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American Hog-nosed Skunk (*Conepatus leuconotus*)**

WESLEY A. BRASHEAR¹

Department of Biology, Angelo State University, San Angelo, Texas 76909

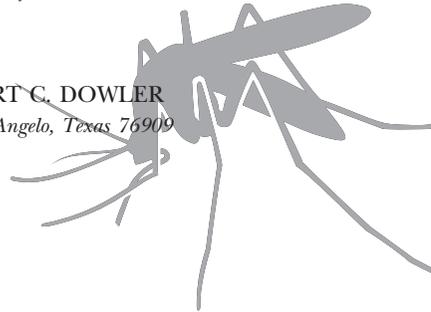
ADAM W. FERGUSON

Department of Biological Sciences, Texas Tech University, Lubbock 79409

AND

NICHOLAS J. NEGOVETICH AND ROBERT C. DOWLER

Department of Biology, Angelo State University, San Angelo, Texas 76909



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ABSTRACT.—The American hog-nosed skunk (*Conepatus leuconotus*) is an understudied mesocarnivore for which no extensive ecological studies have been conducted. We radiocollared 29 skunks (15 male, 14 female) at a site in west-central Texas, U.S.A. and used data from 14 (5 male, 9 female) to determine patterns of home range and spatial organization. Home range (95% fixed kernel) of males averaged three times that of females (1.9 km² vs. 0.64 km²) and extensive intrasexual and intersexual overlap in home ranges was documented. Female home ranges and core areas differed significantly in their topography (changes with which were associated with habitat difference) from those of males. Home range sizes were correlated with body size and gender, but intersexual differences between home range sizes and their topography indicate space-use patterns between male and female American hog-nosed skunks are influenced by factors beyond metabolic requirements alone. Specifically, we believe male home ranges are large to maximize encounters with females whereas females selectively choose areas to ensure availability of resources such as foraging and den sites.

INTRODUCTION

Home ranges, as estimated by researchers, are meant to reflect nonrandom patterns of space-use directed by an animal's behavior within the context of its abiotic and biotic environments (Powell, 2000). In other words home ranges represent an emergent property of animal behavior. Despite the potential for misrepresenting these behaviors because of several theoretical and methodological limitations (*see* Powell, 2012a and articles therein), home range estimates remain one of the most basic ecological characteristics of any mammalian species. From a conservation standpoint, understanding the spatial patterns and requirements of individual species allows for the estimation of those geographical and environmental parameters necessary for the maintenance of viable populations (Gosse *et al.*, 2005). Examination of space-use patterns and home ranges can also provide insight into social organization and mating behaviors (Sandell, 1989; Farías *et al.*, 2006), extinction risks (Cardillo *et al.*, 2005; Schipper *et al.*, 2008; Davidson *et al.*, 2009), parasite loads (Bordes *et al.*, 2009), the impacts of edge effects on particular species (Woodroffe and Ginsberg, 1998), energy and shelter requirements (Gittleman and Harvey, 1982; Crooks, 1998; Lesmeister *et al.*, 2008), and philopatry (Støen *et al.*, 2005). Therefore, estimating the home range of

¹Corresponding author present address: Interdisciplinary Program in Genetics, Veterinary Integrative Biosciences, Texas A&M University, College Station, Texas 77843; e-mail: wbrashear@cvm.tamu.edu

a species addresses broader biological questions and allows for the development of species-specific hypotheses to explain individual space-use patterns.

For particular groups of animals, including mammalian carnivores, knowledge of the spatial ecology of individual species can be considered vital for effective conservation (Powell, 2012b). For carnivore species whose distribution includes the United States, only one species remains for which home range or space-use patterns have not been examined: the American hog-nosed skunk (*Conepatus leuconotus*; hereafter hog-nosed skunk; Rosatte and Larivière, 2003). In fact relatively few studies have investigated the ecology of the hog-nosed skunk and most of our knowledge regarding the natural history of this species remains anecdotal (Dragoo and Sheffield, 2009). Our objectives were to estimate home range size and space-use patterns in the hog-nosed skunk via radio-tracking data from a population in west-central Texas, U.S.A. Specifically, we sought to investigate the spatial organization and home range characteristics of hog-nosed skunks in relation to habitat type, gender, and body size in order to identify important factors and resources influencing the formation of home ranges by this understudied carnivore. Given the paucity of data regarding the ecology of this species, we predicted patterns in spatial organization would follow those of members of the same genus, with males displaying significantly larger home ranges and a large degree of intra- and intersexual home range overlap (Castillo *et al.*, 2011; Kasper *et al.*, 2012).

