Journal of Mammalogy, 93(3):716–721, 2012

Habitat selection of Molina's hog-nosed skunks in relation to prey abundance in the Pampas grassland of Argentina

Diego Fabián Castillo*, Estela Maris Luengos Vidal, Emma Beatriz Casanave, and Mauro Lucherini

GECM – Cat. Fisiología Animal, Depto. Biología, Bioquímica y Farmacia, UNS (DFC, EMLV, EBC, ML) y CONICET (EBC, ML), San Juan 670, 8000 Bahía Blanca, Argentina

* *Correspondent: diefcastillo@gmail.com*

We radiotracked 16 (6 males, 10 females) adult Molina's hog-nosed skunks (*Conepatus chinga*) to examine habitat selection using compositional analysis at 2 spatial scales in a protected area and a landscape fragmented by agriculture. To aid in understanding the habitat use of skunks, the abundance of invertebrates was estimated in each habitat. Habitat use and selection varied between the 2 study sites. Skunks selected habitat at landscape level but not at home range level in the protected area. In the cropland area skunks showed overall habitat selection at both scales, although at landscape level we did not detect a significant ranking of habitats. In both sites, when we found a significant selection grassland patches ranked first. Although this habitat does not reach 10% of the total area, it presented the highest abundance of Coleoptera. Because Coleoptera are the main prey item of this mephitid, these results support the hypothesis that habitat selection in *C. chinga* is highly related to food availability. We conclude that the preservation of grassland patches may be essential for managing *C. chinga* populations in the highly human-modified landscapes of the Pampas.

Key words: compositional analysis, *Conepatus chinga*, Mephitidae, radiotelemetry

DOI: 10.1644/11-MAMM-A-300.2

Habitat selection occurs when components of the landscape are used in proportions greater than their relative availability (Mysterud and Ims 1998). Selected habitats most likely offer the best trade-off between resource acquisition and constraints from competition, risk of predation, and other threats (Morris 2003). Conversion of grassland habitats into agricultural fields is widespread and has had a variety of consequences that affect the biodiversity (Robinson and Sutherland 2002). This is the case of the Pampas grassland, where habitat loss due to row-crop agriculture and cattle grazing has severely reduced and fragmented native grasslands (Bilenca and Miñarro 2004). The response of carnivores to environmental changes varies across species (Ordeñana 2009). Thus studies exploring the effects of habitat modification over the ecology of the species are needed to develop management and conservation plans.

The Molina's hog-nosed skunk (*Conepatus chinga* Molina 1782) is a mephitid morphologically adapted for capturing ground invertebrates that constitute its principal preys (Castillo 2011; Donadio et al. 2004). Despite its large distribution in South America (Redford and Eisenberg 1992), there is little information on the ecology of *C. chinga* (Castillo et al. 2011; Donadio et al. 2001).

Although the terms habitat use, selection, and preference are used frequently as synonymous, Johnson (1980) defined habitat use as the quantity of habitat used by the consumer, and habitat selection as the disproportionate use of a habitat relative to its availability. Aebischer et al. (1993) used the term habitat preference on a relative scale only, for ranking habitat selection relative to specific, alternate habitats. These definitions will be used here.

We investigated the habitat use and selection derived from radiotracking data of Molina's hog-nosed skunks in a protected area and a landscape fragmented by agriculture. Both crop activities and herbivore grazing may negatively affect the structure and abundance of invertebrate communities (de la Fuente et al. 2006). Variations in food abundance are among the major factors in determining an animal's use of an area (Mortelliti and Boitani 2008; Neiswenter and Dowler 2007), so we predicted that undisturbed habitats (i.e., natural and seminatural grasslands) would be preferred by skunks, whereas it was expected that agricultural habitats would be the least used.

