



## Home range dynamics of the Tehuantepec Jackrabbit in Oaxaca, Mexico

### Dinámica del ámbito hogareño de la liebre de Tehuantepec en Oaxaca, México

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**Abstract.** Information on the spatial ecology of the Tehuantepec jackrabbit (*Lepus flavigularis*) is important for developing management strategies to preserve it in its habitat. We radio-collared and monitored 60 jackrabbits from May 2006 to April 2008. We estimated annual and seasonal home ranges and core areas by using the fixed-kernel isopleth to 95% and 50% of confidence, respectively. This jackrabbit showed a highly variable seasonal home range: 1.13 ha to 152.61 ha for females and 0.20 ha to 71.87 ha for males. Annual and seasonal home ranges and core areas of females were significantly wider than male home ranges. There was considerable overlap of ranges within and between sexes, with the home range of each jackrabbit overlapping with the ranges of 1 to 46 other individuals. Home range and overlap analysis confirms that the Tehuantepec jackrabbit is a polygamous and non-territorial species. Conservation of savannas and grassy dunes is indispensable to assure the survival of the species.

Key words: *Lepus flavigularis*, home range, core area.

**Resumen.** La información sobre la ecología espacial de la liebre de Tehuantepec (*Lepus flavigularis*) es importante para el desarrollo de estrategias de manejo para conservar su hábitat. Se radio-marcaron y monitorearon 60 liebres, desde mayo del 2006 hasta abril del 2008. Se estimó el valor del ámbito hogareño anual y su área núcleo utilizando el método de la isopleta de Kernel fijo con 95% y 50% de confianza, respectivamente. Esta especie de liebre mostró un ámbito hogareño estacional altamente variable: de 1.13 ha a 152.61 ha para las hembras y de 0.20 ha a 71.87 ha para los machos. El ámbito hogareño anual y estacional así como sus áreas núcleo fueron significativamente mayores para las hembras que para los machos. Se encontró un traslape considerable de las áreas de actividad entre sexos y entre individuos, cada liebre traslapó su ámbito hogareño con 1 a 46 individuos. El análisis de ámbito hogareño y traslape confirma que la liebre de Tehuantepec es una especie polígama y no territorial. La conservación de las áreas de pastizal y dunas costeras es indispensable para asegurar la sobrevivencia de la especie.

Palabras clave: *Lepus flavigularis*, ámbito hogareño, área núcleo.

## Introduction

It is possible to infer significant information about social organization and reproductive behavior by knowing how a species uses available space through time (Parker and Waite, 1997; Powell, 2000; Kernohan et al., 2001; Farías et al., 2006; Cooper and Randall, 2007), and even to make decisions about the size of the area to be protected for the preservation of a viable population or planning land management focused on conservation (Hulbert et al., 1996; Knapp and Owens, 2005; Boyce and Barry, 2007). This is particularly important for threatened species (Morrison et al., 1998). Home range analyses allow determination

of the size and boundaries of the area used by either an individual or a population. The home range is the area used by an individual in a specific period, while the core area is the portion inside the home range where an individual concentrates its activities (Samuel et al., 1985; Samuel and Garton, 1987). Both home range and core area are correlated with population density and social organization, and may vary depending on the availability and distribution of resources and habitat quality (Ford, 1983; Macdonald, 1983; Komdeur and Deerenberg, 1997). Land management practices also influence home range dynamics since these alterations inevitably affect the availability of resources for wildlife (McGee, 1982; Hobbs and Spowart, 1984; Ford et al., 2000; R  he and Hohmann, 2004; Lorenzo et al., 2008).

The Tehuantepec jackrabbit (*L. flavigularis*) is a threatened species due to habitat loss and fragmentation, poaching, and genetic isolation. At present, only four small populations exist in the surroundings of the upper and lower lagoons in the southern part of the Isthmus of Tehuantepec, Oaxaca, México (Montecillo Santa Cruz, San Francisco del Mar, Aguachil, and Santa María del Mar; López-Forment, 1989; Flux and Angermann, 1990; Lorenzo et al., 2003; Lorenzo et al., 2006). This situation has driven the Mexican government to declare the species as endangered (INE, 1997, Diario Oficial de la Federación, 2001), which concurs with its inclusion in the Red List of threatened species (IUCN, 2009).

