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SPATIAL AND TEMPORAL DISTRIBUTIONS OF THE SPINOSE EAR TICK, *OTOBIOUS MEGNINI*, WITHIN ANIMAL SHELTERS AT FOSSIL RIM WILDLIFE CENTER

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**Abstract**—Spinose ear ticks, *Otobius megnini*, are monoxenous parasites that feed within the ear of ungulates, subjecting them to debilitating conditions. Little is known about the spatial dispersion of spinose ticks in animal shelters or the temporal variation in their abundance. Therefore, the objectives of this study were to: 1) determine the temporal distribution of spinose ear tick abundance within animal shelters, 2) determine the spatial distribution of larvae and adults within animal shelters, and 3) examine the effects of climatic variables on tick abundance. No temporal trend was identified for larval or adult ticks. Larval abundance was highest in quadrats located against the shelter wall while no spatial difference was found in adult abundance. Mean larval tick abundance was significantly correlated with mean temperature while mean adult tick abundance was significantly correlated with mean relative humidity.

**Resumen**—Las garrapatas espinosas del oído, *Otobius megnini*, son parásitos monóxenos que obtienen su alimento dentro de los oídos de los ungulados, sometiéndolos a condiciones debilitantes. Poco se sabe sobre la dispersión de garrapatas espinosas en los refugios de animales o la variación temporal en su abundancia. Por lo tanto, los objetivos de este estudio fueron: 1) determinar la distribución temporal de la abundancia de garrapatas espinosas del oído dentro de los refugios de animales, 2) determinar la distribución espacial de las larvas y adultos dentro de los refugios de animales, y 3) examinar los efectos de las variables climáticas sobre la abundancia de garrapatas. No se identificó ninguna tendencia temporal en las larvas o adultos de garrapatas. La abundancia de larvas fue mayor en los cuadrantes ubicados cerca de la pared del refugio, mientras que no se encontró ninguna diferencia espacial en abundancia de adultos. La media de la abundancia de larvas de garrapatas se correlacionó significativamente con la media de la temperatura, mientras la media de la abundancia de los adultos se correlacionó significativamente con la media de la humedad relativa.

The spinose ear tick, *Otobius megnini*, is a soft-bodied tick belonging to the family Argasidae. Their distribution is in the Nearctic and they are most prevalent in arid to semiarid regions of the southwestern United States and northern Mexico (Bishop and Trembley, 1945; Keirans and Pound, 2003). These ticks are less mobile than other species and spend a portion of their life cycle off-host (Needham and Teal, 1991). The host-seeking behavior of *O. megnini* exposes them to variable climatic conditions. In many cases, climatic variables (e.g., temperature and relative humidity) and changes in vegetation can be useful in predicting tick abundance (Cumming, 2002; Gilbert, 2010). Of course, the exact relationship between population size and environmental factors is spatially variable across its geographic distribution. For example, the ranges of temperatures that are suitable for ticks in areas with high humidity may not be the same suitable temperatures for ticks in environments with low humidity (Estrada-Pena et al., 2010). In addition, tick abundance may change temporally in response to seasonal variation in environmental conditions.

*Otobius megnini* have a monoxenous life cycle with four stages: 1) egg, 2) six-legged larva, 3) eight-legged nymph, and 4) eight-legged adult. Ticks developing in temperatures between 21–24°C typically have oviposition 6–12 d after dropping as nymphs from their hosts. The number of eggs, which are laid in the nesting grounds of potential hosts, can range from 398–1,187 depending on the weight of the female (Nava et al., 2008). Egg incubation ranges from 14–19 d in laboratory studies (Loomis, 1961) and 18–23 d in field studies (Herms, 1917). Once hatching occurs, larvae seek hosts for survival; unfed larvae have been found to survive in the laboratory up to 78 d (Wanchinga and Barker, 1986). Larvae feed on the host for 1–5 wk and then molt into the nymph stage. The majority of nymphs will feed between 2–4 mo (Loomis, 1961) but have been noted to feed up to 6 mo (Wanchinga and Barker, 1986). The nymph will feed...
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until it is completely engorged, exit the ear canal, fall off the host, and seek cover for the last molt into the nonparasitic, eight-legged adult life stage (Hooker, 1908). Adults remain off the host, use stored reserves obtained during the nymph stage (Anonymous, 1991), and can survive up to 2 y (Mayberry, 2003). During this time, adults search for a mate and reproduce. The typical amount of time for *O. megnini* to complete its life cycle ranges from 62–118 d (Loomis, 1961).

