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POPULATIONAL ATTRIBUTES OF THE CENTRAL AMERICAN RED BROCKET DEER (*Mazama temama*) IN THE SIERRA DE ZONGOLICA, VERACRUZ, MEXICO

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ABSTRACT

The Sierra de Zongolica is a biogeographic region with ecosystems and species of nearctic and neotropical affinity in the state of Veracruz, Mexico. However, no studies have been conducted on populations of the red brocket deer (*Mazama temama* Erxleben 1777) in this region. Such type of studies is essential to propose actions for sustainable management of the species and the habitat by the rural communities. The objective of this study was to describe the populational attributes of *M. temama* (distribution, population abundance, and patterns of activity) in the Sierra de Zongolica. Information was gathered through interviews, spoor detection and camera trapping from September 2014 to May 2015. To identify the sites where the deer is present, 76 inhabitants of four municipalities of the Sierra de Zongolica were interviewed. In the localities described with presence of the deer, 20 walking trails 300 m long by 1 m wide were identified. Six of the trails were in primary vegetation (1.8 km), 10 in secondary vegetation (3 km), and four in the area of cultivation (1.2 km) where 54 spoors were recorded (45 hoofprints and nine droppings), equivalent to nine signs of deer per km. The population of *M. temama* was higher in the farming area than in primary or secondary vegetation. In the 43 stations of camera traps, 71 independent images of *M. temama* were obtained. Of these images, 79 % were between 18:00 and 05:00 h, indicating a pattern of crepuscular and nocturnal activity. This species had a relative abundance index of 2.5 brockets per km^2 in the Sierra de Zongolica, suggesting a population susceptible to management under the system of Management Units for Conservation and Sustainable Use of Wildlife (in Mexico, UMAs).

Keyword: Cervidae, populational distribution, trails, spoor index, camera traps, abundance.

INTRODUCTION

The Central American red brocket deer (*Mazama temama* Erxleben 1777; Mammalia: Cervidae) is an indicator species for the conservation status of the ecosystem since presence and behaviour change under pressure from anthropogenic activities (Muñoz-Vázquez and Gallina-Tessaro, 2016). This species balances ecological dynamics of the vegetation; its presence can indicate the existence of large felines, and its abundance determines the quality of the habitat (Villarreal-Espino-Barros *et al*., 2019). However, due to habitat loss (Pérez-Solano and Mandujano, 2013), pressure from clandestine hunting (Salazar-Ortiz *et al*., 2020), and a little genetic flow due to geographic isolation (Serna-Lagunes *et al*., 2021), this species faces difficulties for maintenance and survival. Populations of *M. temama* are decreasing throughout their geographic distribution. Moreover, for their classification status in the risk categories of the International Union for Conservation of Nature, there is a lack of ecological data regarding those populations (Bello *et al*., 2016). Neither in Mexico has the extinction risk status of *M. temama* been determined through the population risk evaluation method (SEMARNAT, 2010). The conservation and sustainable use of this species depends on the availability of information on population attributes (Villareal-Espino *et al*., 2017), biology, patterns of activity, individuals body size, territorial needs, habitat preferences, spatial arrangement, and potential distribution of the population (Bello-Gutiérrez *et al*., 2010; Serna-Lagunes *et al*., 2014).

The Sierra de Zongolica (Veracruz, Mexico) is an interesting biogeographic scenario where species converge, with ecological affinity to nearctic and neotropical zoogeographic regions. It is one of the least explored mountain ranges, and thus there is little scientific knowledge on the wild mammals that inhabit these ecosystems (González-Christen and Delfín-Alfonso, 2016). Similar to other ecological regions of Mexico where *M. temama* is distributed, decision-making on conservation and sustainable use of the species by rural communities is limited by the lack of knowledge concerning their population attributes and because there are not ecological studies reported weighing the effects of overexploitation at the regional level (Villarreal-Espino-Barro *et al*., 2014).