Materials and Methods

Study site.—We selected 2 study sites in the Pampas grasslands with different levels of anthropic disturbance. The 1st site (protected area: PA, henceforward) was Parque Provincial Ernesto Tornquist (38°00′S, 62°00′W), located in the central part of the Ventania mountain range, southern Buenos Aires Province, Argentina. This 6,700-ha protected area ranges in elevation from 450 m to 1,172 m above seal level (asl). The climate is temperate with mean 500–800 mm annual precipitation. Its vegetation is characterized by native grassland but introduced tree/shrub patches are also frequent (Zalba and Villamil 2002).

The 2nd site (cropland area: CA) is located in an unprotected farming area (38°37′S, 60°53′W) of the same region with an elevation of 120–150 m asl. The climate is temperate with mean 500–1,000 mm annual precipitation. Land was mostly used for livestock breeding (cows and sheep) and intensive agriculture activities.

Capture and handling.—Live trapping was carried out from October 2002 to February 2007. We spotlighted Molina's hog-nosed skunks (skunks, henceforward) from a vehicle and restrained them manually. Restrained individuals were chemically immobilized (Castillo et al. 2012). All trapping and handling procedures followed the guidelines of the American Society of Mammalogists (Sikes et al. 2011).

Radiotelemetry and home range estimation.—We radiocollared skunks and tracked them on foot homogeneously throughout the 24 h. We recorded independent telemetry locations 2–3 times per week and obtained radio locations for each animal with a minimum 2-h interval (Castillo et al. 2011) using standard telemetry techniques (White and Garrott 1990). We estimated home range size with Ranges V software (Kenward and Hodder 1996) using the 100% minimum convex polygon (MCP—Worton 1989).

Habitat analysis.—Habitat selection was evaluated using compositional analysis (e.g., Dickson and Beier 2007; Kauhala and Auttila 2009) that uses radiocollared animals as sampling units, and considers all habitat types simultaneously. Because the minimum number of individuals for statistical inference from compositional analyses is six (Aebischer et al. 1993), the sexes were pooled. Multivariate analysis of variance was used to test the null hypothesis of no selection. Rejection of the null hypothesis led to a series of paired Student's *t*-tests, which were used to rank habitat types from most preferred to least preferred (Aebischer et al. 1993). When a habitat was available but not used it was assigned a value of 0.01% to avoid dividing by zero. Similarly, when a particular habitat type was neither used nor available, we substituted a small value (0.01%) to both the used and available proportions (Koen 2005). These substitutions do not affect the outcome of the category rankings (Aebischer et al. 1993).

Habitat availability and utilization.—At PA habitat types were classified from satellite images (Google Earth) in three exclusive categories: rocky areas, woodland, and grassland patches. Rocky areas consisted of patches largely covered by outcropping rock with a moderate to high slope. The vegetation height and density in this area was strongly influenced by the presence of large numbers of feral horses (Scorolli et al. 2006). Woodland was composed by introduced trees (predominantly *Pinus* sp. and *Eucalyptus* sp.). In this habitat the density of feral horses was high too. Grassland patches were fenced areas, where horses were excluded and grasses were denser and taller. At CA we classified the following habitat types: crop fields, pastures, and grassland patches. Crop fields were typically seeded, harvested, and cultivated annually with small grains (oat, wheat, and soya) or oil crops (sunflowers). Pastures consisted mostly of alfalfa and hayfields. Grass patches were marginal areas without management located mainly along a railroad, a stream, or in rocky soil.

The availability of each habitat type inside individual home ranges and the 2 study sites was estimated from proportional habitat coverages, calculated using a raster-based habitat map constructed in Arc Gis 9.2. The study site boundaries were defined by the MCP that encompassed all radiolocation fixes recorded plus a 126-m-wide buffer area (mean distance from the center to the borders of home ranges).

Because habitat selection is likely a spatially hierarchical process (Gaillard et al. 2010), in this study we examined it at 2 levels: the habitat composition inside home ranges compared with availability within study area (2nd-order selection, sensu Johnson 1980) and habitat use (i.e., number of locations) within individual home ranges compared with habitat availability within those ranges (3rd-order selection—Johnson 1980).

