Interindividual interactions of Molina's hog-nosed skunks *Conepatus chinga* in the Pampas grassland of Argentina

Juan I. REPPUCCI, Diego F. CASTILLO*, Mauro LUCHERINI, Estela M. LUENGOS VIDAL and Emma B. CASANAVE

Reppucci J. I., Castillo D. F., Lucherini M., Luengos Vidal E. M. and Casanave E. B. 2009. Interindividual interactions of Molina's hog-nosed skunks *Conepatus chinga* in the Pampas grassland of Argentina. Acta Theriologica 54: 87–94.

During one year, we radiotracked two female and two male Molina's hog-nosed skunks *Conepatus chinga* (Molina, 1782), a little studied mephitid, in the Pampas of central Argentina, to analyze the static and dynamic interactions between individuals. Mean home range overlap was large (44.5%), but males shared a smaller proportion of their home ranges than females. The average percentage of localizations in the overlap area (39.3%) indicates that these areas were not marginal sections of individual home ranges, but this value was greater for individuals of different genders than intrasexual dyads. The Coefficient of Spatial Association confirmed that the distances between individuals of different sexes were smaller than between animals of the same sex. During simultaneous locations, females were closer than males, but reciprocal distances between individuals varied over the time. These patterns are congruent with those described as typical for mustelids and mephitids. Our results confirm that an analysis of home range overlap should not be considered complete without the study of dynamic interactions among individuals and their temporal variations, which are necessary to overcome the limitations of spatial overlap analysis.

Grupo de Ecología Comportamental de Mamíferos (GECM), Cátedra Fisiología Animal, Departamento Biología, Bioquímica y Farmacia, Universidad Nacional del Sur, San Juan 670, (8000) Bahía Blanca, Argentina (JIR, DFC, ML, EMLV, EBC); CONICET Researcher (ML, EBC)

Key words: home range overlap, dynamic interactions, static interactions, Mephitidae, radiotelemetry

Introduction

In general, the social organization of solitary species is based on territoriality: both males and females defend their territories from other individuals of the same sex (Rogers 1977, Powell 1979). In this context, males usually range over larger areas than females, and home range overlap is wider intersexually than intrasexually (Gittleman and Harvey 1982). The purpose of this is to enable males to access to more than one female during mating (Kruuk and Macdonald

* Corresponding author – e-mail: diefcastillo@gmail.com

1985, Eisenberg 1986). This social organization system is common among the carnivore Families (Kruuk and Macdonald 1985), but has never been studied in the South American skunks of genus *Conepatus*.

Until some years ago, skunks were considered to be members of the *Mustelidae* family. However, genetic evidence suggested that skunks are phylogenetically distinct from other mustelids, and they were placed in a new family, called *Mephitidae* (Rosatte and Lariviere 2003). The Molina's hog-nosed skunk *Conepatus chinga* (Molina, 1782) is one of the most widespread South American species and is found from Bolivia south through Uruguay and Western Paraguay into Argentina at least as far south as Neuquén province and central Chile (Redford and Eisenberg 1992).

The analysis of home range overlap and the interactions among the individuals that share these areas is used commonly in the analysis of the social organization of carnivores, where territoriality is frequently difficult to study (Powell 2000). Interindividual interactions can be classified in two groups: static and dynamic. Static interactions are defined as the spatial overlap between home ranges of two or more individuals. The study of static interactions represents a first approach to the understanding of the spatial organization of species. However, if we aim to understand the importance of shared areas, it is advisable to analyze dynamic interactions, which imply the addition of time factor and the study of reciprocal positions and independent movements of the individuals whose home ranges overlap (Powell 2000). The comprehension of dynamic interactions allows determining if two individuals are using an area in contemporary form (Doncaster and Macdonald 1997, Powell 2000).

The present work aims to contribute to the understanding of interindividual interactions and the social organization in *C. chinga*.