Distribution of *M. temama* in the Sierra de Zongolica includes areas whose anthropogenic activities risk deer populations and habitat. However, there is interest on the part of rural communities in the management of this species through the plan of Management Units for Conservation and Sustainable Use of Wildlife (Unidades de Manejo para la Conservacion y Aprovechamiento Sustentable de Vida Silvestre -UMA) (Macario *et al*., 2019; Salazar-Ortiz *et al*., 2020). For this reason, the objective of this study was to describe population attributes (distribution, abundance, and patterns of activity) of *M. temama* in the Sierra de Zongolica, Veracruz, Mexico, since it is necessary to promote conservation, sustainable management, and habitat restoration through community participation within UMA (Benítez-Badillo *et al*., 2010).

MATERIALS AND METHODS

The study area included the municipalities of San Andres Tenejapan, Tequila, Los Reyes and Zongolica located in the Sierra de Zongolica region, Veracruz, Mexico. The region includes 14 municipalities (12 of them with indigenous Nahuatl populations) at altitudes from 620 to 2200m. It is bordered on the north by the Sierra Negra de Puebla, to the east by the Coastal Plain of the Gulf of Mexico, on the west by the National Park Pico de Orizaba and the National Park Cañon del Rio Blanco, and to the south by the Sierra Mazateca of Oaxaca (Figure 1).

The municipality of San Andrés Tenejapan has a population of 2715 inhabitants, highly marginalized with socioeconomic activities based on agriculture (maize, coffee, and beans) and pig production. It is located at an average altitude of 1200 m where the ecosystems are temperate deciduous forest and temperate pine forests in temperate humid climate, 21 °C mean temperature and 2106 mm average yearly precipitation (INEGI, 2010).

The population of the municipality of Tequila is indigenous of Nahuatl origin dedicated to production of maize, coffee berries, and pigs. The territory is located at altitudes from 600 m to 2700 m; 56 % of the territory has temperate subhumid climate with abundant summer rain; 32 % has cool humid climate with abundant summer rain; 12 % has a cool humid climate with rains throughout the year. Temperature varies from 14° to 22 °C and precipitation is 1400-2600 mm. Forests make up 13.4 % of the territory, secondary vegetation is 64.7 %, and 21.9 % is destined to agriculture (INEGI, 2010).