Food availability.—On the basis of the main prey items found in the feces of *C. chinga* (Castillo 2011; Donadio et al. 2004), we used the abundance of invertebrates available at ground level to estimate food availability, using pitfall traps (Ausden 1996). The traps were placed in 20- × 20-m grids, each one consisting of 9 plastic containers 10 cm in diameter and 7 cm deep filled with saltwater solution and placed in pits deep enough to bury the cups up to the rim on the ground. In each habitat type and season we activated 3 randomly located grids that were active for 3 consecutive nights. After this period, invertebrates were collected, identified (on the basis of morphological types), and counted. The abundance was calculated as the average number of individuals captured per grid. This analysis only included the main prey items found in the diet of skunks from the same areas: Coleoptera, Coloptera larvae, Lepidoptera larvae, and Scorpiones (Castillo 2011).

Results

We radiocollared 16 adult Molina's hog-nosed skunks that were monitored for (mean ± *SD*) 211.69 ± 89.68 days. Habitat analyses were conducted for 7 skunks (3 males, 4 females) at PA and 9 skunks (3 males, 6 females) at CA. A total of 469 (range: 41–103) location fixes was recorded at PA, where study area covered 1,257.8 ha. At CA, 595 (range: 30–86) fixes corresponded to a study area of 5,067 ha.

Habitat selection, 2nd-order resolution.—Skunks utilized habitat in a nonrandom manner at both study areas (PA: $\Lambda = 0.27$, $d.f. = 2$, $P = 0.01$; CA: $\Lambda = 0.51$, $d.f. = 2$, $P = 0.005$;