The clearest morphological characteristic of this species is the presence of two brown stripes that spread from the base of each ear to the nape. The ventral part of the body is white, and the tail is black on the top and white at the base (Flux and Angermann, 1990). Its ears are markedly long and are brown, without the black marks near the tips as in many other hare species (Cervantes, 1993). An average weight of up to 2 kg has been reported for this species (Lorenzo et al., 2000). As in other species of hares, the Tehuantepec jackrabbit has his periods of major activity during the night, when it feeds and socializes with other individuals. During the day, the Tehuantepec jackrabbit rests under bushes and grasses (Farías et al., 2006).

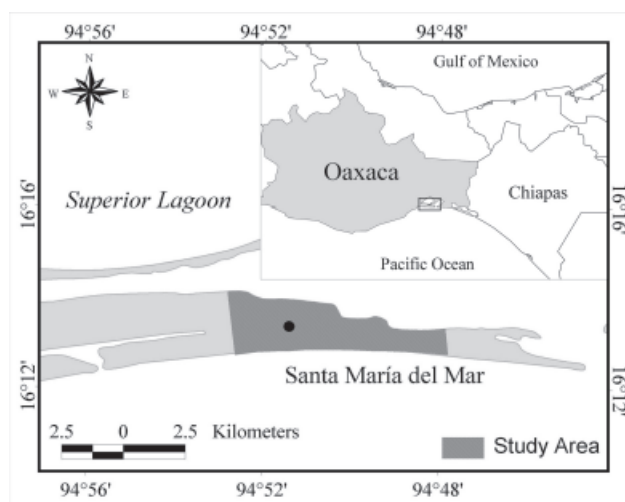
Few studies have been carried out on this species. A single survey had been carried out on the home range of a Tehuantepec jackrabbit population located north of the Lower Lagoon (Farías et al., 2006). The findings allowed the authors to speculate about the social organization system in that jackrabbit population. They reported possible polygamous and non-territorial behavior. These authors also found home range values from 8 to 166 ha (Farías et al., 2006), showing a high intraspecific variability as in other *Lepus* species (Best, 1996; Kunst et al., 2001; Stott, 2003; Rùhe and Hohmann, 2004). It can be inferred from these studies that *Lepus* populations adjust their home range sizes to resource availability (Smith et al., 1988; Hulbert et al., 1996; Farías et al., 2006). Food availability and cover has been shown to influence home range size by enlarging it during periods of scarcity and shrinking it when resources are abundant (Hewson and Hinge, 1990; Hulbert et al., 1996; Wolfe and Hayden, 1996; Kunst et al., 2001).

This study aimed to evaluate annual and seasonal home range sizes of the Tehuantepec jackrabbit's population, in Santa María del Mar, Oaxaca, Mexico. Home range overlap was also monitored, and implications for management and conservation of this endangered species are also discussed.

## Material and methods

The study area was a 14 km<sup>2</sup> portion of savanna, in the surroundings of Santa María del Mar (16°13'15.36" N, 94°51'24.08" W; Fig. 1) in the municipality of Juchitán de Zaragoza, Oaxaca. The locality Santa María del Mar is inhabited by 739 Huave indigenous people (INEGI, 2000; Vargas, 2000). Local people make their living by fishing, hunting, raising cattle, and occasionally by farming. Poaching is an activity historically carried out in Santa María del Mar. Poachers arrive from other localities to hunt several species including Tehuantepec jackrabbit for their own consumption and commercial purposes (Vargas, 2000). At present, poaching is an activity that adds stress to this already endangered population. Currently, local authorities protect the Tehuantepec jackrabbit by surveillance and fining of poachers (Municipal agent of Santa María del Mar, *pers. comm.*). However, poaching and consumption of terrestrial vertebrates continue to be common activities, since they belong to deep-rooted traditions and due to the impoverished social and economic conditions in the area (Vargas-Espindola, 2001).

The local climate is tropical with a mean annual temperature of 25°C and a mean annual rainfall of 800 mm (García, 1988). The rainy season is from May to October with a summer drought in August; while the dry season starts in November and ends in April (Zizumbo and Colunga, 1982). The area is dominated by grasslands with species like donkey grass (*Jouvea pilosa*), and grasslands are associated with cacti (*Opuntia spp.*) and some shrub species such as black sage (*Cordia curassavica*), manchineel (*Hippomane mancinella*) and cuachalalate (*Amphipterygium adstringens*). A few small patches of



**Figure 1.** Study area location in the Isthmus of Tehuantepec, Oaxaca, Mexico.

button mangrove (*Conocarpus erecta*) are also present in the area (Vargas, 2000). Native mammals associated with the Tehuantepec jackrabbit are castilian rabbits (*Sylvilagus floridanus*), armadillos (*Dasypus novemcinctus*), skunks (*Mephitis macroura* and *Conepatus leuconotus*), opossums (*Didelphis spp.*), gray foxes (*Urocyon cinereoargenteus*), and coyotes (*Canis latrans*; Cervantes and Yépez, 1995; Ramírez-Pulido et al., 2005).

