THERYA, 2025, Vol. 16(3):XXX-XXX DOI:10.12933/therya-25-6190 ISSN 2007-3364

Changes in the activity pattern of white-tailed deer in the Tehuacán-Cuicatlán Biosphere Reserve, Mexico

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The activity patterns of white-tailed deer are intricately linked to their fundamental requirements for nutrition, rest, and reproduction. These patterns naturally fluctuate in response to seasonal variations and environmental conditions. This study analyzed the daily activity patterns of the white-tailed deer, *Odocoileus virginianus*, inhabiting the scrubland and tropical dry ecosystem within the Tehuacán-Cuicatlán Biosphere Reserve (TCBR), Mexico. Our investigation specifically focused on comparing these activity patterns across different reproductive periods (rut, gestation, and fawning) considering potential variations based on the individual's sex and geographical location. We used 100 camera trap stations across four localities from February 2012 to February 2016. We analyzed white-tailed deer activity with circular statistics (Watson tests), kernel density estimates, Watson tests and activity range core. We obtained a total sampling effort of 22,809 days-trap, resulting in 1,656 independent records. Our findings revealed that the white-tailed deer presented a bimodal activity pattern during the day, with activity peaks between 06:00-12:00 h and 17:00-19:00 h. We found significant differences in the activity peaks between the rut and fawning periods with the gestation period, between females and males, and between localities in the TCBR. White-tailed deer show remarkable adaptability to habitats with varying environmental and ecological conditions, as temperate, semi-arid, and tropical regions. Generally, it is considered crepuscular because it tends to present greater activity during dawn and dusk. However, our results diverge from this classification, as the white-tailed deer's activity pattern was mainly diurnal, and their activity peaks changed depending on the physiological period, sex, and local habitat conditions. These variations could be attributed to habitat characteristics because extreme temperatures are not present in this tropical dry forest, as in arid and semi-arid zones. Moreover, the vegetation cover may protect against heat during the rainy season, and some plant species offer water sources for deer during the dry season. These findings contribute valuable insights into the biology and behavior of this species inhabiting the tropical dry forests of Mexico.

Key words: fawning; gestation; Oaxaca; *Odocoileus virginianus*; photo trapping; rut.

Los patrones de actividad de los venados cola blanca están relacionados con la necesidad de cubrir sus requerimientos nutricionales, de descanso y reproducción, por lo que varían dependiendo de la estación y las condiciones ambientales. En este trabajo analizamos el patrón de actividad del venado cola blanca *Odocoileus virginianus* del bosque tropical seco en la Reserva de la Biosfera Tehuacán-Cuicatlán (RBTC), México. Nuestra investigación se enfocó en comparar el patrón de actividad entre épocas reproductivas (celo, gestación y crianza), sexos y localidades. Colocamos 100 estaciones de muestreo con cámaras trampa en cuatro localidades, entre febrero de 2012 y febrero de 2016. Analizamos la actividad del venado cola blanca con estadística circular (prueba Watson), estimaciones de densidad kernel e intervalos de actividad núcleo. Obtuvimos un esfuerzo de muestreo de 22,809 días trampa y 1,656 registros independientes. El venado cola blanca mostró un patrón de actividad bimodal en el día con picos de actividad de 06:00 a 12:00 h y 17:00 a 19:00 h. Encontramos diferencias significativas en los picos de actividad entre el periodo de apareamiento y crianza con el de la gestación, entre hembras y machos, y entre localidades en la RBTC. El venado cola blanca muestra marcada adaptabilidad a hábitats con diferentes condiciones ambientales y ecológicas, como regiones templadas, semi-áridas y tropicales. Generalmente es considerada crepuscular porque presenta mayor actividad en el amanecer y atardecer. Sin embargo, nuestros resultados divergieron de esta clasificación, ya que su patrón de actividad fue principalmente diurno y sus picos cambiaron dependiendo del periodo fisiológico, el sexo y las condiciones locales del hábitat. Estas variaciones pueden deberse a las características del hábitat, ya que en este bosque tropical seco no se presentan temperaturas extremas como en las zonas áridas y semi-áridas. Además, la cobertura vegetal protege al venado del calor durante la época de lluvias y algunas especies de plantas les proveen recursos hídricos en la época seca. Nuestros resultados aportan nueva información sobre la biología y el comportamiento de esta especie en los bosques tropicales secos de México.

Palabras clave: Apareamiento; crianza; fototrampeo; gestación; Oaxaca; *Odocoileus virginianus*.

Activity patterns are a crucial element contributing to the optimization of energy balance in animals (Cid *et al.* 2020). These patterns in mammals are linked to the basic needs of nutrition, rest, and reproduction (McFarland 1999). It is known that activity patterns can be regulated by intrinsic factors such as age, sex, and physiological status, alongside extrinsic variables including diurnal-nocturnal transitions, temperature, precipitation, lunar phases, food availability, and interspecies interactions (Oliveira-Santos *et al.* 2009; Harmsen *et al.* 2010; Foster *et al.* 2013; Monterroso *et al.* 2013). Some studies have demonstrated that the presence of domestic species can also influence the activity patterns of wild species, thereby reducing encounters and consequent competition or predation risks (Carter *et al.* 2015; Zapata-Ríos and Branch 2016; Díaz-Ruiz *et al.* 2016). However, studying mammal activity through direct observation is especially difficult when the species of interest have shy behavior or if it inhabits spatially complex environments, which hinders the robust acquisition of ecological data.