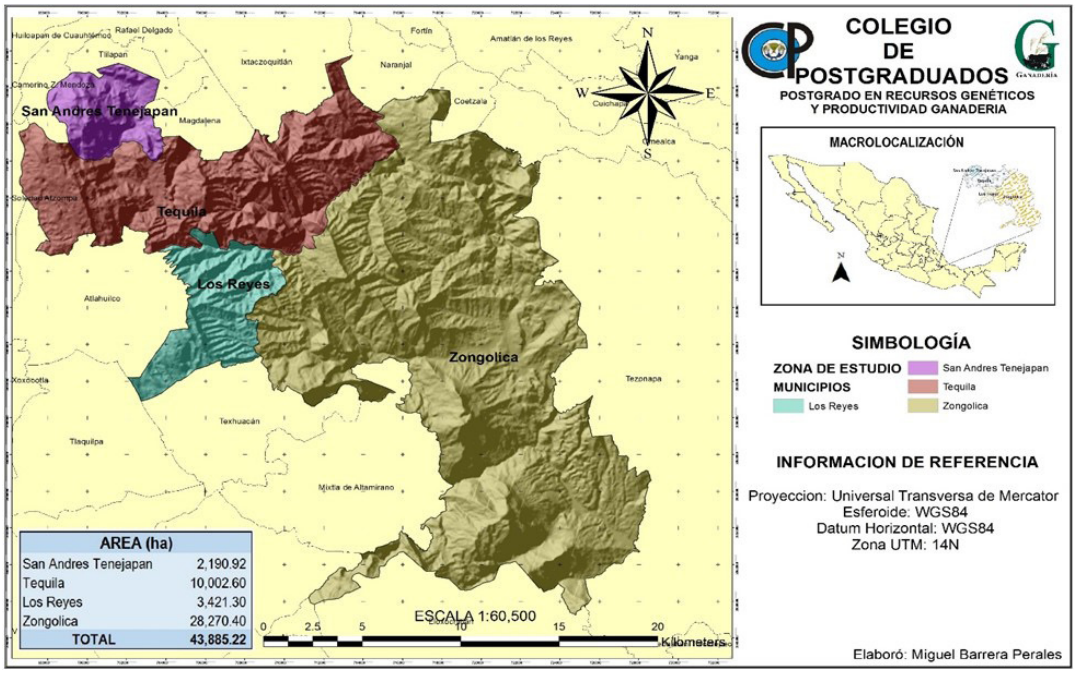

Figure 1. Geographic location of the Sierra de Zongolica and the sampled municipalities in Veracruz, Mexico.

The municipality Los Reyes has rough terrain where maize, beans and coffee are cultivated near native ecosystems such as tropical evergreen forest and mesophyll mountain forest (average altitude 1640 m). The climate is cold and humid, 17 °C mean temperature and 1500 mm average annual precipitation (INEGI, 2010).

The municipality of Zongolica has altitudes above 2000 m, extreme-humid temperate climate (17 °C mean temperature and 2270 mm average annual precipitation), and a diversity of vegetation types and agroecosystems (INEGI, 2010).

This study was conducted from September 2014 to May 2015. During this period, 12 trips were made onto the field; along with questionnaires applied to people dwelling in the areas; present trails were examined, and camera traps placed to monitor the species. Each simple questionnaire contained questions on knowledge and localities of *M. temama* presence was applied to randomly selected inhabitants in each municipality. The information on questionnaires was collected in interviews, and the responses were recorded in frequency tables.

In the specific areas where interviewees indicated the presence of *M. temama*, identified trails were walked 20 times; the trails were 300 m long by 1 m wide, making a total of 6 km (Mandujano, 1994) since in the field it has been observed that in this area the likelihood of registering signs of the species increases (Muñoz-Vázquez *et al*., 2022). The trails, based on the mentions of *M. temama* presence, were set up as: six trails in primary vegetation (1.8 km), 10 in secondary vegetation (3 km) and four in the area destined to agriculture (1.2 km). The trails were plotted, georeferenced, and walked by a person at a speed of 3 km h^{-1} at different hours and dates to record spoor (scat, footprints, resting spots, scratching posts, browsing areas, and direct observation) of *M. temama* (Figure 2).

With the dataset on the presence of *M. temama* spoor, the spoor index (*Ir*) was estimated by vegetation type with the equation: $Ir=Nr/Nt$, where *Nr* is the spoor count by vegetation and *Nt* is the total length of the walk. *Ir* is considered the distribution of the population by following spoors in different types of plant cover (Carrillo *et al*., 2000).

To estimate relative abundance of *M. temama* by vegetation type, 43 camera traps (Bushnell® Trophy Camera Brown model 119437, Stealth Cam® model STC-Q8X and Cuddeback® Black Flash model E3) were placed 1 km apart, since the species has an area of activity no more than 1 km in diameter (Gallina, 2005). Twenty camera traps were distributed in secondary vegetation, 14 in primary vegetation, and nine in the cultivation area. They were secured on trees facing gaps, in the same specific areas where the inhabitants observed *M. temama* specimens. An effective camera trapping area of 10.7 km^2 was estimated, which covers the extrapolated area that each camera trap monitored during the study. This area is equivalent to 25% of the total area under study (Figure 3).