Study area

We conducted our study at Parque Provincial Ernesto Tornquist (PPET), located in the central part of the Ventania mountain range (38°00'S – 62°00'O), southern Buenos Aires province, Argentina. This protected area has a surface of approximately 6700 ha and a maximum altitude of 1240 m

a.s.l. The climate is temperate with mean annual precipitation of 500–800 mm (Frangi and Bottino 1995). This area is part of the Pampas ecoregion (USAID 1995) and vegetation is characterized by native grassland (genuses *Stipa*, *Piptochaetium*, *Festuca* and *Briza*; Cabrera 1976). Introduced plant patches (*Pinus*, *Cupressus, Acacia*, *Eucalyptus* and specimens of the *Rosacea* family) are also frequent (Zalba and Villamil 2002). The vegetation in the study area was extensively affected by the presence of a dense population of feral horses that feed on natural grasses, but there was a little fenced area (24.5 ha), where horses were excluded and grasses were denser and taller.

Material and methods

Capture and handling

Trapping was carried out from October 2002 to March 2005. During the first two years, we used box traps, but, in spite of a relatively large trapping effort, we had little success (we only trapped 2 skunks). For this reason, we decided to use a different method, and spotlighted skunks from a vehicle to restrain them manually, using a blanket to avoid being sprayed. With this new method we trapped 6 skunks. Restrained individuals were chemically immobilized for handling with a combination of ketamine hydrochloride (24.64 mg/kg) and xylazine (1.96 mg/kg). Capture and handling procedures were conducted in accordance with a protocol elaborated by our team and tested in more than 200 carnivore captures (Luengos Vidal *et al*. 2003), and were authorized by Ministerio de Asuntos Agrarios, Buenos Aires province (the governmental agency in charge of wildlife research and management).

Radiotelemetry

We fitted adult skunks with Telemetry Solutions (Concord, California) and AVM Instrument (Colfax, California) radiocollars, equipped with activity and mortality sensors. Radiotelemetry sampling was carried out on foot and homogeneously distributed throughout the 24 hours. We used standard telemetry techniques to track skunks (White and Garrot 1990). Most (87%) locations were obtained using the Homing technique, which provides great precision (White and Garrot 1990). The remaining locations were obtained by triangulation (through the LOCATE II software; Nams 1990) of ≥ 3 bearings obtained with a 3-element hand-held yagi antenna and compass from points located through a GPS receiver. To minimize telemetry error, locations with a minimum angle of intersection < 60° or a maximum angle > 120° were discarded.

We used Ranges V (Kenward and Hodder 1996) software to estimate the sizes of skunk home ranges and core areas, as well as their percent overlap utilizing the Kernel estimator (Worton 1989). We calculated home ranges at 95% isopleths (henceforward 95% K) to avoid including excursions outside normally used area, while 45% isopleths were used to define core areas. We utilized fixed Kernel estimator because this method is superior to others to describe spatial use (Worton 1995, Seaman and Powell 1996).

Study of interactions

We first calculated the sizes of overlap areas between individual home ranges and core areas. Then we estimated the time spent by each individual in the portion of its home range overlapping with another animal using the percentage of locations in this area.

For the study of dynamic interactions, it is necessary to define the distance at which an individual is aware of the presence of a co-specific. While previous authors studying dynamic interactions adopted an arbitrary distance (Salvatori *et al.* 1999, Harrington and Macdonald 2008), we analyzed the frequency distribution of distances between individuals and observed a marked decrease at distances of less than 300 m. Over this base, we assumed that two skunks at less than 300 m are detecting one another, and we considered that two animals were "together" when the distance between them was < 300 m.

We adopted the period of two hours as a threshold between locations of two animals to assume them as contemporaneous, based on the analysis of the distances traveled during different time interval (D. Castillo, unpubl.). However, the mean time between locations was 1h 03', the time lapse between locations was less than one hour in 64.6% and less than 1h 30' in 80.4% of the cases.