Camera traps are a benchmark field method for acquiring data about activity patterns since they can obtain a large amount of data without disrupting the behavior of the target species and can be settled across diverse field conditions (O'Connell *et al.* 2011; Rovero and Zimmermann 2016). This technique is employed to address specific research on ecological patterns and the response of mammal populations to management actions. As such, camera trapping research provide information about the impact of accessibility to hunters on activity patterns (Espinosa and Salvador 2017), the correlation between frugivorous species activity and fruiting tree phenology (Mendoza *et al.* 2019; Mandujano and López-Tello 2022), predator-prey dynamics (Caravaggi et al. 2018), resource partitioning through activity patterns (Xue *et al.* 2018), as well as ecological research and management of megaherbivores species (Thapa *et al.* 2019), arboreal mammals (Astiazarán *et al.* 2020), among others. Consequently, camera traps appear as indispensable tools for investigating the activity patterns of various ungulate species, including the white-tailed deer (*Odocoileus virginianus*) (e.g., Tobler *et al.* 2009, Chen *et al.* 2019; Ikeda *et al.* 2019; Rahman and Mardiastuti 2021).

The white-tailed deer (*Odocoileus virginianus*, hereafter deer) is a species with a wide geographical distribution in the Americas and an adaptive capacity that allows it to inhabit distinct types of habitats with different environmental conditions (Gallina *et al.* 2019; Ortega-Santos *et al.* 2011). Also, it is considered crepuscular because it is most active at dawn and dusk (Holzenbein and Schwede 1989, Webb *et al.* 2010, Massé and Côté 2013). In places with marked seasonality, such as the tropical dry forest, the deer adjusts its activity depending on the availability and quality of food. In the season with a greater abundance of food resources, the deer spends more time moving and foraging, while in the season with lower abundance, it dedicates more time to digestion to avoid energy loss (Holzenbein and Schwede 1989, Webb *et al.* 2010, Massé and Côté 2013). Moreover, some studies suggest that the activity of females and males is related to their metabolic demands, with the former requiring more time to forage to have a better nutrition than males (Beier and McCullough 1990; Gallina *et al.* 2005). Another factor that can influence deer activity is human activities, such as hunting (Kilgo *et al.* 1998) and livestock (Cooper *et al.* 2008; Kukielka *et al.* 2013). Some studies report that deer decrease their activity in places where livestock is present (Cooper *et al.* 2008; Kukielka *et al.* 2013), and that they are more active at night during the hunting season (Kilgo *et al.* 1998). Deer can also modulate their activity to avoid natural predators such as coyotes, especially during the fawning season, with nursery groups being more diurnal compared to nocturnal activity by coyotes (Crawford *et al.* 2021).

In the central Mexican region encompassing the Tehuacán-Cuicatlán Biosphere Reserve (TCBR), a diverse assemblage of wild ungulate species can be found, such as white-tailed deer, collared peccary (*Pecari tajacu*), and red brocket deer (*Mazama temama*), including domestic ungulates such as goats (*Capra hircus*), cattle (*Bos taurus*), horses (*Equus caballus*), and donkeys (*Equus asinus*) (Mandujano *et al.* 2019; Ortíz-García *et al.* 2012). White-tailed deer hold significant importance for local human communities within TCBR (Mandujano *et al.* 2016a). Subsistence hunting of white-tailed deer has long been a customary practice in the region, with trophy hunting emerging as a contemporary addition (López-Téllez *et al.* 2016). This species has been subject to extensive ecological and behavioral research as part of a comprehensive, long-term monitoring initiative (Barrera-Salazar *et al.*, 2015; Ramos-Robles *et al.*, 2013; Yañez-Arenas and Mandujano, 2015; Yañez-Arenas *et al.* 2012).

In this study we describe the activity pattern of white-tailed deer in four localities within the La Cañada region of TCBR. We hypothesized that the physiological seasons, sex and anthropogenic pressure regulate the activity pattern of deer. Therefore, we expected that 1) activity would be greater at twilight during the gestation period to avoid predation, 2) males present greater nocturnal activity than females, and 3) activity will vary between localities as a function of differences in habitat structure and anthropogenic pressures (livestock, free-roaming dogs and poaching). This study presents a comprehensive investigation into the activity patterns of white-tailed deer, shedding light on the complex interplay of factors governing their behavior within the unique ecological context of the TCBR.

Methods

Study are. The TCBR encompasses the northwestern sector of the Meseta of Oaxaca, situated within the La Cañada region, as a constituent of the Sierra Madre del Sur. Geographically, it spans the extreme southeastern region of the state of Puebla and northeastern Oaxaca, encompassing coordinates ranging from 17°39' to 18°53' N latitude and 96°55' to 97°44' W longitude (Figure 1). The reserve covers 490,187 hectares and has an elevation gradient extending from 600 to 2,950 meters above sea level. Climatically, the region experiences an average annual temperature range of 18° to 24.5°C (Mandujano *et al.* 2016a). Precipitation patterns within the valley region display an annual average range of 250 - 500 millimeters, primarily concentrated between May to October, with peak precipitation occurring from June to September (CONANP 2013).