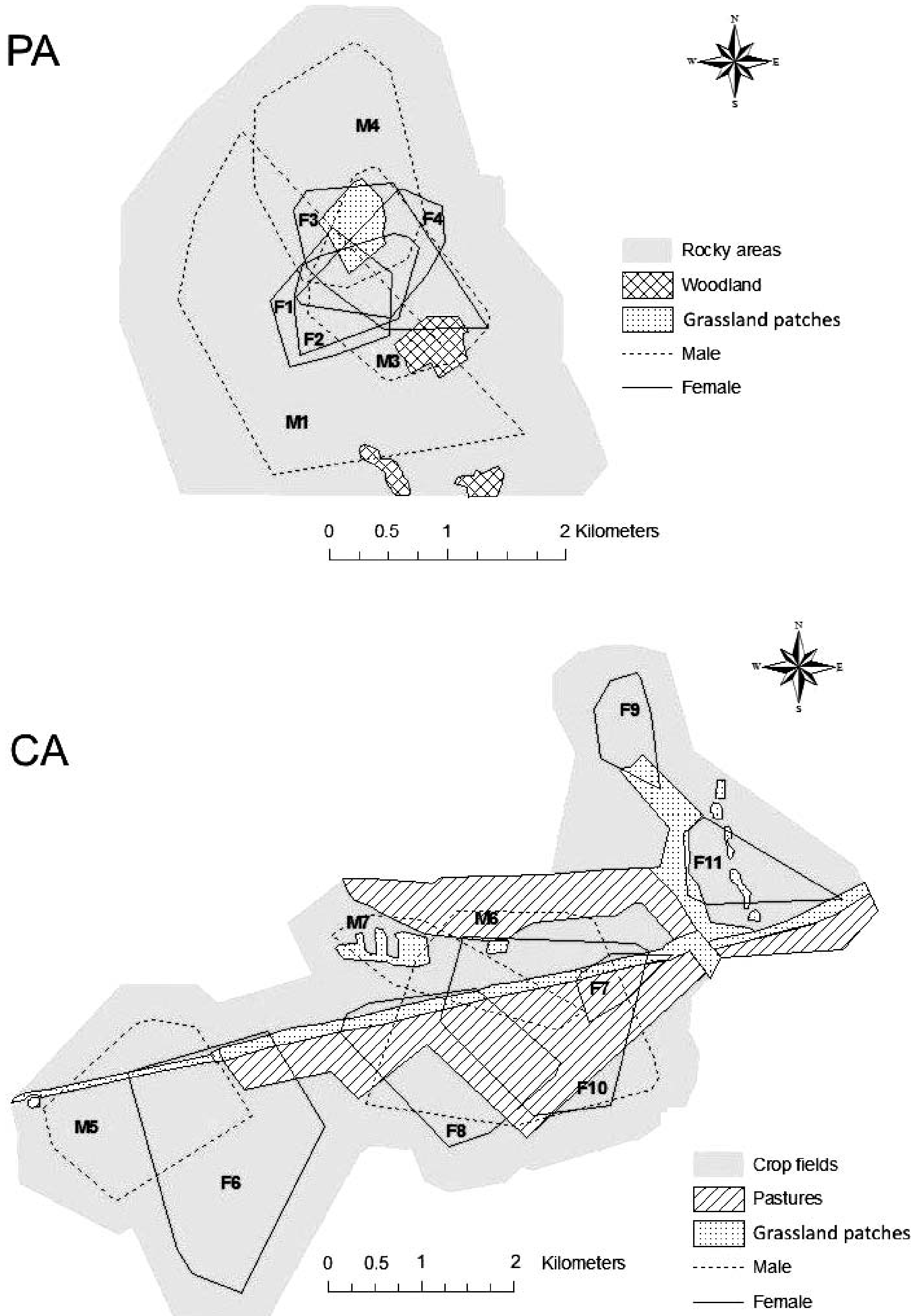

FIG. 1.—Location of home ranges of radiocollared Molina's hog-nosed skunks (*Conepatus chinga*) with respect to habitat types in a protected area (PA, $n = 7$) and a cropland area (CA, $n = 9$) in the Pampas grassland of Argentina.

Fig. 1). The following order of preference was found for PA: grassland patches > rocky areas > woodland (where the difference between rocky areas and woodland was not significant at $\alpha = 0.05$; Table 1). At CA, multiple comparisons tests did not detect a significant order of preference (Table 2A).

Habitat selection, 3rd-order resolution.—In PA, habitat utilization within skunk home ranges was random ($\Lambda = 0.54$, *d.f.* $= 2$, $P = 0.11$), whereas skunks showed overall nonrandom habitat utilization at CA ($\Lambda = 0.39$, *d.f.* $= 2$, $P = 0.001$, Table 2B), multiple comparison tests detected significant differences between all habitat type pairs, and the order of preference was grassland patches > pastures > crop fields (Table 2B).

Prey availability.—In both areas, grassland was the habitat with the highest abundance of Coleoptera, whereas woodland

Table 1.—Student's *t*-values (below the diagonal), significance (above the diagonal), and relative ranking of habitat types derived from pair-wise log-ratio differences between utilized and available habitat compositions (2nd-order resolution) for Molina's hog-nosed skunks in a protected area (not significant [ns] = $P > 0.05$,* = $P < 0.05$) of the Pampas grassland of Argentina.

	Grassland patches	Rocky areas	Woodland	Rank
Grassland patches	—	0.008*	0.01*	1
Rocky areas	3.84	—	0.63ns	2
Woodland	3.27	0.65	—	3

(at PA) and pastures (at CA) showed the lowest abundances of these invertebrates (Fig. 2). At PA, rocky areas had the greatest abundances of both types of larvae and scorpions (Fig. 2). Despite the low abundance of Coleoptera, pastures were the habitat type with the highest abundance of Lepidoptera and Coloptera larvae in CA (Fig. 2).

Discussion

Our study presents the 1st information on habitat selection by *C. chinga* in the Pampas grassland and shows that skunks did not use habitats randomly (at least at 1 of the 2 orders of resolution we tested). This selectivity agrees with that reported for other members of the Mephitidae (Baldwin et al. 2004; Neiswenter and Dowler 2007) and with the only previous data for 2 collared Molina's hog-nosed skunks in the Patagonian steppe (Donadio et al. 2001). As predicted, when we found significant selection and were able to develop a ranking (PA: 2nd order of selection, CA: 3rd order), grassland patches were the most preferred environment for *C. chinga* in both study areas. This habitat did not reach 10% of the total size of both study areas, but presented the highest abundance of Coleoptera, the main prey in the diet of *C. chinga*. The 2nd preferred habitats were rocky areas and pastures in PA and CA, respectively. Although these habitats had comparatively lower abundances of Coleoptera, they showed high numbers of Coleoptera larvae, Lepidoptera larvae, and scorpions (in the case of rocky areas), so they would provide