We calculated the coefficient of spatial association, as the proportion of contemporaneous locations at distances < 300 m over all contemporaneous locations recorded for a pair of individuals (Ferreras *et al.* 1997).

We also computed the mean distance between two individuals in the pairs of contemporaneous locations and the mean distance considering all locations for each individual, then we compared these two values through the Jacob's Index (Kenward and Hodder 1996, Freer 2004), which takes positive values ($0 < J < 1$) when distances between two individuals are smaller than expected by chance (ie, they tend to be associated) and negative values ($-1 > J > 0$) when distances are greater than expected.

Finally, we analyzed distances between individuals in relation to their activity stage (active-inactive), and the variation of these distances over the study period.

Results

We radiotagged 8 adult skunks, but for the analyses of this paper we used only data from the four individuals (two males and two females) which were tracked simultaneously.

From October 2004 to October 2005, we collected an average (± SD) of 74.2 ± 22.8 locations per animal. Mean home range size was 109.1 ± 51.8 ha. On average, male home ranges were 2.3 times larger than female home ranges (Fig. 1).
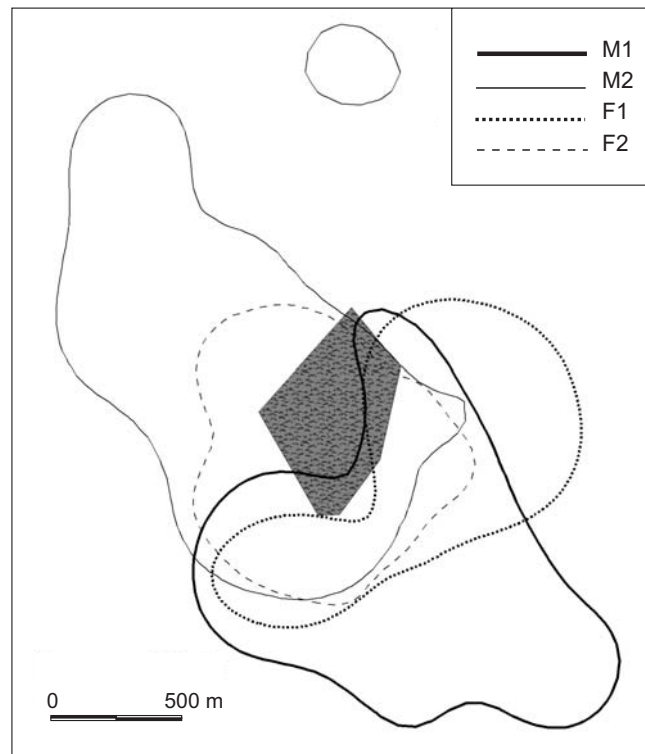

Fig. 1. Spatial distribution of home ranges (95% Kernel estimator) of 4 *C. chinga* individuals in the Pampas grassland of Argentina. The shaded polygon indicates the fenced area from which horses were excluded. F – female, M – male.

Mean home range overlap was 44.5% (Table 1). The home range of F1 was almost completely included in M2's. The two males shared a slightly more reduced proportion of their home ranges in comparison to females (Table 1). The average percentage of locations in the overlap area was 39.3%, but the time spent within the area of overlap ranged widely and was the greatest between F1 and M2, and minimum for the M2-F2 dyad (Table 2). Although this difference was not significant (Mann-Whitney U-test: $Z = -1.622$, $p = 0.106$), on average, in the overlap areas between individuals of different gender, we recorded 45.3% of the total locations while this proportion was only 27.5% for intrasexual pairs (Fig. 2, Table 2).

Core area overlap was extensive between F1 and M2, while it was more reduced for the other pairs. No overlap was recorded between females, as well as between F2 and M2 (Table 2).