For our study, we selected four localities within the state of Oaxaca, namely San Gabriel Casa Blanca (CBL), San Juan Los Cues (LCU), San Juan Bautista Cuicatlán (CUI), and San Pedro Chicozapotes (CHI) (Figure 1). The dominant vegetation types in CBL and LCU comprise crassicaule thicket and dry tropical forest (Scrub-TDF), characterized by a prevalence of cacti from the *Neobuxbamia* genus. In

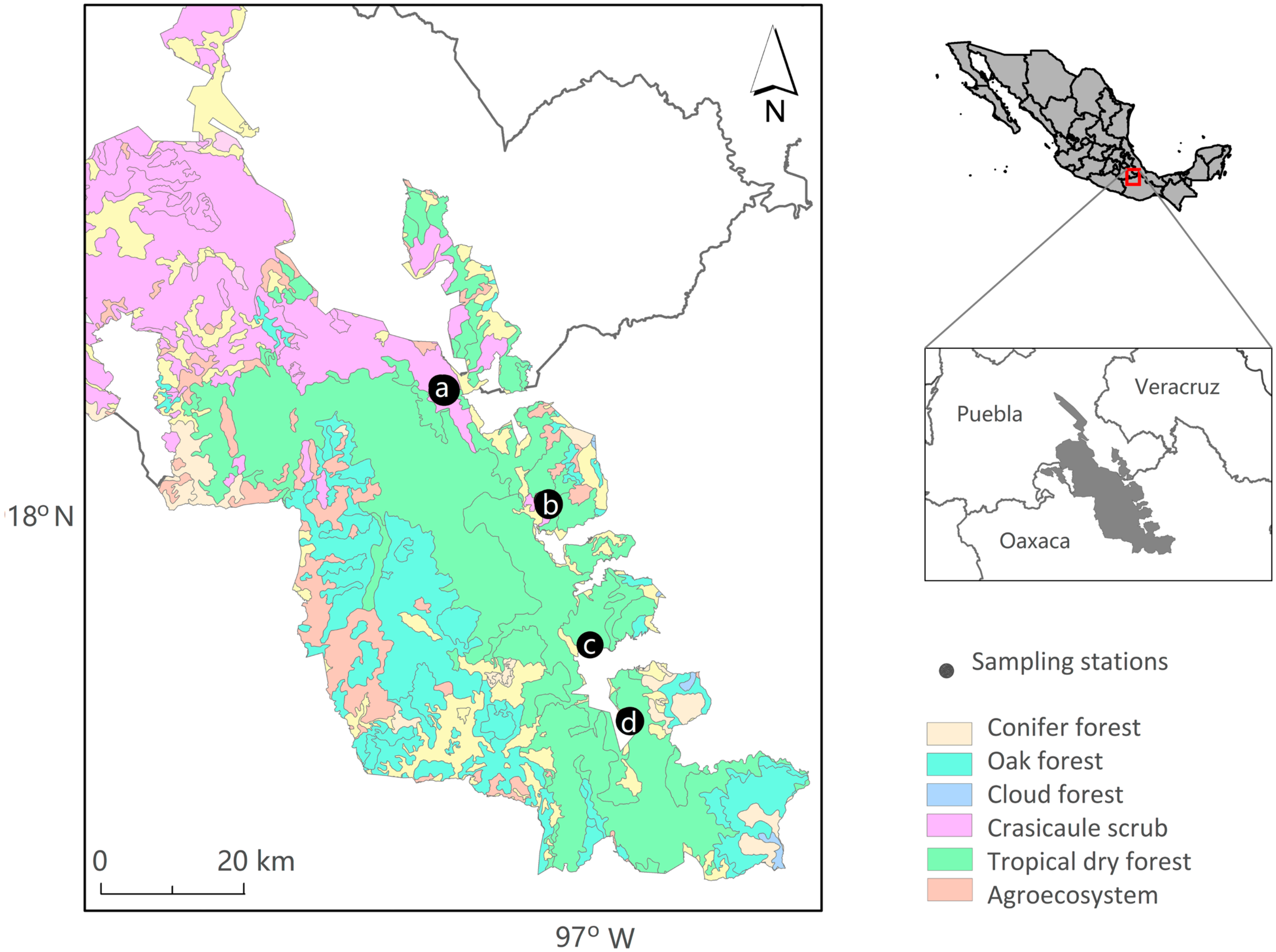

Figure 1. Geographical localization of the Tehuacán-Cuicatlán Biosphere Reserve, the main types of vegetation, and the location of four localities Casa Blanca (A), Los Cues (B), Cuicatlán (C), and Chicozapotes (D) in the region of La Cañada, Oaxaca.

contrast, CUI and CHI are predominantly characterized by tropical dry forests (TDF), featuring a denser and taller tree canopy, and areas with steeper topography (Barrera-Salazar *et al*. 2015). CBL is a site with rough terrain between canyons, hills, and mountains such as Nahualtepec, Cihualtepec, and Petlanco; LCU is located within a plateau in the Cañada region; CUI has a very rugged orography and has large hills; and CHI has a topography made up of alluvial plain, colluvial slope, high hills, and steep slopes and peaks (INAFED 2010). Across all four localities, the primary economic activities consist of agriculture and goat farming, semi-extensive cattle ranching is prevalent in LCU, CUI, and CHI (INEGI 2005).

Data collection. To document the activity patterns of the white-tailed deer, we employed digital camera traps equipped with motion sensors (Cousins Truth Cam 35® and Moultrie Game Spy D-55IR® models). These camera traps were placed in trees, maintaining a consistent height of 20 to 30 cm above ground. To ensure spatial independence, we adhered to a minimum linear distance of 500 meters between each camera. In total, our study encompassed 100 sampling sites, which were distributed across the following periods and localities: 65 sites in CBL, spanning from February 2012 to February 2016; 13 sites in CHI, covering the period from February 2012 to April 2013; 14 sites in CUI, spanning from July 2012 to July 2014; and eight sites in LCU, extending from August 2012 to April 2013. The number of camera sites in CBL and CUI varied across years, maintaining an annual average of 16 and 11 cameras, respectively. All camera traps were programmed to capture a sequence of 3 photographs at intervals of 10 to 15 seconds, remaining operational for a continuous 24-hour cycle. Monthly maintenance checks were conducted to replace storage cards and verify the proper functioning of the camera traps. Subsequently, the collected images were organized and classified using the *camtrapR* package (Niedballa *et al.* 2016). An independent record was considered as a sequence of photographs separated by a minimum time interval of one hour or when distinct individuals were discernible within a shorter period, based on distinctive features such as scars or sexual dimorphism (Peral *et al.* 2022; Suárez López 2023).