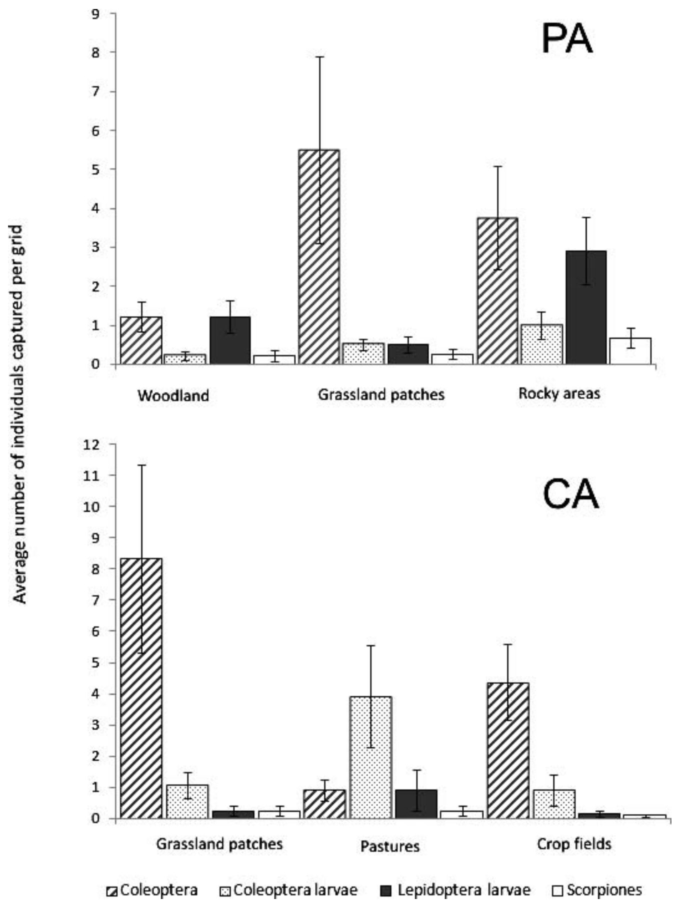

Fig. 2.—Abundance (mean number of individuals captured per grid ± standard error) of the main prey of Molina's hog-nosed skunk in different habitat types of a protected area (PA) and cropland area (CA) in the Pampas grassland of Argentina.

sources of alternative food. Finally, crop fields were the least preferred habitat at CA. Because crop fields presented an abundance of Coleoptera higher than average, this would be surprising if food abundance was the only factor driving habitat selection. However, the spatial and temporal patterns of food availability may also affect an animal's choice, especially in carnivores (Gough and Rushton 2000; Johnson 1980). Crop fields are a very unpredictable habitat because their vegetation structure and location change seasonally. Bare soil and stubble (both seasonal variations of crop fields habitat) do not provide a high abundance of the main prey of *C. chinga* (Castillo 2011), suggesting that instability in the vegetation cover was associated directly with a strong variability in food availability. All the above indicate that avoidance of crop fields by *C. chinga* was mostly dictated by food availability.

Another factor that may influence habitat selection is the risk of predation (Gough and Rushton 2000; Johnson 1980), especially in farmland areas, such as CA, where human conflicts are important causes of skunk mortality (Dragoo and Sheffield 2009). In this sense, high vegetation cover and availability of dens provided by grasslands (Castillo et al. 2011) may contribute to the habitat preference exhibited by skunks toward this habitat.