To study dynamic interactions, we collected 213 pairs of simultaneous locations, 54 of them of 2 animals, 33 of 3, and 10 including 4 individuals. For simultaneous locations, the average distance (± SD) between males and females was 732.9 ± 428.9 m. Females were closer (mean distance between the two females: 541.1 ± 143.7 m) than males (1265.9 ± 579.3 m; Student t-test: $t = -8.2$, df = 62, $p = 0.001$). The distance did not vary with the activity stage for any type of dyad (female-female: $t = 0.64$, df = 2, $p = 0.29$; male-male: $t = -0.44$, df = 6, $p = 0.33$; male-female $t = 0.37$, df = 18, $p = 0.36$).

The average Coefficient of Spatial Association had a greater value in intersexual dyads

Table 1. Home range percent overlap matrix as obtained using the 95% Kernel estimator for 4 *C. chinga* individuals in the Pampas grassland of Argentina. F – female, M – male.

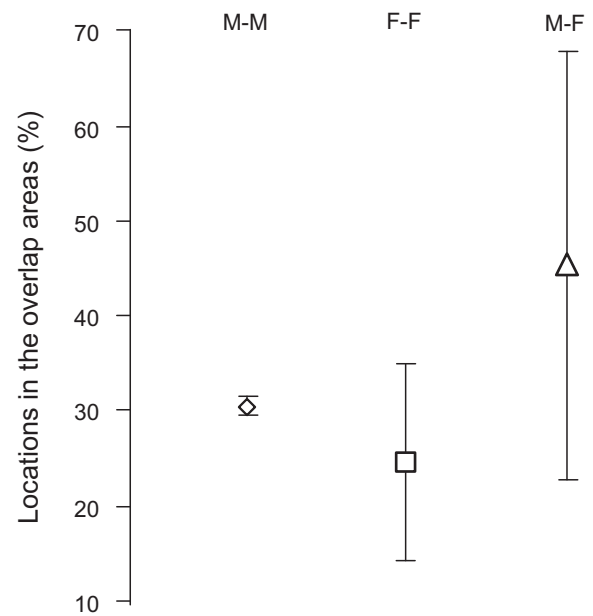| ID	M1	M2	F1	F2
M1	–	31.8	34.1	42
M2	26.7	–	46.8	18.9
F1	55.8	91.2	–	41.9
F2	67.7	36.2	41.2	–

Fig. 2. Average percentages (± SD) of locations in the overlap areas of home ranges (95% Kernel estimator) for intra and intersexual dyads of *C. chinga* in the Pampas grassland of Argentina. F – female, M – male.

Table 2. Matrix showing the percentages of locations in the overlap area between individual home ranges (HR), calculated with 95% K, and core areas (CA), calculated with 45% K, for 4 *C. chinga* individuals in the Pampas grassland of Argentina. F – female, M – male.

ID	M1		M2		F1		F2	
	HR	CA	HR	CA	HR	CA	HR	CA
M1	–	–	31	8.8	32	1.2	47	3.9
M2	29.9	10.3	–	–	53.7	38.6	7.5	0
F1	43.9	3.1	86.6	84.4	–	–	17.1	0
F2	55.3	8.9	36.2	0	31.9	0	–	–

Table 3. Matrix showing the Coefficient of Spatial Association (CSA) and Jacob´s index (Ji) values for the dynamic interactions between 4 *C. chinga* individuals in the Pampas grassland of Argentina. F: female; M: male.