Between March 2006 and January 2007 we captured and radio-collared 60 adult jackrabbits, 34 females and 26 males. Captures were carried out both day and night on savanna and grassy dunes. Two capture methods were used because the hare has two different periods of activity for the day and for the night (Farías et al., 2006). At night, jackrabbits were spotted by two observers from a vehicle moving slowly through the area. As soon as an individual was located, it was temporarily blinded using spotlights and captured with handheld fishing cast nets (3-4 m in diameter). During the day, jackrabbits were driven toward previously set fishing nets (seines) approximately 1 m high and 70 m long. Once the jackrabbits were captured, we rapidly placed them in cloth sacks for their manipulation (Lorenzo et al., 2000; Farías et al., 2006; Rioja et al., 2008). We recorded sex, age (juvenile or adult), weight, and general measurements (total length, tail length, back leg length, ear length) of every specimen captured. Adult jackrabbits (an adult individual was defined as being at least 1.8 kg, 55.6 cm-long, and with a completely formed clitoris or penis; see Farías et al., 2006) were fitted with 35 g, 24-month battery, activity/mortality sensor VHF radio-collar transmitters (TX-35/24, 148 MHz, TELENAX, Mexico). No tag marks were used. Juveniles were released without radio-collars. Capture and handling of jackrabbits complied with Mexican law (permit SGPA/DGVS/02094/07; Dirección General de Vida Silvestre, SEMARNAT). We also followed the guidelines approved by the American Society of Mammalogists (Gannon et al., 2007).

We intensively monitored radio-collared jackrabbits from May 2006 to April 2008. Monitoring was done by walking day and night through the study area. Twelve periods of monitoring were realized during two years of study, each one with duration of 20 to 30 days. During each monitoring period, we located every radio-collared jackrabbit in 1-3 day tracking periods, recording 12-36 positions per jackrabbit. Locations were registered every two hours. Locations were taken by detecting radio-signals from radio-collared individuals with 148-172 MHz portable receivers (R-1000, Communications Specialist Inc., Orange, CA.) and 3-element Yagui antennas (TELENAX, Mexico). Once a signal was received, we approached the marked jackrabbit until it was visible at a distance of 50-70

m, avoiding closer encounters that could interfere with its natural behavior (White and Garrott, 1990; Farías et al., 2006). We recorded the time (hour and minutes) when the radio-collared individual was sighted, and then we waited until the jackrabbit walked away before obtaining the Universal Transverse Mercator (UTM) coordinates for the locations of sighting. Coordinates were obtained from a global positioning system handheld receiver (eTrex Vista, 3-15 m accuracy, Garmin, Olathe, KS).

We analyzed radio-telemetry data in a seasonal basis. We considered the rainy season as the period from May to October (2006 and 2007), and the dry season from November to April (2007 and 2008). We used the information gathered throughout study (May 2006 to April 2007, and May 2007 to April 2008) and for each radio-collared jackrabbit to calculate the 2007 and 2008 annual home range separately. We evaluated the effect of sex and season on size differences in seasonal and annual home ranges and core areas of jackrabbits with analysis of variance (ANOVA, Sokal and Rohlf 1981). Comparisons of annual home range and core areas between the sexes were made by contrasting all the records of annual home range and core area per individual in the two years of monitoring and between sexes per year. Distinctions between seasonal home range and core area between sexes were made by contrasting all the measurements of seasonal home range and core area per individual of every monitored season.

Home ranges and core areas were calculated using the fixed Kernel method with least squares cross-validation (Worton, 1989; Seaman and Powell, 1996; Powell, 2000) through the ArcView GIS software (3.2 version, Environmental Systems Research Institute Inc. ESRI, Redlands, California) with the Spatial Analyst (ESRI) and Animal Movement Analysis extensions (Hooge and Eichenlaub, 1997). A home range was defined as the 95% confidence fixed-kernel isopleth and the core area as the 50% confidence fixed-kernel isopleth (Powell, 2000). We calculated seasonal and annual home ranges and core areas only for jackrabbits with at least 30 records per season.