Data analysis. Independent records of the white-tailed deer were subjected to kernel density transformation and graphically visualized using the *overlap* package (Ridout and Linkie 2009), and we estimate the deer activity range core (50%) for season, sex, and locality (Oliveira-Santos *et al.* 2013) with the *circular* package (Agostinelli and Lund 2013). We were interested in modeling the activity range core, or the 50% kernel isopleth, since it represents the peaks of activity (Oliveira-Santos *et al.* 2013). Within this analysis, we derived estimations for both mean circular, standard deviation circular parameters and von Mises confidences intervals (90%) with 1000 resamples. We explored potential fluctuations in white-tailed deer behavior corresponding to the species' physiological needs by comparing activity patterns across various dimensions. First, we examined activity patterns during different physiological periods, specifically the rut (November-February), is when the females enter in estrus and the males seek them out to mate; gestation (March-June), is when the males shed their antlers and the females are pregnant; and fawning (July-October), is when the females are lactating and the males begin to grow their antlers (Bello *et al.* 2001). These periods were established by observing the photos before running analysis. We also consider activity as diurnal from 7:00 to 18:59 h, nocturnal from 20:00 to 05:59 h, and crepuscular from 06:00-06:59 and from 19:00-19:59 h. Additionally, we conducted a comparative analysis of activity patterns between male and female deer. Finally, we compared deer activity patterns by locality to determine whether difference in habitat characteristics and anthropogenic pressure influences their activity. For this we obtained the frequency of capture (FC) of livestock, hunters, and free-roaming dogs (*Canis familiaris*) and considered that localities with higher FC for these species have more anthropogenic pressures, while localities with lower FC have less anthropogenic pressures.

For estimate the FC, we use the follow formula:

$$FC = \frac{N\ tot}{Day\ tot} X\ 100\ night\ traps$$

Where:
FC = Frequency of capture
N tot = Number of independent records
Day tot = sampling effort (number of cameras * number of active days of the camera)

The multifaceted comparisons were executed with the Watson's two-sample test (Jammalamadaka and SendGupta 2001) and overlap coefficient in activity range core (Oliveira-Santos *et al.* 2013) from the *circular* package (Agostinelli and Lund 2013), facilitating robust statistical evaluation. All statistical analyses were performed within the R 3.4.1 statistical language (R Core Team 2021).

Results

The total sampling effort was 22,809 trap days, and we obtained a total of 1,656 independent records of white-tailed deer. These records included 736 females, 513 males, and 407 instances where sex could not be identified (Table 1). Across all four study localities, white-tailed deer exhibited predominantly diurnal activity patterns characterized by bimodal peaks occurring from 06:00 to 14:30 h and 16:00 to 19:00 h.

Table 1. Sampling effort, independent records, and frequency of capture, in parentheses, to white-tailed deer, livestock, and illegal hunters.

	Locality				Total
	Casa Blanca	Los Cues	Cuicatlán	Chicoza-potes	
Sampling effort	14,649	1,372	3,573	3,215	22,809
Number of camera traps	65	8	14	13	100
Deer records	1,201 (8.20)	238 (17.35)	145 (4.06)	72 (2.24)	1,656 (7.26)
Females	565 (3.86)	126 (9.18)	25 (0.70)	20 (0.62)	736 (3.22)
Males	347 (2.36)	74 (5.39)	58 (1.62)	34 (1.06)	513 (2.25)
Unidentified	289 (1.97)	38 (2.77)	62 (1.74)	18 (0.56)	407 (1.78)
Cattle records	0 (0)	170 (12.39)	447 (12.51)	15 (0.47)	632 (2.77)
Donkey records	0 (0)	0 (0)	193 (5.40)	0 (0)	193 (0.85)
Free domestic dog records	9 (0.06)	0 (0)	55 (1.54)	2 (0.06)	66 (0.29)
Poaching records	0 (0)	1 (0.07)	5 (0.14)	0 (0)	6 (0.03)

During the rut season, deer showed two activity range core (50%) from 06:58 to 12:45 h and from 15:57 to 18:52; in gestation was from 06:00 to 11:19 and from 17:32 to 20:57; while in fawning was from 06:10 to 13:03 and from 15:52 to 17:49 (Figure 2). We found significant differences in the activity hour mean between the rut (11:56 ± 1.73, CI = 11:09-12:49) and gestation (07:47 ± 2.20, CI = 04:12-10:36; Table 2) periods with overlap coefficient of 0.64 in activity range core (50%). Additionally, we found a significant difference in the activity hour mean between the gestation and fawning (11:16 ± 1.67, CI = 10:37-11:57; Table 2) periods with overlap coefficient of 0.63 in activity range core (50%). During gestation, deer showed less activity between 11:20 and 17:00 h and increased nocturnal activity, whereas during the fawning season, deer were more active during the daytime (Figure 2). We did not find significant differences in the activity hour mean between the rut and fawning season and, overlap coefficients in activity range core (50%) was 0.86.

Table 2. Comparison of activity pattern of white-tailed deer by locality, sex, and season. Watson test (U^2).