ID	F2		M1		M2	
	CSA	Ji	CSA	Ji	CSA	Ji
M1	0.028	0.085	–	–	–	–
M2	0.036	0.033	0.019	–0.227	–	–
F1	0	0.149	0.295	0.574	0.235	–0.010
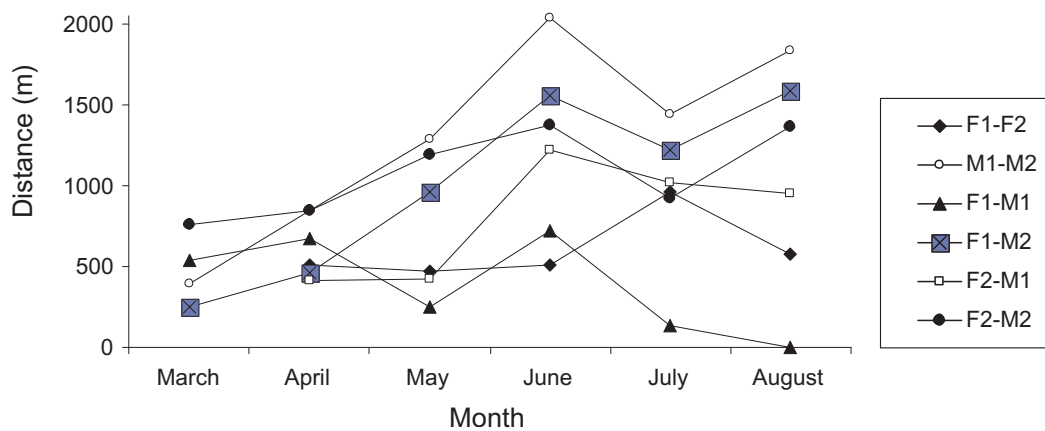
Fig. 3. Monthly variations of the distances between 4 individuals of *C. chinga*, in the Pampas grassland of Argentina. F – female, M – male.

(0.14) than for dyads of the same gender (0.02 between males and 0 between females, Table 3). The values of this coefficient were large for F1 with both males, whereas all other possible dyads spent less than 4% of their locations at less than 300 m of distance.

Mostly, Jacob's index values were close to 0, indicating neutral spatial association. The most negative value was between males (–0.23), while the index value of 0.57 for the M1-F1 dyad is suggestive of spatial association (Table 3).

Reciprocal distances between individuals varied over the time. All animals were relatively closer in March and April, and then their reciprocal distances increased, until reaching a peak in June, when the highest average distance between dyads was recorded. The distance between females seemed to be more constant than for the other dyads. It is interesting to observe that while the distance in the M1-F1 dyad decreased along the study period, the distance between F1 and M2 was gradually increasing (Fig. 3).

Discussion

In general, overlap between individual home ranges in the Molina's hog-nosed skunk in the Pampas grassland was wide. This was true even if we excluded the most external locations, which can possibly due to occasional excursions that increase the home range size of an animal, and, as a consequence, its overlap with other individuals. Furthermore, these areas of overlap did not represent marginal sections of individual home ranges, since they were used in a relatively intense form (collared animals spent 38–48% of their time there). The most solitary

carnivore species have reduced intrasexual home range overlap, in particular between females, whose reproductive success is mainly determined by the access to trophic resources (eg, Macdonald 1983, Sandell 1989). This spatial organization has been described as typical in the Mustelidae family (Powell 1979). However, it is expected that the home range overlap in a population of carnivores be also strongly affected by the dispersion of the main resources that they use (Kruuk and Macdonald 1985, Fournier *et al*. 2008). Molina's hog-nosed skunks feed mostly on insects (Travaini *et al*. 1998, Donadio *et al*. 2001), and this resource, being abundant and of quick renovation, can favor a greater overlap among individual home ranges (Johnson *et al*. 2000).

Home range overlap in our sample of individuals was larger intersexually than intrasexually. This result, together with a bigger home range size in males, is in accordance with expectations, since mustelid males usually try to expand their territories to increase their chances of accessing to a greater number of females (Powell 1979). This explanation is also supported by the fact that the average overlap of male home ranges with females was 32–39%, a proportion that would enable each male to overlap its action area with three females.