We calculated the home range and the core area overlap as the area shared by 2 neighboring individuals in the same temporal record using Minta's index (1992), where overlap values range from 0 (no overlap) to 1 (a 100% overlap; Farías et al. 2006). Using ArcView GIS with the Spatial Analyst and GeoProcessing Wizard (ESRI) extensions, we estimated the size of overlap areas (Farías et al., 2006). We compared home range and core area overlap indices for female-female, male-male, and female-male dyads. All instances of overlap between neighboring annual and seasonal home ranges and core areas, as well as between and within sexes with  $\geq 1$  individual were considered as a dyad. We also evaluated the effect of sex and season

on home range overlap with an analysis of variance (ANOVA - Sokal and Rohlf, 1981). Comparisons between annual home range overlap and core area overlap between sexes were made by contrasting the overlap indices of all annual home range and core area overlap per dyads in the two years of monitoring and between sexes per year. Distinctions between seasonal home range overlap and core area overlap between sexes were made by contrasting the overlap indices of all seasonal home range and core area per dyads of each monitored season.

## Results

Annual home ranges were estimated for 48 jackrabbits for the 2007 data and 49 jackrabbits for 2008, each with at least 30 records per season. Seasonal home ranges were calculated for 48 jackrabbits during the 2006 rainy season, 55 during the 2007 dry season, 53 during the 2007 rainy season and 49 during the 2008 dry season (Table 1). The individuals who survived from the capture period to the end of the study were monitored throughout two years. Of all captured females (34 individuals), 25 were monitored throughout two years of study (73.5 %), of the whole of captured males (26 individuals), 23 survived throughout two years (88.5 %).

Tehuantepec jackrabbits showed wide variation in their seasonal home ranges during the four radio-tracking seasons (Table 1). Females had similar home ranges and core areas ( $P>0.05$ ) between the 2006 rainy season and the 2007 dry season. In contrast, males had smaller home

ranges and core areas between 2006 rainy season and 2007 dry season, although this difference was not statistically significant ( $P>0.05$ ). The largest change was observed between the dry and rainy seasons of 2007, when both home range and core area shrunk dramatically in both males and females ( $P<0.05$ ). From the 2007 rainy season to the 2008 dry season both females and males showed a slight increase in the size of their area of movement. Nevertheless the increase in home range and core area size was not significant ( $P>0.05$ ). The general tendency throughout our 2 year study was toward a reduction in home range and core area size between seasons. When we compared home range and core areas of males and females between the 2006-2007 rainy seasons and the 2007-2008 dry seasons, we found highly significant differences between seasons, verifying the disparity between the two years of the study.

When all seasonal home range values per individual were compared, males tended to have significantly smaller annual home range sizes and core area sizes than females for all seasons monitored ( $F=15.74$ ,  $d.f.=1,23$ ,  $P=0.00$  and  $F=22.06$ ,  $d.f.=1,23$ ,  $P=0.00$ , respectively).

Annual home range and core area sizes averaged (2007-2008)  $30.44 \pm 4.05$  ha and  $7.24 \pm 1.35$  ha for females ( $n=25$ ), and  $13.52 \pm 2.27$  ha and  $3.62 \pm 1.11$  ha for males ( $n=23$ ). The size of the home ranges of males and females diminished between 2007 and 2008 (Table 1), whereas the size of the core area increased slightly in both sexes for the same period. When compared, differences between years were not significant ( $P>0.05$ ). Between males and females a significant difference in annual home range and

**Table 1.** Annual and seasonal home ranges and core areas (hectares), fixed-Kernel (K) method, with 95% (home range) and 50% (core area) of confidence