With the photo captures of *M. temama* obtained with the camera traps, the index of relative abundance (*IAR*) in the Sierra de Zongolica was estimated with the number of photo-captures of different individuals of the species (Xi), divided by the total number

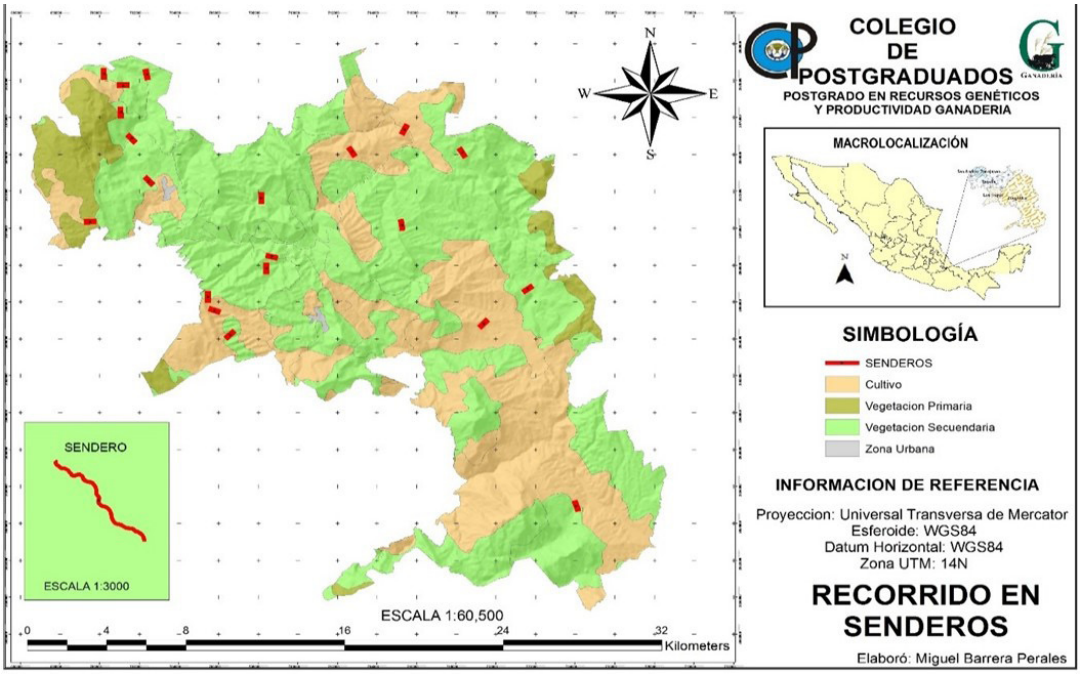

Figure 2. Trails walked to record *Mazama temama* spoor in the Sierra de Zongolica, Veracruz, México.