MATERIALS AND METHODS

STUDY AREA

The study was conducted on two adjacent, privately owned ranches comprising a 16 km² site near the town of Knickerbocker (31.26656°N 100.623154°W) in west-central Texas, U.S.A. The study site comprised a mixture of four habitat types associated with topography: (1) rocky upland areas dominated by native grasses and scattered mottes of live oak (*Quercus fusiformis*), (2) dense stands of mixed juniper (*Juniperus pinchotii*, *J. ashei*) situated on limestone slopes, (3) lowland thorn scrub characterized by honey mesquite (*Prosopis glandulosa*) and associated vegetation, and (4) a riparian area with mature stands of pecan trees (*Carya illinoensis*) and greenbriar (*Smilax rotundifolia*) understory. Prickly pear cactus (*Opuntia engelmannii*) is common throughout the first three habitat types as well as knife-leaf condalia (*Condalia spathulata*), agarita (*Berberis trifoliolata*), and Texas persimmon (*Diospyros texana*). A small portion of the study site was used for row-crop agriculture. The climate is semi-arid with a mean annual precipitation of 530 mm, a mean monthly low temperature in January of 0 C, and an average high temperature in July of 36 C (Larkin and Bomar, 1983).

CAPTURE AND HANDLING

Home range patterns of hog-nosed skunks were studied between July 2008 and November 2010. Because hog-nosed skunks have proven difficult to capture using baited live traps (Bailey, 1905; Ebeling, 2006), we located skunks during spotlight surveys conducted along roads, and we captured skunks with a large insect net or by hand.

We anesthetized captured hog-nosed skunks with a 2:1:1 ratio of ketamine hydrochloride (10 mg/kg), xylazine (5 mg/kg), and acepromazine (1 mg/kg; Doty and Dowler, 2006) or with 10 mg Telazol (Larivière and Messier, 1996a). We attached unique ear tags (National Band and Tag Company, Newport, Kentucky, U.S.A.) and/or subcutaneously inserted passive integrated transponders (Avid Identification Systems Inc., Norco, California, U.S.A.) into each hog-nosed skunk to allow for future identification. We recorded total length, length of tail, length of hind foot including claws, length of ear (from the auricular notch to

the most distal portion), and mass of each captured individual. Estimation of age was based on size and reproductive condition (*e.g.*, nulliparous, post-lactating), and we classified each skunk as either juvenile, post-dispersal young, or adult. We fit adult skunks with 24 to 42 g very high frequency (VHF) radio-collars (Telemetry Solutions, Concord, California, U.S.A.; Advanced Telemetry Systems, Isanti, Minnesota, U.S.A.) and released them at the point of capture following their recovery from sedation. All capturing and handling techniques followed protocols set forth by the Angelo State University Animal Care and Use Committee and taxon-specific guidelines for use of wild mammals in research as outlined by the American Society of Mammalogists (Sikes *et al.*, 2011; Sikes *et al.*, 2012).

We captured 40 hog-nosed skunks during the study period. Twenty-nine skunks (15 males and 14 females) were fitted with VHF radio collars and subsequently monitored. We recaptured 9 (4 males and 5 females) of the 29 radio-collared skunks during the study period to replace collars that had ceased to function. Fourteen *C. leuconotus* (5 males, 9 females) were tracked ≥ 24 times (= 43; range = 24–83) and were used in the home range analyses. Despite extensive surveying and radio-tracking, we captured or tracked skunks to locations only in three habitat types and never in the riparian and agricultural areas.

RADIO-TRACKING

We tracked radio-collared hog-nosed skunks on foot with a handheld VHF receiver (Communications Specialists, Inc., Orange, California, U.S.A.) equipped with a 3-element Yagi antenna. Location data were collected exclusively by the homing technique (White and Garrott, 1990), as this method is more accurate given the disturbance-tolerant nature of skunks (Larivière and Messier, 1998a). Because access to the study site was sometimes restricted due to private hunting operations, radio-collared hog-nosed skunks were tracked sporadically with timespans between recorded locations ranging from less than 24 h to several weeks. We typically located hog-nosed skunks to resting sites during daylight hours and made direct observations when possible. We recorded active locations of skunks by tracking at night until the animal was directly observed. Active locations were augmented by opportunistically recording observations of radio-collared skunks during spotlight surveys aimed at acquiring new individuals for the study. Although most of the locations recorded for skunks were den sites, we believe they provide a valid estimate of home range given the large number of unique sites and the fact we frequently observed signs of foraging close to den sites (large areas of disturbed soil several cm in depth – Drago and Sheffield, 2009). Battery depletion and loss of function in radio collars resulted in the inability to track some skunks for several months before they were relocated during spotlight surveys and their radio-collars were replaced. Multiple skunks ($n = 9$) were tracked for longer than 12 mo. Asymptote analysis suggested a minimum of 24 locations are required for adequate home range estimates (*see below*). As such, the locations were pooled across years to estimate a maximum rather than annual home range. We recorded the locations of tracked skunks using a handheld global positioning system with an estimated error of 10 m (Garmin, Kansas, U.S.A.).