Season / Sex / Locality	U^2	p
Rut - Gestation	0.70	0.001*
Rut - Fawning	0.12	0.10
Gestation - Fawning	0.67	0.001*
Female - Male	0.20	<0.05*
Casa Blanca - Los Cues	0.22	<0.05*
Casa Blanca - Cuicatlán	0.08	0.10
Casa Blanca - Chicozapotes	0.06	0.10
Los Cues - Cuicatlán	0.22	<0.05*
Los Cues - Chicozapotes	0.09	0.10
Cuicatlán - Chicozapotes	0.09	0.10

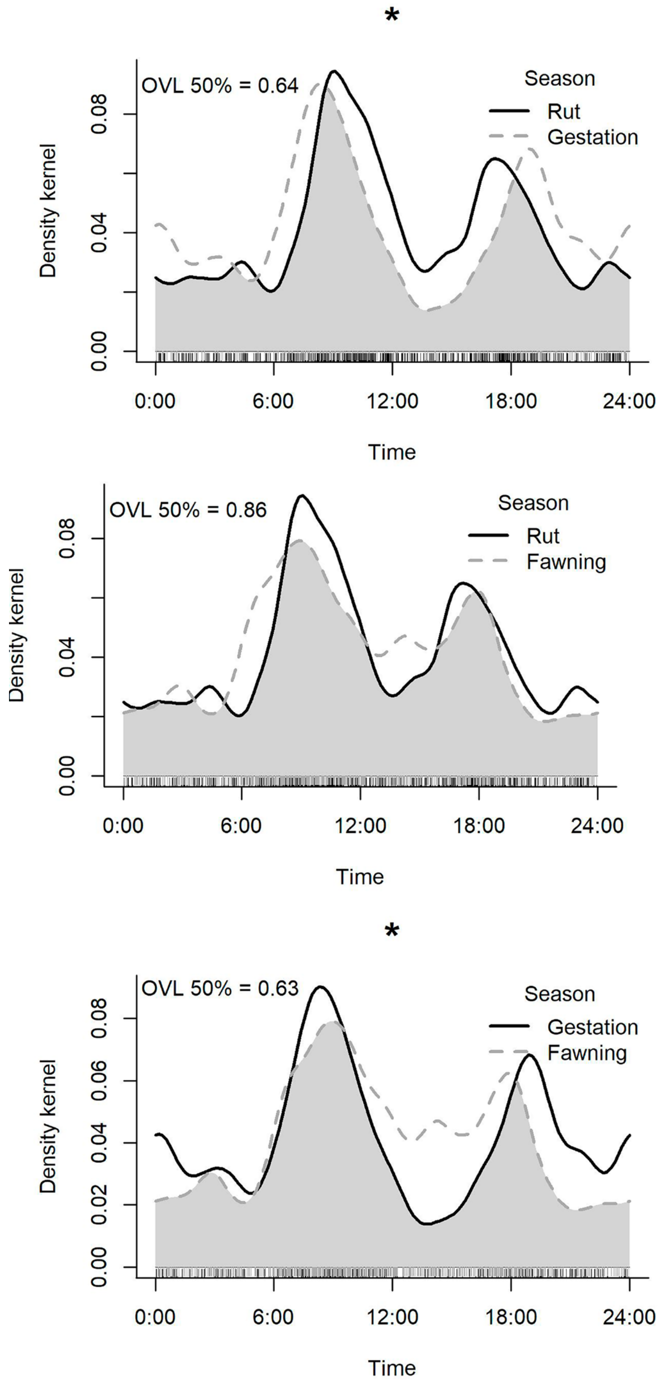

Figure 2. White-tailed deer activity pattern for physiological season in TCBR. The * indicates statistically significant differences between activity hours means and OVL 50% is overlap activity range core (50%).

In terms of sex-based comparisons, both sexes showed two activity range core (50%): females one activity range core from 06:37 to 12:22 h and the other from 16:07 to 18:48 h, while males one activity range core from 06:00 to 13:09 h and the other from 16:16 to 17:57 h (Figure 3). Our analysis indicated that activity hour means of females (12:00 ± 1.65, CI = 11:09-12:31) were statistically different when compared to males (10:20 ± 1.78, CI = 09:28-11:18; Table 2) and overlap coefficients in activity range core (50%) was 0.85.

In three localities (CBL, LCU, and CUI), deer also showed two activity range core (50%), one in the morning and another in the afternoon, while they were unimodal in CHI. Specifically, deer was active from 06:31 to 12:22 h and from 16:01 to 19:07 h in CBL; from 06:00 to 12:16 h and from 16:55 to 17:37 h in LCU; from 06:02 to 13:06 h and from 17:50 to 20:20 h in CUI; and from 06:00 to 14:34 h in CHI (Figure 4). Furthermore, we found significant statistical differences in activity hour mean between CBL (11:47 ± 1.81, CI = 11:09-12:29) and LCU (10:02 ± 1.57, CI = 09:05-11:09) with overlap coefficient of 0.75 in activity range core (50%), as well as between CUI (11:10 ± 1.91, CI = 09:01-13:52) and LCU with overlap coefficient of 0.62 in activity range core (50%) (Table 2). We did no find significant statistical differences were observed with CHI (10:03 ± 1.76, CI = 07:33-12:45) and overlap coefficients in activity range core (50%) were 0.67 (CBL), 0.73 (LCU) and 0.78 (CUI).