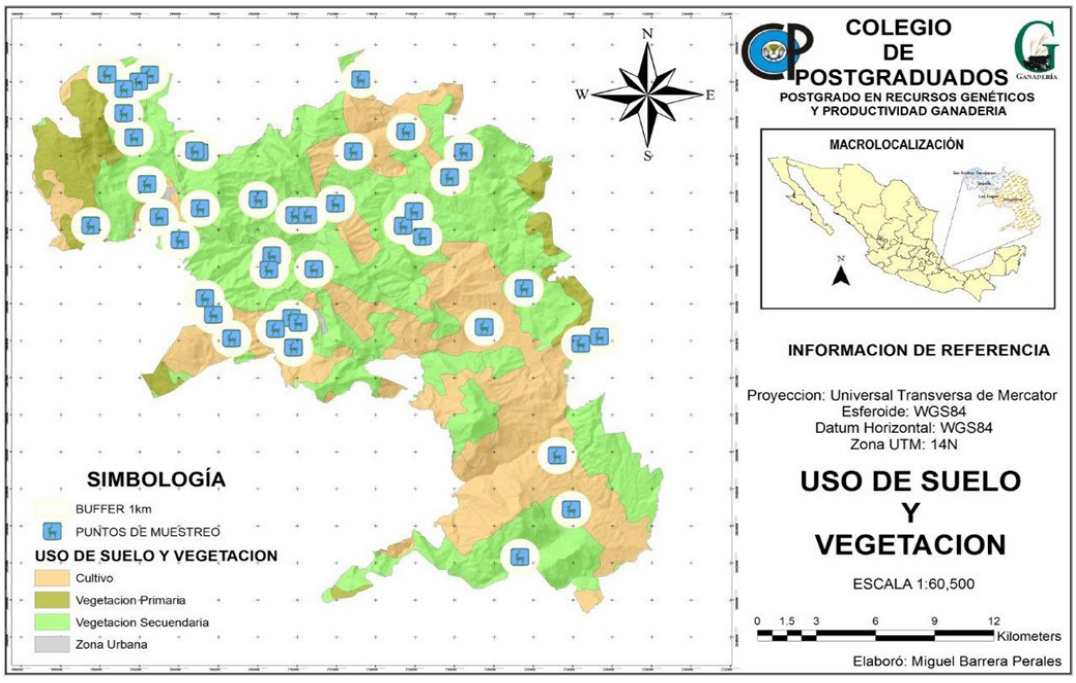

Figure 3. Sampling points (camera traps) for detection of *Mazama temama* in the Sierra de Zongolica, Veracruz, Mexico.

of photo-captures (Yi) and multiplied by 100 camera traps per night (Carbone *et al*., 2001). To identify the different individuals, or an independent register of *M. temama*, each photo-capture was classified under the following criteria: photo-captures of one deer (three photographs in five seconds), b) photo-captures of one or more individuals identified by some distinctive characteristic, c) different individuals clearly distinguishable in the same photo capture, d) photo-captures of the species separated by a lapse of more than 24 h (Chávez *et al*., 2013). The *IAR* evaluates spatial and temporal population dynamics and is grounded in the positive correlation between abundance and detection probability (Tobler *et al*., 2008).

Time record in the independent photo-captures of *M. temama* was used to describe the pattern of activity for the deer; classified as nocturnal (18:00 to 5:00h), diurnal (06:00 h to 17:00 h) or crepuscular (17:00 to 18:00 h and 05:00 h to 06:00 h) (Serna-Lagunes *et al*., 2019).

RESULTS AND DISCUSSION

In the four municipalities of the Sierra de Zongolica, 76 questionnaires were answered by farmers; merchants of groceries, wood, and other forest products; undergraduate students; construction workers; owners of small businesses (bakery and butcher shops); and administration workers of the municipal government (technical support for agriculture, civil protection, tourism office, and Municipality Secretariat). Regarding presence of *M. temama* in the study area, 94% of the interviewees indicated they know about it, whereas 6% informed they knew nothing of presence. An 85% of the interviewees have observed specimens of *M. temama*, while 15% declared that they have only seen photographs or skins, antlers and feet made into handcrafts or as ornaments. Hunting *M. temama* was practiced by 78% of the interviewees, most for home consumption but some sell its meat (22%; Table 1).

Fifty-four spoors of *M. temama* were identified, 45 of them were tracks and nine were scats (five fresh faeces groups and four dry), the equivalent of a spoor index (*Ir*) of 9 *M. temama* spoors per km. In secondary vegetation 23 signals were recorded (21 tracks and two scats), 16 in secondary vegetation (12 tracks and four scats), and 15 in the area of cultivation (12 tracks and 3 scats). However, the *Ir* was higher in the area of cultivation than in primary and secondary vegetation (Table 2).

Table 1. Responses on knowledge of *Mazama temama* presence in the Sierra de Zongolica, Veracruz, Mexico.

Municipality	Aware	Unaware	Has seen	Has not seen	Ever hunt	Not ever hunt
San Andrés	12	8	8	9	3	17
Los Reyes	19	1	10	9	2	18
Tequila	19	1	15	5	6	14
Zongolica	16	4	14	5	7	13

Table 2. Spoors of *Mazama temama* recorded in trails in the Sierra de Zongolica, Veracruz, Mexico.

