54.

Pérez-Irineo G, Santos Moreno A (2012). Diversidad de mamíferos terrestres de talla grande y media de una selva subcaducifolia del noreste de Oaxaca, México. Revista Mexicana de Biodiversidad 83:164-169.

Pérez-Irineo G, Santos-Moreno A (2016). Abundance and activity patterns of médium-sized felids (Felidae, Carnivora) in Southeastern Mexico. The Southwestern Naturalist 61(1):33-39.

Pina GPL, Gómez RAC, González CAL (2004). Distribution, habitat association and activity patterns of médium and large sized mammals of Sonora, Mexico. Natural Areas Journal 24:354-357.

Rodríguez-Luna E, Gómez Pompa A, López-Acosta JC, Velázquez-Rosas N, Aguilar-Domínguez Y, Vázquez-Torres M (2011). Atlas de los espacios naturales protegidos de Veracruz. Gobierno del estado de Veracruz. Veracruz, México: Universidad Veracruzana.

Salas-Morales SH, Saynes A, Schibli L (2003). Flora de la costa de Oaxaca, México: lista florística de la región de Zimatán. Boletín de la Sociedad Botánica de México 72:21-58.

Sunquist M, Sunquist F (2002). Wild coast of the world. Chicago, USA: Chicago University Press.

Tobler MW, Carrillo-Percastegui S, Leite R, Mares R, Powell G (2008). An evaluation of camera traps for inventorying large- and médium-sized mammals. Animal Conservation Journal 11:169-178.

Torres-Colín R (2004). Tipos de vegetación. In. García Mendoza AJ, Ordóñez MJ, Briones Salas MA (eds.), Biodiversidad de Oaxaca. México, DF: Instituto de Biología, Universidad Nacional Autónoma de México, Fondo Oaxaqueño para la Conservación de la Naturaleza, World Wildlife Fund, pp. 105-117.

Trejo I (1998). Distribución y diversidad de selvas bajas de México: relación con clima y suelo.Tesis de Doctorado, Universidad Nacional Autónoma de México, México.

Trejo I (2010). Las selvas secas del Pacífico mexicano. In: Ceballos G, Martínez L, García A, Espinoza E, Bezaury J, Dirzo R (eds.), Diversidad, amenazas y áreas naturales prioritarias para la conservación de las selvas secas del Pacífico de México, México. México, DF: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Fondo de Cultura Económica, México, pp. 4-51.

Valdéz M, Téllez G (2005). Sciurus aureogaster F. Cuvier, 1829. In. Ceballos G, Oliva G, (eds.), Los mamíferos de México. México, DF: Fondo de Cultura Económica, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. pp. 547-548.

Van Schaik CP, Griffiths M (1996). Activity periods of Indonesian Rain Forest Mammals. Biotropica 28:105-112.

Vera MR, Fábian ME (2018). Daily activity patterns of médium and large Neotropical mammals during different seasons in an area of huigh altitude atlantic rain forest in the South of Brazil. Zoociencias 19(3): 38-64.

Valenzuela-Galván D, De León-Ibarra A, Lavalle-Sánchez A, Orozco-Lugo L, Chávez C (2013). The margay Leopardus wiedii and bobcat Lynx rufus from the dry forests of Southern Morelos, Morelos. Southwestern Naturalist 58:118-120.

Zar JH (2010). Biostatistical analysis. Prentice Hall, Upper Saddle River, New Jersey, USA.