*Otobius megnini* larvae are the infective stage to the host. Once larvae hatch from the egg, they actively sense information from their environment to detect the presence of a host (Parola and Raoult, 2001). Ticks have a specialized sensory structure, called Haller’s organ, that detects the presence of carbon dioxide, temperature, and humidity (Klompen and Oliver, 1993). Haller’s organ is a minute cavity at the terminal segment of the first pair of a tick’s legs and is composed of a pit and a capsule that contain sensory setae with numerous chemoreceptors designed to target the carbon dioxide (CO$_2$) of exhaling hosts (Klompen and Oliver 1993). *Otobius megnini* parasitizes domesticated animals, such as cattle, as well as native and exotic wildlife (Becklund, 1968) such as *Addax nasomaculatus* (addax), *Oryx gazella* (gazelle), *Tragelaphus angasii* (nyala), *Hippotragus niger* (sable antelope), *Giraffa camelopardalis* (giraffe), and *Equus quagga* (zebras). A spinose ear tick has even been reported to parasitize humans (Bishopp and Trembley, 1945; Eads and Campos, 1984), although this is considered to be a rare occurrence.

*Otobius megnini* is not known to be a vector for disease. However, a study has shown this tick to be infected with *Coxiella burnetii*, which can cause Q fever (Jellison et al., 1948). Severe irritation in the host can occur due to the tick attaching deep within the internal part of the ear. The irritation to the host promotes scratching that leads to lacerations that may be prone to secondary infections. Ear tick infestations can result in reduced body weight, reduced milk production, and overall lack of vitality (Parish, 1949) or, in some extreme cases, disfigurement or death of the host (Bishopp and Trembley, 1945). These negative effects of tick infestation are a concern for captive breeding programs trying to manage indigenous and exotic species, particularly those focusing on endangered and threatened species.

The ultimate goal of this project was to improve the quality of life for indigenous and exotic animals at Fossil Rim Wildlife Center (FRWC) by better understanding spatial and temporal variation in the abundance of *O. megnini*. The objectives of this study were to determine the temporal distribution of spinose ear tick abundance within animal shelters, examine the spatial dispersion of adult and larval ticks within animal shelters, and examine the effects of climatic variables on tick abundance. A limited amount of data exists on microhabitat preferences within animal shelters at Fossil Rim WC and patterns of tick abundance; therefore, this research represents a contribution to the scientific literature by examining temporal trends in tick abundance, identifying where these ticks are mostly likely to be found within animal shelters, and determining which environmental factors are most associated with tick abundance.

**Materials and Methods**—Our study location was at the Fossil Rim Wildlife Center, located near Glen Rose, Texas. Fossil Rim WC is a not-for-profit, Association of Zoos & Aquariums-accredited facility specializing in captive breeding programs for indigenous and exotic endangered and threatened species of animals (http://www.fossilrim.org). The Fossil Rim WC is approximately 688 ha and supports over 1,000 animals consisting of 50 native and nonnative species. This study was conducted within the main pasture at Fossil Rim WC, which is approximately 172 ha and is occupied by a variety of ungulates species. These include the addax (*A. nasomaculatus*), sable antelope (*H. niger*), gemsbok (*O. gazella*), fallow deer (*D. dama*), and white-tailed deer (*O. virginianus*). The main pasture contains a total of 11 shelters from which we selected two of similar size and construction (shelter three = 117 m$^2$; shelter four = 126 m$^2$) to include in this study. The shelter numbers described in this study were kept consistent with the numbering scheme assigned to Fossil Rim WC. We subdivided each shelter into quadrats (1 m × 1 m) for sampling purposes. Quadrats were grouped according to those along the wall, those in the middle of the shelter, and those located along the outer edge of the shelter to characterize the spatial variation within an animal shelter. We randomly sampled four quadrats within each area of a shelter, resulting in a total of 12 quadrats per animal shelter. Both shelters were sampled biweekly from August 2012–July 2013 to characterize temporal variation in distribution and abundance of larval and adult spinose ear ticks.