Discussion

White-tailed deer show remarkable adaptability to habitats with varying environmental and ecological conditions, as temperate, semi-arid, and tropical regions (Ortega-Santos *et al.* 2011; Gallina *et al.* 2019). Generally, deer are regarded as crepuscular because they tend to exhibit greater activity during dawn and dusk, consistent with a behavioral strategy aimed at conserving energy and water during extreme temperature hours (Beier and McCullough 1990; Kammermeyer and Marchinton 1977). In regions characterized by marked seasonality, deer adjust their activity patterns based on the availability and quality of food resources. During periods of abundant food, they allocate more time to movement and foraging, whereas with of food scarcity, they increase hours of digestion to conserve energy (Holzenbein and Schwede 1989; Webb *et al.* 2010; Massé and Côté 2013; Gallina and Bello 2014).

Our results show that white-tailed deer is mainly diurnal in TCBR, an activity pattern that contrasts with the results of the studies previously mentioned. These differences could be related to habitat characteristics, such as type of vegetation, temperature, and anthropogenic pressure. For example, our study area does not present such marked changes in temperature unlike the other studies (North of country, United States, and Canada); the predominant vegetation is dry tropical forest, while that other studies are closed forest, open forest, swamp, or scrub (Holzenbein and Schwede 1989; Webb *et al.* 2010; Massé and Côté 2013; Gallina and Bello 2014). These factors possibly benefit diurnal activity because the vegetation cover may protect against heat during the rainy season, and some plants species offer water sources for deer during the dry season, when water availability decreases (Arceo *et al.* 2005; Ramos-Robles *et al.* 2013). Another important characteristic of our study area, which could have influenced deer activity, was the presence of poachers, cattle, and free-roaming dogs, of the four localities, only one (CBL) had few records of this kind. Moreover, camera trapping studies have also reported that this specie presented greater diurnal activity in tropical dry forest and other types of habitats (Hernández-Saintmartín *et al.* 2013; Soria-Díaz and Monroy-Vilchis 2015;

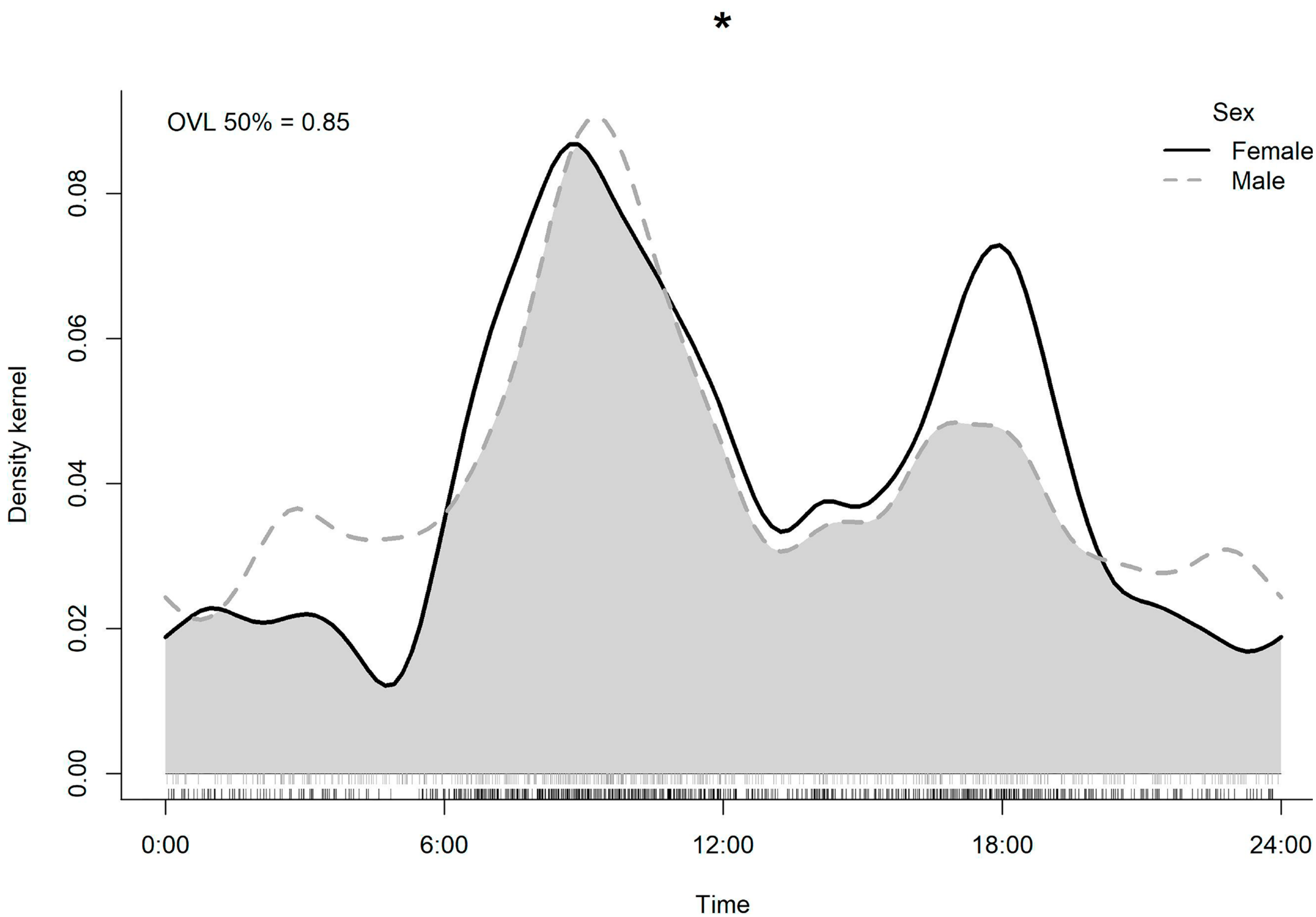

Figure 3. Females and males white-tailed deer activity pattern in the TCBR. The * indicates statistically significant differences between activity hours means and OVL 50% is overlap activity range core (50%).