DATA ANALYSES

We assessed sexual dimorphism in body size using recorded field measurements within the study group using multivariate analysis of variance (MANOVA) and permutational MANOVA (Oksanen *et al.*, 2013). Juveniles and post-dispersal young were not included in these analyses.

We estimated home ranges and core areas for all radio-collared skunks with ≥ 24 points using the software ABODE (Laver, 2005) and ArcGIS (version 9.2, Environmental Systems

Research Institute Inc. [ESRI], Redlands, California, U.S.A.). All locations used in home range and core area estimates were taken at least 24 h apart to minimize the effects of serial spatial correlation (Swihart and Slade, 1985). We estimated 95% fixed-kernel (FK) utilization distributions with least-squares cross-validation (Worton, 1989; Seaman and Powell, 1996; Powell, 2000) as estimates of home range. Asymptote analyses were conducted as suggested by Laver and Kelly (2008). We calculated core areas as described in Seaman and Powell (1990) and Powell (2000, 2012b). We assessed differences in male and female home range and core area sizes using ANOVA. Transformations were applied to the dependent variable to satisfy the assumptions of ANOVA when appropriate. An ANCOVA was used to examine the relationship between body size, gender, and home range dimensions.

We defined intersexual overlap as the percentage of an individual hog-nosed skunk's estimated home range or core area shared with ≥ 1 member of the opposite sex and intrasexual overlap as the percentage of an individual's home range or core area as shared with ≥ 1 member of the same sex. Estimated overlap values represent a minimum percentage overlap as several radio-collared individuals were not included in space-use analyses and it is unlikely every hog-nosed skunk on the study site was radio-collared. We used 95% fixed kernel estimates for all overlap analyses and intersexual comparisons. We assessed differences between intra- and inter-sexual home range and core area overlap, as well as between male and female home range and core area intrasexual overlap using ANOVA. Assumptions of analysis were met following arcsine transformation of the percentages. Two-sample *t*-tests on the transformed values were not used because we had unequal numbers of male and female skunks and unequal sample sizes diminish the usefulness of *t*-tests for slight violations of the test assumptions. For intra- and inter-sexual home range and core area overlap, a mixed-effects model was used to account for the potential non-independence. Specifically, a percentage overlap of home range and core area was generated for each individual and both values were used in the analysis. Significance of the main effects, *i.e.*, intra- vs. inter-sexual overlap, was assessed through randomization methods (Faraway, 2006).

Because habitat type at the study site was strongly associated with the topography of the area, we estimated the mean elevation of each home range and core area as a substitute for habitat composition to assess intersexual differences. A 10 m resolution ASCII digital elevation model was imported into ArcGIS, transformed into a raster layer, and used to calculate the mean pixel value for each home range. We used ANOVA to compare differences in mean elevation between sexes. We used the R software package (version 3.0, R Development Core Team, 2013) and a significance threshold of 0.05 for all statistical calculations.

We estimated the density of the studied population by constructing a 100% minimum convex polygon (MCP; Mohr, 1947; Hayne, 1949) around every location recorded for the 29 radio-collared skunks during the study period. We then divided the total land area covered by the 100% MCP by the total number of radio-collared skunks used to calculate the MCP. Whereas some skunks were not tracked simultaneously during the study, we believe their inclusion in this density estimate compensates for those individuals that were neither captured nor radio-collared but nevertheless inhabited the study area.