Because larvae represent the host-seeking stage of *O. megnini*, they are attracted to CO$_2$ as it provides a proximate cue that a host is in the area. We therefore used a modified version of the compressed CO$_2$ trap developed by Niebuhr et al. (2013) to capture the larval ticks. The trap consisted of a 2.27-kg compressed CO$_2$ tank with a flow regulator coupled to a network of vinyl tubing with an inside diameter of 0.64 cm. The tubing was split at three points along the main lines to achieve a total of 12 tubes that were placed separately into the 12 sampling quadrats; hose clamps were used to secure tubing at each split. A 22-ga dissecting needle was used to puncture holes 0.2 m from the end of each tube. The open end of the tubing was sealed with a 0.64-cm-diameter eyebolt to prevent leakage. Metal frames (0.3 m × 0.3 m) covered in white cotton cloth were placed over the holes on each tube. For each sampling period, CO$_2$ was released at a rate of 10 psi for 30 min. After 30 min, larvae were harvested from the frames using an aspirator and stored in vials containing 70% ethanol to be counted at a later time in the laboratory using a dissecting scope.

Adult ticks, which represent a nonfeeding stage, are not attracted to the CO$_2$ released by a potential host and, therefore, were sampled differently than the larvae. To collect adults at each quadrat, we used an uncovered metal frame (0.3 m × 0.3 m) to delineate the space where ground litter was collected. All of the litter located within the sampling frame was placed into plastic bags for laboratory analysis. These sealed bags were sifted through a series of three screens to reduce the final amount of
litter that needed to be searched to locate adults. The screens are sized in such a way that the adults passed through the first and second screen but did not pass through the third screen (1st screen = 1.27 cm², 2nd screen = 0.64 cm², 3rd screen = 0.32 cm²). The third screen was then exposed to a black light for approximately 20 min; the black light exposes the fluorescing legs of the adults to help aid in detection.

The environmental data collected included temperature and relative humidity. A Kestrel® 3,000 handheld weather station (Kestrel Meters, Birmingham, Michigan) was used to gather temperature and relative humidity data once per shelter during each sampling period; both temperature and relative humidity were recorded at ground level in the middle of the shelter. We used SPSS software (https://www-01.ibm.com/software/analytics/spss/) to generate sequence charts for adult and larval tick abundances within each animal shelter (dependent variables) as well as for each of the two environmental factors (independent variables). An analysis of covariance was used to statistically compare the abundance of larval and adult ticks between the two animal shelters; time was used as a covariate. We quantified the degree of dispersion within each shelter using Morisita’s index (Morisita, 1971), which characterizes the spatial distribution as being consistent with aggregated, uniform, or random patterns. We also used an analysis of covariance to determine whether quadrats along the wall, those in the middle of the shelter, or those located along the outer edge of the shelter contained the most individuals; time was used as a covariate. Linear regression was used to predict the abundance of ticks as a function of environmental conditions.

**RESULTS**—The abundance of *O. megnini* varied over time with multiple peaks in spring, summer, and fall months; ticks were collected during winter months but in low abundances (Fig. 1). Adult abundances were considerably lower than larval abundances but both exhibited seasonal peaks in abundance. Overall, there was neither a net decrease nor a net increase in abundance over time for both larval ($F = 0.299; df = 1, 68; P = 0.586$) and adult ticks ($F = 1.764; df = 1, 68; P = 0.189$). There was no difference in larval tick abundance between the two shelters ($F = 0.687; df = 1, 45; P = 0.412$) as well as no difference in adult abundance between the two shelters ($F = 2.628; df = 1, 45; P = 0.112$).

Because there was no difference in temperature ($F = 0.445; df = 1, 45; P = 0.508$) and relative humidity ($F = 0.505; df = 1, 45; P = 0.481$) between the two shelters over time, we used the mean between the two shelters as estimates of environmental conditions. Mean larval tick abundance was significantly correlated with mean temperature ($r = 0.408; P = 0.048$; Fig. 2) but not significantly correlated with mean relative humidity ($r = 0.130; P = 0.544$; Fig. 3). Mean adult tick abundance was not significantly correlated with mean temperature ($r = 0.202; P = 0.343$; Fig. 2) but was significantly correlated with mean relative humidity ($r = 0.443; P = 0.030$; Fig. 3).