Table 2.—Student's *t*-values (below the diagonal), significance (above the diagonal), and relative ranking of habitat types derived from pair-wise log-ratio differences between utilized and available habitat compositions at 2nd- (A) and 3rd- (B) order resolution for Molina's hog-nosed skunks in a cropland area of of the Pampas grassland of Argentina. Not significant (ns) = $P > 0.05$; * =$P < 0.05$.

	Grassland patches	Pastures	Crop fields	Rank
(A) 2nd-order resolution				
Grassland patches	—	0.17ns	0.16ns	1
Pastures	1.49	—	0.78ns	2
Crop fields	1.51	−0.28	—	3
(B) 3rd-order resolution				
Grassland patches	—	0.037*	0.009*	1
Pastures	2.5	—	0.03*	2
Crop fields	3.46	2.62	—	3

We conclude that the preservation of the fragmented grassland areas (a habitat that provides both protection from predators and a relatively constant availability of food resources) may be vital for managing sustainably *C. chinga* populations in the human-modified landscapes of present-day Pampas.

Resumen

Colocamos radiocollares a 16 (6 machos, 10 hembras) zorrinos comunes adultos (*Conepatus chinga*) para examinar la selección de hábitat utilizando el análisis composicional a dos escalas en dos áreas: una protegida y una fragmentada por actividades agrícolas. Además, para ayudar a entender la preferencia exhibida por los zorrinos, se estimó la abundancia de invertebrados. El uso y la selección de hábitat variaron entre ambas áreas de estudio. En el área protegida los zorrinos seleccionaron el hábitat a nivel de paisaje pero no a nivel del área de acción. En el área rural los zorrinos mostraron selección general a ambas escalas, aunque a escala de paisaje no se pudo establecer un ranking de hábitats. Los parches de pastizal ocuparon el primer lugar del ranking. Aunque este hábitat no alcanza el 10% del área total, presenta la mayor abundancia de coleópteros. Debido a que estos insectos constituyen el ítem principal de la dieta de este mefítido, estos resultados avalan la hipótesis de que la selección de hábitat realizada por *C. chinga* está relacionada con la disponibilidad de alimento. Podemos concluir que la preservación de los parches de pastizales en el ecosistema pampeano podría ser esencial para el manejo de las poblaciones de *C. chinga.*

Acknowledgments

We thank Grupo de Ecología Comportamental de Mamíferos members and collaborators for their help in fieldwork and to the farm owners, especially the Merino family. The staff of Tornquist Provincial Park provided logistic support. DFC and EMLV were supported by a scholarship from CONICET. The paper was funded by Earthwatch Institute, Grant by ANPCyT and SGCyT, Universidad Nacional del Sur.

Literature Cited

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radiotracking data. Ecology 74:1313–1325.

Ausden, M. 1996. Invertebrates. Pp. 139–177 in Ecological census techniques. A handbook (W. J. Sutherland, ed.). Cambridge University Press, Cambridge, United Kingdom.

Baldwin, R. A., A. E. Houston, M. L. Kennedy, and P. S. Liu. 2004. An assessment of microhabitat variables and capture success of striped skunks (*Mephitis mephitis*). Journal of Mammalogy 85:1068–1076.

Bilenca, D., and F. Miñarro. 2004. Identificacion de Áreas Valiosas del Pastizal (AVPs) en las Pampas y Campos de Argentina, Uruguay y sur de Brasil. Fundacion Vida Silvestre Argentina, Buenos Aires, Argentina.

Castillo, D. 2011. Ecología espacial, temporal y trófica del zorrino (*Conepatus chinga*) en un área natural y un área de uso agrícola. Ph.D. dissertation, Universidad Nacional del Sur, Bahía Blanca, Argentina.

Castillo, D., M. Lucherini, and E. B. Casanave. 2011. Denning ecology of Molina's hog-nosed skunk in a farmland area in the Pampas grassland of Argentina. Ecological Research 26:845–850.