RESULTS

SEXUAL DIMORPHISM

We found no significant sexual dimorphism in body size among 30 mature skunks (15 males and 15 females) captured during the study period ($F_{5,24} = 1.77$; $P = 0.16$). When

the MANOVA was conducted using only hog-nosed skunks for which we examined space-use patterns ($n = 14$), it revealed males were significantly larger than females ($F_{5,8} = 4.18$; $P = 0.036$). Small total sample size ($n = 30$) relative to the number of measurement variables ($k = 5$) and slight deviations from normality decreased the power of MANOVA when using all 30 skunks. As such, a permutational MANOVA was performed using a Bray-Curtis dissimilarity matrix created with the set of dependent variables. Sexual dimorphism was detected using permutational MANOVA for the full dataset ($P = 0.045$) and for the 14 skunks used to investigate space-use patterns ($P = 0.031$). Univariate ANOVA on each measurement revealed males had significantly larger hind feet ($F_{1,28} = 4.22$; $P = 0.049$) and longer tails ($F_{1,28} = 4.78$; $P = 0.037$).

HOME RANGE, CORE AREA, AND POPULATION DENSITY

Average male home range (95% FK) and core area sizes were 1.94 km^2 ($SD = 0.62$) and 0.95 km^2 ($SD = 0.53$), respectively. Average female home range (95 % FK) and core area sizes were 0.638 km^2 ($SD = 0.24 \text{ km}^2$) and 0.23 km^2 ($SD = 0.07$; Table 1), respectively. Male home ranges were significantly larger than female home ranges ($F_{1,12} = 33.09$, $P < 0.0001$), as were the logarithms of core area size ($F_{1,12} = 33.09$, $P < 0.0001$). Asymptote analyses showed home range sizes stabilized after approximately 24 locations.

Because sexual dimorphism was strongest in the length of tail and hind foot in the hog-nosed skunks considered in this study, and because differences in home range size for the two sexes may be caused by correlations between home range dimensions and skunk size, we used these measurements in the ANCOVA. The ANCOVA revealed a significant effect of tail length ($F_{1,11} = 26.39$, $P = 0.0003$) and hindfoot length ($F_{1,11} = 32.44$, $P = 0.0001$) on home range size. After removing the effect of tail or hind foot length, male skunks still exhibited a larger home range (tail ANCOVA: $F_{1,11} = 14.30$, $P = 0.003$; hindfoot ANCOVA: $F_{1,11} = 7.27$, $P = 0.021$).

Both intrasexual and intersexual home range and core area overlap were extensive (Table 2). Analysis with mixed-effects models revealed a lower degree of intrasexual overlap for core area (randomization methods, $P = 0.009$) but not home ranges (randomization methods, $P = 0.051$). Additionally, there was significantly less overlap of home range for males ($F_{1,12} = 4.86$, $P = 0.048$) but no difference in the core area overlap between males and females ($F_{1,12} = 0.72$, $P = 0.41$).

Estimated mean elevations for home ranges of males and females were 654.2 m ($SD = 5.2$) and 661.3 m ($SD = 2.6$), respectively. Mean elevation (m) of core areas for males was 655.4 ($SD = 6.7$) and for females was 662.1 ($SD = 2.4$). Elevation was higher in females for both home range ($F_{1,12} = 11.97$, $P = 0.005$) and core area ($F_{1,12} = 7.87$, $P = 0.016$). The estimate of population density was 2.6 skunks/km^2 .

DISCUSSION

Hog-nosed skunks were never radio-tracked or visually observed within the riparian area, even though they have been reported to use this habitat type (Schmidly and Hendricks, 1984). Whereas reasons for this were not ascertained, it could be due to a variety of factors, including a lack of resources, competitive exclusion, or because the hog-nosed skunk is a more arid-adapted species. In addition we did not detect the utilization of agricultural fields by hog-nosed skunks during our study.

Home range sizes for hog-nosed skunks were similar to those reported for *Conepatus chinga* by Castillo *et al.* (2011; protected area: average 2.13 km^2 and 0.81 km^2 for males and females, respectively) in Argentina, Kasper *et al.* (2012; average 2.55 km^2 and 1.00 km^2

TABLE 1.—Home range and core area size of 14 *Conepatus leuconotus*. The 95% fixed kernel isopleths (0.95 FK, km²), core areas (CA, km²), and core area contour volumes (CACV) are given for individual hog-nosed skunks (ID); sample size (*n*) is the number of unique locations