Also the study of the percentage of locations in the overlap areas among home ranges showed that their importance was greater for the female-male dyads than for intrasexual dyads. The last aspect studied by static interactions was core area overlap. As it can be expected for solitary species, we found a null or very reduced overlap in core areas for most radiotracked skunk dyads. Nevertheless, we also observed a comparatively wide overlap between M2 and F1, and also a certain degree of overlap between the two males. The explanations of these two cases are probably different. While the intersexual overlap of M2 and F1 could be due to the formation of a reproductive pair, for the other dyad a possible explanation is that the overlap area is inside or near the horse exclusion area, a patch where food was probably very abundant because grassland is in better conditions and supported a greater richness and abundance of arthropods (D. Castillo, unpubl.). A similar behaviour was reported by Bixler and Gittleman (2000) for striped skunks *Mephitis mephitis* in a campground/picnic area where people fed them. However, we are aware that other possible explanations cannot be ruled out. In particular, our study did not include genetic analysis of the individuals and therefore does not allow us to make conclusions on the specific role of kinship in the interactions we observed.

In any case, our results confirm that an analysis of home range overlap cannot be considered complete if the dynamic interactions among individuals have not been studied, because this is the information that we need in order to understand whether the animals who share parts of their home ranges try to reduce contacts, or not. The Coefficient of Spatial Association confirmed that, in general, Molina's hog-nosed skunks of different sexes tended to spend more time at small distances than individuals of the same sex. On the other hand, it allowed detecting differences between F1, who spent a lot of time in proximity of both males, and F2, who was rarely "together" with the males. Jacob's Index is a further refinement of this analysis, and in our case, showed that F1 was only spatially associated to M1 and not to M2, in contrast with what suggested by the static interaction analysis. In agreement with this result, the mean distance between F1 and M1 was smaller than that recorded for the dyad F1-M2. This index also indicates that the two males, in spite of their extensive overlap in home ranges, are unfrequently spatially associated.

Finally, it is interesting to notice that the average distance between radiotagged skunks could vary markedly over time. This kind of observations should discourage researchers from analyzing and interpreting interindividual interactions as a static phenomenon.

Our sample size (in term of number of locations, and, especially, of individuals tracked) prevents us from drawing definitive conclusions about the social organization of *C. chinga*. The presence of other individuals in the area used by the four radiotracked animals, proved by captures and direct observations, could also possibly change the picture obtained by this study.

Even if these limitations cannot be overlooked, we can conclude that our data for *C. chinga*, suggesting stronger intrasexual than intersexual territoriality and a greater tolerance between females than males, are in agreement with the pattern of social organization described in the literature as typical for mustelids and mephitids, particularly if the availability of their typical food sources is accounted for. However, they also confirmed that it is difficult to reduce the complexity and flexibility in the strategies for resource use to fixed schemes (Johnson *et al*. 2000), especially when individuals are used as sampling units. Finally, we suggest that the analysis of dynamic interactions is clearly a fundamental tool to improve our understanding of social behavior since (as in our case) they can potentially give a different view of this complex aspect of vertebrate ecology than that provided by static interaction studies and that more effort should be devoted at developing standardize protocols of study of dynamic interactions enabling direct comparisons among studies and species.

References

Bixler A. and Gittleman J. L. 2000. Variation in home range size and habitat use in the Striped Skunk (*Mephitis mephitis*). Journal of Zoology, London 251: 525–533.

Cabrera A. L. 1976. Regiones Fitogeográficas Argentinas/ Enciclopedia Argentina de Agricultura y Jardinería, Tomo 2, Fascículo 1. Acmé Editorial Buenos Aires: 1–85.

Donadio E., Di Martino S., Aubone M. and Novaro A. J. 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.

Doncaster C. P. and Macdonald D. W. 1997. Activity patterns and interactions of red foxes (*Vulpes vulpes*) in Oxford city. Journal of Zoology, London 241: 73–87.

Eisenberg J. 1986. Life history strategies of the Felidae: variations on a common theme. [In: Cats of the world: biology, conservation and management. S. D. Miller and D. D. Everett, eds]. National Wildlife Federation, Washington, D.C.: 293–303.

Ferreras P., Beltrán J. F., Aldama J. I. and Delibes M. 1997. Spatial organization and land tenure system of the endangered Iberian Lynx (*Lynx pardinus*). Journal of Zoology, London 243: 163–189.