Castillo, D., E. M. Luengos Vidal, E. B. Casanave, and M. Lucherini. 2012. Field immobilization of Molina's hog-nosed skunk (*Conepatus chinga*) using ketamine and xylazine. Journal of Wildlife Diseases 48:173–175.

de la Fuente, E. B., A. E. Lenardis, S. A. Suárez, A. Gil, and C. M. Ghersa. 2006. Insect communities related to wheat and coriander cropping histories and essential oils in the Rolling Pampa, Argentina. European Journal of Agronomy 24:385–395.

Dickson, B. G., and P. Beier. 2007. Quantifying the influence of topographic position on cougar (*Puma concolor*) movement in southern California, USA. Journal of Zoology (London) 271:270–277.

Donadio, E., S. D. Martino, M. Aubone, and A. J. Novaro. 2001. Activity patterns, home-range, and habitat selection of the common hog-nosed skunk, *Conepatus chinga* (Mammalia, Mustelidae), in northwestern Patagonia. Mammalia 65:49–54.

Donadio, E., S. D. Martino, M. Aubone, and A. J. Novaro. 2004. Feeding ecology of the Andean hog-nosed skunk (*Conepatus chinga*) in areas under different land use in northwestern Patagonia. Journal of Arid Environments 56:709–718.

Dragoo, J. W., and S. R. Sheffield. 2009. *Conepatus leuconotus* (Carnivora: Mephitidae). Mammalian Species 827:1–8.

Gaillard, J. M., et al. 2010. Habitat–performance relationships: finding the right metric at a given spatial scale. Philosophical Transactions of the Royal Society of London, B. Biological Sciences 365:2255–2265.

Gough, M., and S. Rushton. 2000. The application of GIS-modelling to mustelid landscape ecology. Mammal Review 30:197–216.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Kauhala, K., and M. Auttila. 2009. Estimating habitat selection of badgers—a test between different methods. Folia Zoologica 59:16–25.

Kenward, E. E., and K. H. Hodder. 1996. RANGES V. An analysis system for biological location data. Programme The Home Range, Version 1.5.

Koen, E. L. 2005. Home range, population density, habitat preference, and survival of fishers (*Martes pennanti*) in eastern Ontario. M.Sc. thesis, University of Ottawa, Ottawa, Ontario, Canada.

Morris, D. W. 2003. Toward an ecological synthesis: a case for habitat selection. Oecologia 136:1–13.

Mortelliti, A., and L. Boitani. 2008. Interaction of food resources and landscape structure in determining the probability of patch use by carnivores in fragmented landscapes. Landscape Ecology 23:285–298.

Mysterud, A., and R. A. Ims. 1998. Functional responses in habitat use: availability influences relative use in trade-off situations. Ecology 79:1435–1441.

Neiswenter, S. A., and R. C. Dowler. 2007. Habitat use of western spotted skunks and striped skunks in Texas. Journal of Wildlife Management 71:583–586.

Ordeñana, M. 2009. The effects of urbanization on carnivore species distribution and richness in Southern California. M.Sc. thesis, University of California, Davis, Davis, California.

Redford, K. H., and J. F. Eisenberg. 1992. Mammals of the Neotropics: the southern cone. The University of Chicago Press, Chicago, Illinois.

Robinson, R. A., and W. J. Sutherland. 2002. Postwar changes in arable farming and biodiversity in Great Britain. Journal of Applied Ecology 39:157–176.

Scorolli, A. L., A. C. Lopez Cazorla, and L. A. Tejera. 2006. Unusual mass mortality of feral horses during a violent rainstorm in Parque Provincial Tornquist, Argentina. Mastozoología Neotropical 13:255–258.

Sikes, R. S., W. L. Gannon, and The Animal Care and Use Committee of the American Society of Mammalogists. 2011. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. Journal of Mammalogy 92:235–253.

White, G. C., and R. A. Garrott. 1990. Analysis of wildlife radio-tracking data. Academic Press, New York.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home range studies. Ecology 70:165–168.

Zalba, S. M., and C. B. Villamil. 2002. Woody plant invasion in relictual grasslands. Biological Invasions 4:55–72.

Submitted 26 August 2011. Accepted 12 December 2011.

Associate Editor was Ricardo A. Ojeda.