Females					Males				
ID	<i>n</i>	0.95 FK	CA	CA CV	ID	<i>n</i>	0.95 FK	CA	CA CV
C001	83	0.52	0.16	50%	C006	72	2.42	0.98	62%
C003	34	0.65	0.29	65%	C009	24	2.47	1.71	83%
C010	45	0.47	0.22	72%	C019	37	1.42	0.46	56%
C014	42	0.27	0.16	78%	C021	43	1.14	0.46	65%
C015	28	0.50	0.23	65%	C023	36	2.24	1.16	76%
C016	27	1.04	0.35	65%					
C017	68	0.76	0.18	45%					
C018	32	0.63	0.18	61%					
C026	37	0.90	0.31	62%					

for males and females, respectively) in southern Brazil, and Reppucci *et al.* (2009; average 1.1 km² for male and female combined with males being 2.3 times larger) in Argentina. Our results differ from those reported by Donadio *et al.* (2001), who found no difference between male and female home range size in *C. chinga* in northwestern Patagonia, although those results were based on data from only a single male and female. Other

TABLE 2.—Intrasexual and intersexual home range and core area overlap (%) are given for individual (ID) hog-nosed skunks (*Conepatus leuconotus*). The number of individuals (*n*) with which the home range of a given skunk overlaps is provided

Intrasexual overlap											
Home range						Core area					
Females			Males			Females			Males		
ID	<i>n</i>	Overlap	ID	<i>n</i>	Overlap	ID	<i>n</i>	Overlap	ID	<i>n</i>	Overlap
C001	4	0.69	C006	2	0.59	C001	2	0.47	C006	2	0.37
C003	3	0.66	C009	2	0.38	C003	3	0.32	C009	1	0.17
C010	3	0.88	C019	2	0.33	C010	2	0.47	C019	2	0.00
C014	3	0.97	C021	2	0.73	C014	3	0.24	C021	1	0.63
C015	3	0.95	C023	4	0.64	C015	2	0.57	C023	2	0.31
C016	3	0.66				C016	3	0.17			
C017	3	0.78				C017	1	0.14			
C018	4	0.53				C018	2	0.18			
C026	2	0.08				C026	0	0.00			
Intersexual overlap											
C001	3	1.00	C006	5	0.60	C001	2	0.91	C006	4	0.45
C003	3	0.99	C009	4	0.40	C003	2	0.50	C009	4	0.22
C010	2	0.90	C019	2	1.00	C010	2	0.71	C019	0	0.00
C014	2	1.00	C021	5	0.08	C014	2	0.70	C021	4	0.63
C015	2	1.00	C023	4	0.86	C015	2	0.96	C023	4	0.08
C016	4	0.71				C016	2	0.65			
C017	4	0.66				C017	2	0.16			
C018	2	1.00				C018	2	0.84			
C026	3	0.49				C026	0	0.00			

species of skunks typically show patterns of larger home range size in males (e.g., Larivière and Messier, 1998b, *Mephitis mephitis*; Lesmeister, 2007, *Spilogale putorius*); however, Bixler and Gittleman (2000) found no difference in male and female striped skunk home range sizes in eastern Tennessee, U.S.A. Home ranges of *C. leuconotus* in this study are larger than those reported for *C. semistriatus* in Venezuela (0.18 to 0.53 km²; Sunquist *et al.*, 1989) and *C. humboldti* in southern Chile (0.07 to 0.16 km²; Fuller *et al.*, 1987). These differences might reflect different levels of habitat productivity or resource abundance given that reported *M. mephitis* home ranges vary from 0.5 to 12 km² (Dragoo, 2009) and home range size of *C. chinga* increased in anthropogenically-modified habitats as opposed to relatively undisturbed areas (Castillo *et al.*, 2011). It should be noted that previous studies investigating the space use patterns of members of the genus *Conepatus* have relatively small sample sizes, and thus comparisons between studies should be made with this caveat in mind.

The extensive overlap found in this study represents only the minimum amount possible, as several radio-collared skunks ($n = 15$) were excluded from analyses based on the minimum number of locations required for estimation of home range and core area. Many of these skunks were frequently tracked to areas within the known ranges of skunks included in this study. This degree of overlap is expected when food resources vary in location, availability, and abundance throughout the year (Sandell, 1989).

Many aposematic animals have only short range sensory abilities (Larivière and Messier, 1996b, 1998b), and the sensory abilities of *C. leuconotus* would seem to place it in this category (Dragoo, 2009). Given this distinction, it is possible the large degree of intrasexual overlap found in this study might be facilitated by the inability of hog-nosed skunks to detect other individuals unless they are relatively close (Larivière and Messier, 1996b). However, we documented several cases of same-sex, adult hog-nosed skunks denning together or in close proximity (< 5m), as well as intersexual pairs denning together outside of the purported breeding season. An investigation incorporating genetic relatedness with spatial organization could provide further insight into the social interactions of this species.