Season	N	Females		N	Males		N	Total mean	
		Home range	Core area		Home range	Core area		Home range	Core area
2006 Rainy <sup>a</sup>	25	$45.84 \pm 18.33$	$9.99 \pm 3.51$	23	$25.70 \pm 5.51$	$4.58 \pm 0.90$	48	$36.19 \pm 27.30$	$7.4 \pm 4.8$
2007 Dry <sup>b</sup>	31	$41.32 \pm 12.59$	$9.03 \pm 2.91$	24	$13.38 \pm 3.60$	$2.64 \pm 0.50$	55	$35.72 \pm 29.13$	$7.27 \pm 4.26$
2007 Rainy <sup>c</sup>	29	$12.66 \pm 4.32$	$3.01 \pm 1.60$	24	$5.21 \pm 2.45$	$1.16 \pm 0.57$	53	$10.99 \pm 8.2$	$2.72 \pm 1.52$
2008 Dry <sup>d</sup>	26	$16.25 \pm 6.15$	$5.30 \pm 1.53$	23	$8.61 \pm 3.52$	$3.14 \pm 0.49$	49	$12.66 \pm 6.27$	$4.31 \pm 1.68$
Annual 2007 <sup>e</sup>	25	$33.60 \pm 10.66$	$6.28 \pm 2.14$	23	$15.13 \pm 8.69$	$2.84 \pm 0.89$	48	$26.02 \pm 18.51$	$4.86 \pm 3.59$
Annual 2008 <sup>f</sup>	26	$27.57 \pm 13.11$	$8.20 \pm 3.03$	23	$11.92 \pm 6.51$	$4.41 \pm 0.90$	49	$20.9 \pm 12.63$	$7.73 \pm 4.52$
Annual mean	25	$30.44 \pm 4.05$	$7.24 \pm 1.35$	23	$13.52 \pm 2.27$	$3.62 \pm 1.11$			

<sup>a</sup> 2006 Rainy: May 2006 to October 2006

<sup>b</sup> 2007 Dry: November 2006 to April 2007

<sup>d</sup> 2008 Dry: November 2007 to April 2008

<sup>c</sup> Annual 2007: May 2006 to April 2007

<sup>f</sup> Annual 2008: May 2007 to April 2008

core area sizes was detected for 2007 ( $F=24.9$ ,  $d.f. = 1,47$ ,  $P=0.039$  and  $F=4.59$ ,  $d.f. = 1,47$ ,  $P=0.017$ , respectively) and for 2008 ( $F=4.62$ ,  $d.f. = 1,48$ ,  $P=0.036$  and  $F=9.49$ ,  $d.f. = 1,48$ ,  $P=0.003$ , respectively). Interestingly, both females and males had smaller home ranges during the 2<sup>nd</sup> year of study compared to the 1<sup>st</sup> year.

We detected overlap between neighboring annual home ranges of all 427 dyads (female-female, female-male and male-male) contrasted, with a mean Minta's index of  $0.39 \pm 0.08$  for all study. Mean overlap index for all female-female dyads ( $n = 141$ ) was  $0.48 \pm 0.14$ , while mean overlap index for all male-male dyads ( $n = 88$ ) was  $0.42 \pm 0.09$ . Mean overlap index for all female-male dyads ( $n = 198$ ) was  $0.37 \pm 0.12$ .

Annual core area overlap occurred in 102 dyads; mean overlap indices were  $0.35 \pm 0.2$  for female-female dyads ( $n = 21$ ),  $0.29 \pm 0.12$  for male-male dyads ( $n = 15$ ), and  $0.15 \pm 0.13$  for female-male dyads ( $n = 66$ ). There were no significant differences ( $P>0.05$ ) between home ranges and core areas of female-female, male-male and female-male dyads.

Seasonal home range overlap was less frequent compared with annual home range overlap. Throughout the 2 years studied, we detected overlap between neighboring seasonal home ranges of 146 dyads contrasted (female-female, female-male and male-male), with a mean Minta's index of  $0.22 \pm 0.09$ . Mean overlap index for female-female dyads ( $n = 73$ ) was  $0.27 \pm 0.1$ , while mean overlap index for male-male dyads ( $n = 34$ ) was  $0.18 \pm 0.04$ , and mean overlap index for female-male dyads ( $n = 39$ ) was  $0.17 \pm 0.04$ . Significant differences were detected between female-female and male-male dyads ( $F=23.97$ ,  $d.f.=1,105$ ,  $P=0.00$ ), as well as for female-female and female-male dyads ( $F=34.79$ ,  $d.f.=1,105$ ,  $P=0.00$ ). In addition, male-male and female-male dyads showed no significant difference ( $F=1.99$ ,  $d.f.=1,71$ ,  $P=0.16$ ).