Higdon *et al.* 2019), including our preliminary study in the TCBR (López-Tello *et al.* 2015).

Across all three physiological periods (rut, gestation, and fawning), the white-tailed deer consistently displayed diurnal activity patterns, with varying expressions of their activity peaks. Moreover, during gestation, deer showed greater crepuscular activity supporting our prediction that deer would be more active during this period to avoid predation, because it is crucial in this life stage. In addition, we found statistically significant differences and low overlap coefficient in activity range core between the rut and gestation periods, as well as between fawning and gestation. During the gestation period, deer decreased their activity range core in the morning, whereas was greater in rut and fawning, also showed less activity range core in the afternoon during fawning. These findings agree with prior studies that suggest variations in deer activity across physiological periods (Kammermeyer and Marchinton 1977; Massé and Côté 2013). Demands to search for mates (in the case of males) or raise offspring (in the case of females) can be influenced mainly by changes in vegetation and predator activity (Cueva-Hurtado et al. 2024). For instance, female deer decrease their activity and movement during gestation, while raising their young to minimize predation risk (Holzenbein and Schwede 1989; Beier and McCullough 1990). In contrast, males increased their activity during the mating season, as they actively seek potential mates (Holzenbein and Schwede 1989; Beier and McCullough 1990).

In the TCBR, the primary predator of white-tailed deer is the puma (*Puma concolor*), a species classified as cathemeral, showing greater activity during nighttime hours (Monroy-Vilchis *et al.* 2009; Hernández-Saintmartín *et al.* 2013; Ávila-Nájera *et al.* 2016). While the coyote can prey on the fawn during nighttime hours, especially in the fawning season (Crawford *et al.* 2021). We did not obtain sufficient puma and coyote records to compare their activity peaks with those of white-tailed deer. However, we do not discard that puma and coyote activity likely influence deer behavior. To mitigate predation risk, deer may show more activity in the morning, when its main predators are less active.

Our results showed that activity patterns of female and male deer, in general, were similar and overlap coefficient in activity range core was high. However, we found significant differences between their mean activity hour and von Mises confidence intervals were narrow. The activity range core of males was greater in the morning than that of females and presented less activity during the sunset, while females