Vegetation type	Tracks	Scat	Spoor count (*Nr*)	Length (km) (*Nt*)	*Ir* (*Nr*/*Nt*)	Spoor proportion
Primary vegetation	12	4	16	1.8	8.9	29.7
Secondary vegetation	21	2	23	3.0	7.7	42.5
Cultivation area	12	3	15	1.2	12.5	27.8
Total	45	9	54	6	9	100

Figure 4. Photo-captures of *Mazama temama* in different places of the Sierra de Zongolica, Veracruz, Mexico. A, in Tequila; B, in San Andres Tenejapan; C, in Los Reyes; D, a young deer in Zongolica; E, scat of *Mazama temama*; F, tracks of *Mazama temama.*

During camera trapping, 1285 d were accumulated per trap, and 2812 photo-captures were obtained. Out of which 230 were independent photo-captures; that is, 71 independent photo-captures of *Mazama temama* (Figure 4) and 159 of other species, such as armadillo (*Dasypus novemcinctus*), coatí (*Nasua narica*), opossum (*Didelphis marsupialis*), tepezcuintle (*Cuniculus paca*), margay (*Leopardus wiedii*), bearded wood-partridge (*Dendrortyx barbatus*), grey fox (*Urocyon cinereoargenteus*), Mexican black agouti (*Dasyprocta mexicana*) (Figure 5) and feral dogs (*Canis lupus familiaris*) (Figure 6).

The *IAR* of *M. temama* in secondary vegetation was higher (45%) than in primary vegetation (31%) and in the area of cultivation (24%). Although a higher number

Figure 5. Fauna recorded by camera trapping in Sierra de Zongolica. From left to right: armadillo (*Dasypus novemcinctus*), coati (*Nasua narica*), opossum (*Didelphis marsupialis*), tepezcuintle (*Cuniculus paca*), margay (*Leopardus wiedii*), bearded wood-partridge (*Dentrortyx barbatus*), grey fox (*Urocyon cinereoargenteus*), Mexican black agouti (*Dasyprocta mexicana*) and a pair of Central American red brocket deer (*Mazama temama*).

Figure 6. Feral dogs in the habitat of *Mazama temama* in the Sierra de Zongolica.

of independent photo-captures of the deer was obtained in secondary vegetation. Possibly due to camera traps were in place for a larger number of days (Table 3).

The pattern of activity of the males and individuals recorded in the photo-captures of *M. temama* in Sierra de Zongolica was predominately nocturnal, although a smaller proportion showed a diurnal and crepuscular pattern of activity (Table 4).

Table 3. Index of relative abundance (IAR) of *Mazama temama* by vegetation type in the Sierra de Zongolica, Veracruz, Mexico.

Vegetation type	Area (%)	Number of camera traps (percentage)	Independent photo-captures	Total photo-captures	*IAR*	Trap-days	Photo-captures of other species
Primary	7.1	2 (4.88)	22	765	2.9	411	54
Crops	34.7	11 (17.07)	17	897	1.9	283	36
Secondary	58.1	30 (78.05)	32	1150	2.8	591	69
Total	100	41 (100)	71	2812	2.5	1285	159

Table 4. Pattern of activity of *Mazama temama* in the Sierra de Zongolica, Veracruz, Mexico.

Sex	Crepuscular	Diurnal	Nocturnal
Male	4.2 %	25 %	70.8 %
Not identified (female, juvenile, and possible males)	12.7 %	4.3 %	83 %

This study reports the presence of *M. temama* in four municipalities of the Sierra de Zongolica in localities not reported in previous studies. This is, a condition of anisotropy (geographic space inhabited by a species within the potential area of distribution and where presence had not been reported; Zunino and Zullini, 2003). This study thus increases the number of known localities of the presence of the species (Ramírez-Bravo and Hernández-Santín, 2012). Most of the interviewees of this study indicated they were aware of *M. temama*, by direct or indirect observation. They also revealed hunting the species either for control in cultivation areas, or for home consumption or meat for sale (Salazar-Ortiz *et al*., 2020).