Seasonal core area overlaps occurred in only 86 dyads; mean overlap indices were  $0.19 \pm 0.03$  for female-female dyads ( $n = 35$ ),  $0.15 \pm 0.02$  for male-male dyads ( $n = 22$ ), and  $0.15 \pm 0.02$  for female-male dyads ( $n = 29$ ). Significant differences were detected between female-female and male-male dyads ( $F=17.66$ ,  $d.f.=1,55$ ,  $P=0.00$ ), and female-female and female-male dyads ( $F=26.75$ ,  $d.f.=1,62$ ,  $P=0.00$ ). Male-male and female-male dyads showed no significant difference ( $F=0.46$ ,  $d.f.=1,49$ ,  $P=0.49$ ).

## Discussion

Home range and core area values recorded for the jackrabbit population at Santa María del Mar showed high intraspecific variability, ranging from 0.20 ha to 152 ha.

High variation of this sort has been observed for this and other *Lepus* species. In most of the studies variation has been attributed to availability of food, refuge, and even to the risk of predation. Farías et al. (2006) estimated home range values from 8 ha to 166 ha for the Tehuantepec jackrabbit population in Montecillo Santa Cruz, while Best (1996) and Kunst et al. (2001) found home ranges of 16-140 ha for the black tailed jackrabbit (*L. californicus*), and 26-190 ha for the brown hare (*L. europaeus*). Probably, high variation in home range size is related to food availability, since the most significant change in home range and core area size occurred from 2007 dry season to 2007 rainy season. As Farías et al. (2006) and Vargas (2000) addressed, during the rainy season, grasses are green and abundant and gradually turn brown as the dry season advances (Hulbert et al., 2001; Rao et al., 2001). Although during years of less rainfall the grasses turn brown earlier during the dry season, during years of abundant rainfall the grasses become abundant during the rainy season and even some months after the rains have ended, making more food available for Tehuantepec jackrabbits (Azucena Velázquez, pers. comm.). This might explain why the home range and core area remained small in the period between the 2007 rainy season and 2008 dry season, due to an unusually abundant rainfall during the 2007 rainy season (51.42 inches) compared to the previous year (mean annual rainfall=31 inches; García, 1988). In addition, many temporary lagoons were formed during 2007 rainy season, and remained until the end of 2008 dry season. It is probable that these unusual climatic conditions increased the quantity of available food in the area, allowing females and males to feed without the need to move larger distances (Hulbert et al., 1996). Carrillo-Reyes (2001) informed that the temporary lagoons formed by intense rains diminished the home range size of *Meleagris gallopavo intermedia* in the dry season.

It reaches our attention that female mean annual home range ( $30.44 \pm 4.05$  ha) and core area ( $7.24 \pm 1.35$  ha) for the Tehuantepec jackrabbit was slightly smaller in our study area compared with the Montecillo Santa Cruz population (43 and 7 ha, respectively; Farías et al., 2006). Furthermore, males mean annual home range ( $13.52 \pm 2.27$ ) and core area ( $3.62 \pm 1.11$ ) were clearly smaller than those data reported by Farías et al. (2006; 66 and 9 ha, respectively), and contrary to Farías et al. (2006) results, female jackrabbits in Santa María del Mar tended to have larger home ranges than males. From November 2006 to April 2007, males significantly reduced their home ranges, while females kept a similar home range size. Reduction of home range size in males is not congruent with the observations of Hulbert et al. (1996) and Wolfe and Hayden (1996), who found that home ranges were larger

when food availability was low because jackrabbits moved over longer distances in a search of food. It is possible that male jackrabbits had smaller home ranges, at Santa María del Mar, during the 2007 dry season as a strategy to save energy when food availability was low, as has been reported for the brown hare (Kunst et al., 2001). Rioja et al. (2008) recently reported that the Tehuantepec jackrabbit has a polygamous mating behavior in which a male mate with several females. It is likely that, due to a higher population density found in our study area than for other populations, males of Santa María del Mar need to travel shorter distances to find mates, an assumption supported by information on population density: Santa María del Mar is the Tehuantepec jackrabbit population with the highest density values ever recorded for this species (12 ind/km<sup>2</sup>; Vargas 2000), while other populations range from 0.76 to 9.5 ind/km<sup>2</sup> at Montecillo Santa Cruz, and 8.9 ind/km<sup>2</sup> at San Francisco del Mar (Sántiz, 2002; Sántiz, 2005; Lorenzo et al., 2008). Nelson (1995) found that at high densities of females, *M. agrestis* males have smaller home ranges than they do at lower female densities.