Larval tick collection numbers were highest in quadrats located in the sampling area directly against the shelter wall ($F = 5.319; df = 2, 68; P = 0.007$). There was no difference found in adult tick abundance among the three areas of the shelter ($F = 0.773; df = 2, 68; P = 0.466$). Larval ticks demonstrated the following overall spatial patterns for shelter three: aggregated = 80%, uniform = 20%, random = 0%; shelter four: aggregated = 74%, uniform = 17%, random = 9%. Adult ticks demonstrated the following spatial patterns for shelter three: aggregated = 61%, uniform = 33%, random = 6%; shelter four: aggregated = 8%, uniform = 50%, and random = 42%. Degree of aggregation was found to be
positively correlated with abundance in both the larval \((r = 0.815; P < 0.001; \text{Fig. 4a})\) and adult \((r = 0.726; P < 0.001; \text{Fig. 4b})\) samples.

**Discussion—Temporal Trends in Abundance**—The abundance of *O. megnini* varied over time with multiple peaks throughout the seasons. There was no overall trend in abundance across the year-long study, coinciding with other studies examining temporal trends in abundance of *O. megnini* (Dreyer et al., 1998; Nava et al., 2008). Nava et al. (2008) found seasonal peaks in abundance, but the timing of the peaks differed from year to year, with highest larval abundance occurring in April–May and August–October consecutively. Dreyer et al. (1998) found similar nymph abundance data as compared to adult abundance in our study, which showed no distinct trend over time. Neither of these studies reported environmental conditions, specifically temperature or relative humidity, which could help explain the variability in seasonal peaks. *Otobius megnini* exhibit endophilic behavior during nonparasitic stages in that they burrow into the ground, rocks, nest of host, etc. in an effort to avoid unfavorable

![Graph](image1)

**Fig. 2**—Correlation between mean tick abundance and mean temperature (2012-2013) measured biweekly in shelters at Fossil Rim Wildlife Center.

![Graph](image2)

**Fig. 3**—Correlation between mean tick abundance and mean relative humidity (2012-2013) measured biweekly in shelters at Fossil Rim Wildlife Center.
environmental conditions (Estrada-Pena et al., 2010). Understanding the link between the environment and the behavior of this species is important when trying to identify temporal distributions. Previous studies demonstrated that various life stages may be differentially affected by environmental conditions such that peaks in abundance of different life stages occur during different seasons (Ostfeld et al., 1996).

**Environmental Conditions**—Larval tick abundances were positively correlated with temperature; no significant relationship existed for relative humidity. Egg hatchment has been found to be linked to temperature, with oviposition occurring between 20–30°C (Loomis, 1961; Sweatman, 1967; Wachinga and Barker, 1986). Abundance of larvae in our study started to increase in March as temperatures approached 20°C and was highest at 26°C, supporting previous findings of egg hatchment. Another study measured the effects of temperature and relative humidity on questing of larval ticks and found that temperature affected distance traveled and amount of time spent questing but that relative humidity had no effect (Vail and Smith, 2002). As nymphs fall off-host to molt into adults, the spatial pattern could appear aggregated due to synchronous detachment of nymphs (Oliver, 1989; Ostfeld et al., 1996). Highest larval abundance was found in the sampling area located directly against the wall while adult abundances did not differ statistically among the three areas of the animal shelter.

**Management**—Direct application of acaricides into the ears of hosts has been shown to reduce *O. megnini* abundances on-host (Drummond et al., 1967; Mayberry, 2003) while other methods such as application of systemic biocides have not been shown to reduce tick abundance (Nava and Guglielmone, 2009). Direct application into the ears can be costly and time consuming, as frequent reapplication is necessary due to continuous infestation of ticks. In addition, this method may be impractical in wildlife facilities, such as Fossil Rim WC, that adopt more of a hands-off approach in their management strategies to mimic natural processes as much as possible. Based on results from this study, we suggest that effective manage-
ment strategies should target specific microhabitats heavily used by ticks while off-host. Within the shelters, our results suggest control efforts should be concentrated along the walls where larval abundance was significantly higher than other areas. Not only does this decrease the amount of interaction with the host, but it also focuses eradication efforts where tick populations tend to be concentrated.

In addition to the application of acaricides to the outer edge of animal shelters, the complete removal of animal bedding in early spring could reduce tick populations by reducing suitable tick habitat. Replacement of bedding should not occur until immediately before the first winter freeze. Of course, the timing of this particular control method is key to its success. This management strategy could especially be useful to wildlife areas that need ways to control parasites off-host, minimizing interactions with threatened and endangered wildlife. By better understanding spatial and temporal dynamics of tick abundance, as well as the environmental drivers of those dynamics, we can implement more-effective and less-invasive management strategies.

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