The *M. temama Ir* and *IAR* obtained in this study represent to our knowledge, the first report on the population attributes of the species in Sierra de Zongolica. The *Ir* of *M. temama* recorded in this study was higher than the spoor index registered for *Mazama americana* in the Biosphere Reserve El Triunfo, Chiapas, Mexico (Lira-Torres and Naranjo-Piñera, 2003). However, in the Sierra de Zongolica the proportion of *M. temama* spoor was higher in the cultivation area, where habits of foraging on bean, maize, edible and other herbs, and weeds in agroecosystems has been recorded, possibly due to primary and secondary vegetation has been altered and food is scarce (Contreras-Moreno *et al*., 2016; Muñoz-Vázquez *et al*. 2022).

In this study, the *M. temama IAR* was higher in primary vegetation, but this varied in relation to those reported for the species in the North-Northeast Sierra and Sierra Negra de Puebla with xerophilic scrub vegetation (3.6 to 8.3 individuals per km^2; Villarreal *et al*., 2008), and in mesophyll mountain forests (0.32 individuals per km^2; Lira-Torres and Naranjo-Piñera, 2003). Variation in *M. temama IAR* may be due to changes in characteristics of the conservation status of the habitat; to factors related to overexploitation, or to the absence of landscape structure variables that determine deer presence (Ceballos and Oliva 2005; Contreras-Moreno *et al*., 2016).

According to the population attributes of *M. temama* obtained in this study, the interest of the community in sustainable management of the species, and with technical assistance of institutions of education and research, land belonging to ejidos and communities can be certified as UMA for a sustainable hunting of specimens based on population studies. The potential of the species can be used in a legal, regulated, and managed under program without decimating deer populations (SEMARNAT, 2008).

On the other hand, increasing their *IAR* and maintaining *M. temama* populations require studies to establish wildlife corridors that connect the Sierra de Zongolica with the National Park Cañon del Río Blanco, considering the masses of dense forest with habitat that is favourable for *M. temama* and other associated species. In addition to a social program of community vigilance and the establishment of lands and installations for Wildlife Management (Manejo de Vida Silverstre - PIMVS) to encourage reproduction and management in captivity (SEMARNAT, 2008).

Red brocket deer, *M. temama* in the Sierra de Zongolica exhibited a daily activity pattern throughout the day (cathemeral). This reflects an increase in energy requirements, so

that they tend to forage at different daily hours (Lira-Torres y Briones-Salas, 2010; Monroy-Vilchis *et al*., 2011). It means their activity was nocturnal (mostly), diurnal, and crepuscular. This active behaviour during different times of the day may be a measure to evade predators, since feral dogs (*Canis lupus familiaris*) appear in photo-captures in the four municipalities. This is a factor of pressure that modifies the pattern of activity and abundance and can negatively affect *M. temama* populations (Manzanero-Barrera *et al*., 2020).

CONCLUSIONS

This study reports a *Mazama temama* population that leaves the largest proportion of spoor in the area of cultivation. However, it had a higher index of relative abundance in primary vegetation. The population of *M. temama* showed a cathemeral daily activity pattern, although the highest number of records were during the night. This pattern may be altered by the presence of feral dogs in the habitat of the species.

The *M. temama* population in the Sierra de Zongolica can be managed by the rural communities organized in wildlife management units, but long-term monitoring covering other regions and vegetation types is required. Thus, it is necessary to increase the number of camera traps to calibrate the spatial and temporal changes in the *M. temama* index of relative abundance, as well as other parallel studies on the landscape structure determining presence.

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