Our results showed smaller home range values if compared to those obtained by Farías et al. (2006); simultaneously, Santa María del Mar support the highest population density of the four known populations. As in the region studied by Farías et al. (2006), cattle were present throughout the study area. It appears that cattle does not affect jackrabbit movements or density, but we did not find a cattle-free area in order to prove it. However, contrary to the population at the northern area of the Lower Lagoon, in our study area the jackrabbit population was not affected by fires, which probably leads to a better quality habitat. It is likely that these particular land management conditions were increasing the quantity and quality of available food in the area, allowing females and males to feed without the need to move larger distances (Hulbert et al., 1996). To understand this relationship, we need to conduct long-term studies on the effect of land management practices on home range and core area of the Tehuantepec jackrabbit (Smith et al., 2005). Lorenzo et al. (2008) found that population density fluctuations of the Tehuantepec jackrabbit were wider (population density was increasing in short periods of time) in populations affected by fire compared with population unaffected by this land management practice. Comparing our results with those of Farías et al. (2006) allow us to suspect that intentional fires directly affect the Tehuantepec jackrabbit by enlarging its home range. This may be an indicator that habitat quality for jackrabbits is better at Santa María del Mar than other jackrabbit populations and emphasizes the need for long-term ecological research. As Farías et al. (2006) reported, local people set fires during the dry season to maintain grass

shoots for their cattle, and recently burned areas are left with little or no herbaceous cover, but jackrabbits can feed on the green sprouts that grow within a few days, and from grass roots that are easily excavated. However, induced fires and free-ranging cattle reduce plant diversity in the study area (Pérez-García et al., 2001), and survival of Tehuantepec jackrabbits may be threatened in frequently burned and overgrazed habitats (Farías, 2004). In addition, it is possible that the fires affect negatively the population of Tehuantepec jackrabbit reducing temporarily the availability of food and refuge. It even seems possible that the fires are a cause of death of babies and individuals who are caught by the fire (Farías, 2004; Lorenzo et al., 2008; Rioja et al., 2008).

Seasonal home range of radio-collared jackrabbits overlapped with at least 1 and up to 46 individuals, showing that Tehuantepec jackrabbits may not have exclusive use of their home ranges. However, as Farías et al. (2006) reported, negligible core area overlaps may indicate that at least some portion of the home range is preferentially not shared with other individuals (Crooks and Van Vuren, 1996).

Furthermore, the high overlap values estimated through Minta's index (0.48 in a dyad) also supports the hypothesis that the Tehuantepec jackrabbit is a non-territorial species (Farías et al., 2006; Rioja et al., 2008), because an important proportion of hares share at least part of its movement area with another jackrabbit. Also, our overlap analyses support the recent findings about the Tehuantepec jackrabbit reproductive behavior documented by Rioja et al. (2008), who observed a polygamous mating behavior for this species, because we detected no instance of extensive (>80%) intersexual overlap (male-female overlap) that would indicate formation of mated pairs, as Powell (2000) stated. Also, female-female overlap in home ranges was both more common and more extensive than male-male and female-male overlap, which supports the observations of Rioja (2008) who mentioned that there is a higher probability to find females together than males or female-male dyads.

In conclusion, knowledge of cattle spatial ecology and social behavior of this threatened species has much to contribute to the analysis of population dynamics and conservation models, and provides information for dealing with problems associated with population management for the recovery of the species (Komdeur and Deerenberg, 1997; Parker and Waite, 1997; Farías et al., 2006). As Farías et al. (2006) affirms, Tehuantepec jackrabbits inhabit savannas and grassy dunes which are part of the lands used by local families, and where jackrabbits are jeopardized by disturbances such as growing human settlements, cattle-raising activities, frequent fires, and poaching (Farías,

2004; Farías et al., 2006). Habitat fragmentation and loss are among the proximate threats for remnant populations of Tehuantepec jackrabbits, and the protection of suitable habitat is essential for the species' survival (Flux and Angermann, 1990; Farías et al., 2006; Lorenzo et al., 2008).

Although it is necessary to conduct more studies in the long term, we can suppose that suitable land management practices do not represent a danger for this population of Tehuantepec jackrabbit, whenever the cattle do not exceed the carrying capacity of the area and prescribed fires are maintained under control. However, implementation of suitable land management practices is complicated in an area with some of the highest indexes of poverty and permanent ethnic conflicts in the country. Consequently, it is indispensable to implement at the same time both programs of biological conservation and projects of social development. Undoubtedly the priority is to preserve savannas and grassy dunes to assure the survival of the species.

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