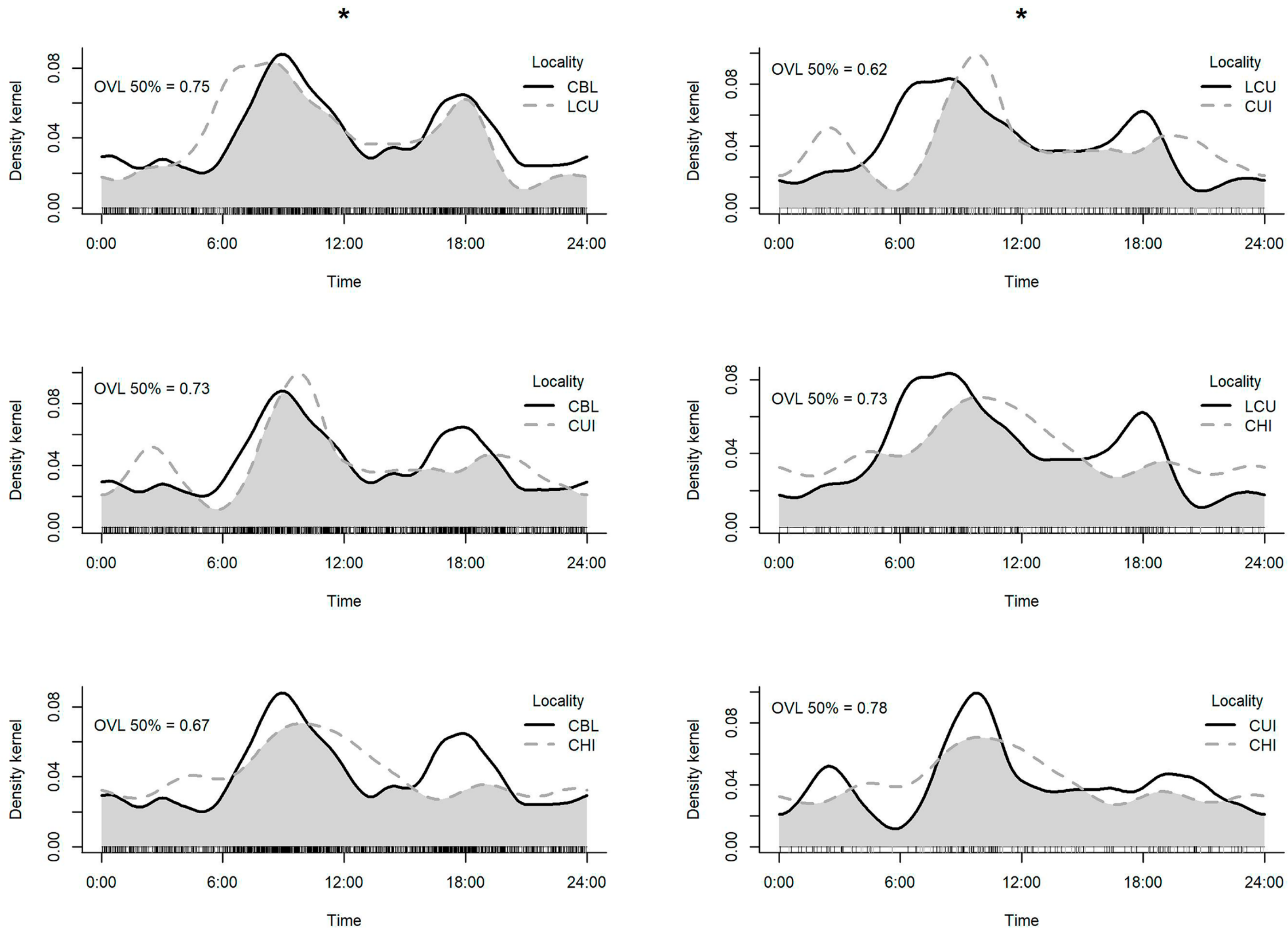

Figure 4. White-tailed deer activity pattern for locality in TCBR. Abbreviations: Casa Blanca (CBL), Los Cues (LCU), Cuicatlán (CUI) and Chicozapotes (CHI). The * indicates statistically significant differences between activity hours means and OVL 50% is overlap activity range core (50%).

displaying peak activity at noon. These results do not agree with our prediction since males had less nocturnal activity, but it suggest that sex-specific physiological requirements play a crucial role. This phenomenon agrees with studies emphasizing sexual dimorphism and metabolic demands, as females necessitate higher-quality food resources and, consequently, allocate more time to foraging (Beier and McCullough 1990; Gallina and Bello 2014). However, some studies have reported similar activity patterns between male and female deer, with distinctions emerging in specific seasons (Beier and McCullough 1990; Gallina *et al.* 2005; Webb *et al.* 2010; Cueva-Hurtado et al. 2024). We did not analyze sex-specific differences within each physiological season due to limited identification in some independent records. However, our results suggest that differences in activity between sexes in the TCBR could be linked to their metabolic requirements and physiological seasons. Females may maintain higher daytime activity during the mating and fawning seasons, coinciding with increased rainfall and vegetation cover, while reducing daytime activity during gestation to avoid exposure to high temperatures when vegetation cover decreases (Beier and McCullough 1990; Webb *et al.* 2010). In addition, other studies have shown that females decrease their activity and movements before parturition due to the decrease in food availability and quality, as well as to avoid predation (Sánchez-Rojas *et al.* 1997; Gallina and Bello 2014). Meanwhile, males increased their movements during rut in search of receptive females (Webb *et al.* 2010), maybe this could explain their activity during the morning, as well as to avoid predators and illegal hunters.

Our results indicate that the white-tailed deer's activity pattern in the TCBR is mainly diurnal across all four study localities, being bimodal in three localities (CBL, LCU, CUI), and unimodal in CHI. However, we found significant differences in deer activity hour means between LCU and CBL, as well as between LCU and CUI. In LCU, the deer activity range core was more restricted in general and in the afternoon compared to CBL and CUI. Moreover, in CUI, the locality with more anthropogenic pressure (measured by greater frequency of captures by domestic species and poachers), deer presented more activity in sunset and night hours. Although the von Mises confidence intervals in CUI were wide and overlap with confidence intervals of LCU, we suggest that the difference between localities should are related to habitat characteristics and anthropogenic pressure, because LCU y CUI presented more open vegetation, higher shrubs, and greater proximity to main roads and agroecosystems unlike CBL (López-Tello 2014). In CBL primarily has goat farming and poaching has decreased due to the establishment of a legal white-tailed deer hunting management unit (UMA by its acronym in Spanish) in 2012 (Mandujano et al. 2016b). Our results are consistent with our prediction and other studies that have been demonstrated that these anthropogenic factors can alter the activity patterns of wildlife species, as they tend to reduce their activity during hours with more human or domestic animal activity to avoid encounters (Kilgo *et al.* 1998; Wang *et al.* 2015).

In conclusion, our study suggests that white-tailed deer in the TCBR exhibit diurnal activity patterns, and their activity peaks are related mainly to sex and physiological periods since their metabolic demands change during different periods of the year, therefore, validating our hypotheses. Also, we found that the activity can be influenced by anthropogenic factors, such as poaching and the presence of domestic species, since deer activity was more nocturnal and crepuscular in CUI, the most disturbed area. However, we suggest that it is important to increase the sampling effort in CHI, CUI and LCU to understand how these variables influence the deer activity pattern. It would also be valuable to obtain a greater number of records of the puma, coyote, domestic species (free-roaming dogs and livestock) and humans to compare their activity patterns against those of deer. Overall, our research provides new insights into the biology and behavior of white-tailed deer in the tropical dry forest of the Tehuacán-Cuicatlán Biosphere Reserve.

Acknowledgments

We would like to express our gratitude for the financial support provided by the Secretaría de Ciencia, Humanidades, Tecnología e Innovación (SECIHTI) through projects CB-2009-01-130702 and CB-2015-01-256549. We are also deeply thankful to the following individuals for their invaluable assistance during fieldwork: P. Ramírez-Barajas, and A. Barrera-Salazar, O. Cruz-Jácome, R. Fabián, and O. Morteo-Montiel. We extend our appreciation to local guides S. Chávez, J. L. Meza, R. Mendoza, T. Hernández, H. Villareal, R. Salinas, A. Hernández, and the communities' residents for their generous support in the field. We would also like to acknowledge the authorities of the four study locaties for their continuous facilitation of our fieldwork. Special thanks are due to R. Rodríguez and T. Pérez for their logistical assistance throughout the project. Thanks to MSc. Jorge Ramos Luna for editing the figures.

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Associated editor: Rafael Reyna Hurtado
Submitted: February 28, 2025; Reviewed: August 1, 2025
Accepted: August 21, 2025; Published on line: September 4, 2025