We were able to detect a significant difference in the mean elevation of male and female home ranges. Although the differences in elevation are not intrinsically meaningful, they do represent general changes in habitat composition. Female home ranges were aggregated onto two adjacent hill tops (Fig. 1), and a majority of skunk captures occurred on these hills. We do not believe the patterns depicted here are the result of sampling bias, as the lower elevation area between the two hill tops was frequently surveyed and few captures were recorded in that area. The tops of these hills were relatively open with scattered oak mottes and shrubs, whereas the slopes of these hills were dense with stands of juniper and generally gave way to wash-out plains of mesquite scrubland.

The disparity in habitat use between males and females may be the result of several factors. Den site selection differs relative to gender in this species and prey abundance may differ between habitat types. Another explanation could be that for solitary polygynous carnivores, female home ranges are determined by the distribution of resources, whereas male space-use patterns are governed, in part, by access to females (Sandell, 1989; Ferguson *et al.*, 2009). The increased home range size seen in males is larger than would be necessitated by the moderate increase in energy requirements due to sexual dimorphism (Sandell, 1989); rather, it is likely due to the attempt of acquiring access to more potential mates. The patterns observed at our study site may be the result of males expanding their home range to incorporate more female home ranges but incidentally into areas where no females were recorded because of decreased resource availability.

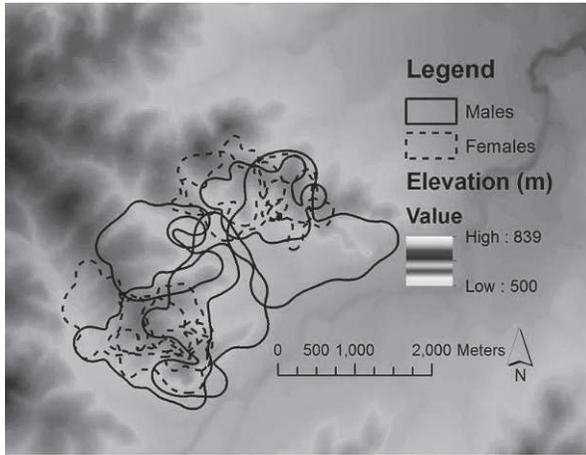


FIG. 1.—Estimated home ranges (95% fixed kernel isopleths) delineated for five male (solid lines) and nine female (dotted lines) *Conepatus leuconotus* studied between July 2008 and November 2010 in west-central Texas. Female home ranges correspond with two elevated hills in the study area and are represented by a 10 m resolution digital elevation model

The density estimate of this study is higher than those reported for *C. leuconotus* in Oaxaca, Mexico, which ranged from 0.6 to 1.3 skunks/km² (Cervantes *et al.*, 2002). The disparity in reported densities is relatively small and could be the result of differences in estimation techniques, habitat productivity, or temporal variation in population numbers. Our density estimate was also higher than those for *C. chinga* in Argentina, which ranged from 0.12 to 1.66 skunks/km² (Castillo *et al.*, 2011). The relatively high density of skunks found in this study is encouraging given the reported population declines and regional extirpations of this species (Rosatte and Larivière, 2003).

This study represents the first examination of space-use patterns in the American hog-nosed skunk, filling in a critical gap in our understanding of the ecological requirements of this mesocarnivore. Although novel for this species, the general patterns of home range size and overlap we recorded are similar to those for congeneric species (Castillo *et al.*, 2011; Kasper *et al.*, 2012; Reppucci *et al.*, 2009). The large degree of inter- and intra-sexual overlap seen in hog-nosed skunks supports the idea these species do not maintain exclusive territories, indicating that other resources (*e.g.*, food, den sites) rather than exclusive access to mates might be affecting their space-use patterns. Future studies investigating how and to what extent food resources shape individual space-use patterns for both genders could provide insight into the relative importance of ecological versus reproductive factors in shaping the spatial organization of hog-nosed skunks. Studies of home range patterns from divergent habitats found within their range (*e.g.*, coastal plains of Oaxaca, Mexico) could provide insight into how different environments affect the spatial organization of populations of this species. Such comparisons are important to further our understanding of hog-nosed skunk ecology as space-use patterns can differ between locations (Castillo *et al.*, 2011). Our data also reinforce suggestions put forth by Kasper *et al.* (2012) to include intersexual comparisons when studying *Conepatus*, as males and females differ in various life history aspects.

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