Fournier P., Maizeret C., Fournier-Chambrillon C., Ilbert N., Aulagnier S. and Spitz F. 2008. Spatial behaviour of European mink *Mustela lutreola* and polecat *Mustela putorius* in southwestern France. Acta Theriologica 53: 343–354.

Frangi J. L and Bottino O. J. 1995. Comunidades vegetales de la Sierra de la Ventana, provincia de Buenos Aires, Argentina. Revista Facultad Agraria La Plata 71: 93–133.

Freer R. A. 2004. The spatial ecology of the Güiña (*Oncifelis guigna*) in Southern Chile. PhD thesis, University of Durham, Durham: 1–219.

Gittleman J. L. and Harvey P. H. 1982. Carnivore home--range size, metabolic needs and ecology. Behavioural Ecology and Sociobiology 10: 57–63.

Harrington L. A. and Macdonald D. W. 2008. Spatial and temporal relationship between invasive American mink and native European polecats in southern United Kingdom. Journal of Mammalogy 89: 991–1000.

Johnson D. D. P., Macdonald D. W. and Dickman A. J. 2000. An analysis and review of models of the sociobiology of the *Mustelidae*. Mammal Review 30: 171–196.

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

Kruuk H. and Macdonald D. W. 1985. Group territories of carnivores: empires and enclaves. [In: Behavioral ecology. R. M. Sibly and R. H Smith, eds]. Blackwell Scientific Publications, Oxford: 531–536.

Luengos Vidal E., Lucherini M. and Casanave E. 2003. An evaluation of three live traps for capturing Pampas fox. Canid News 6: 1–9.

Macdonald D. W. 1983. The ecology of carnivore social behavior. Nature 301: 379–384.

Nams V. 1990. Locate II user's guide. Pacer Computer Software, Truro, Nova Scotia, Canada.

Powell R. A. 1979. Mustelid spacing patterns: variations on a theme by *Mustela*. Zeitschrift für Tierpsychologie 50: 153–165.

Powell R. A. 2000. Animal home ranges and territories and home range estimation. [In: Research techniques in animal ecology. Controversies and consequences. L. Boitani and T. K. Fuller, eds]. Columbia University Press, New York: 65–110.

Redford K. and Eisenberg J. F. 1992. Mammals of the Neotropics. The Southern Cone. Vol II. Chicago University. Press, Chicago: 1–430.

Rogers L. L. 1977. Social relationships, movements, and populations dynamics of black bears in Northeastern Minnesota. PhD thesis, University of Minnesota, Minneapolis: 1–194.

Rosatte R. and Lariviere S. 2003. Skunks. [In: Wild mammals of North America: Biology, management and conservation. G. Fledhamer, B. C. Thompson and J. A. Chapman, eds]. John Hopkins University Press, Baltimore, Maryland: 692–707.

Salvatori V., Vaglio-Laurin G., Meserve P. L., Boitani L. and Campanella A. 1999. Spatial Organization, Activity, and Social Interactions of Culpeo Foxes (*Pseudalopex culpaeus*) in North-Central Chile. Journal of Mammalogy 80: 980–985.

Sandell M. 1989. The mating tactics and spacing patterns of solitary carnivores. [In: Carnivore behavior, ecology, and evolution. Vol. 1. J. L. Gittleman, ed]. Cornell University Press, Cornell, N.Y.: 164–182.

Seaman D. F. and Powel R. A. 1996. An evaluation of the accuracy of Kernel density estimators for home range analysis. Ecology 77: 2075–2085.

Travaini A., Delibes M. and Ceballos O. 1998. Summer foods of the Andean hog-nosed skunk (*Conepatus chinga*) in Patagonia. Journal of Zoology, London 246: 457–460.

USAID (ed). Biodiversity Support Program, Conservation International, The Nature Conservancy, Wildlife Conservation Society, World Resource Institute, and World Wildlife Fund 1995. A regional analysis of geographic priorities for biodiversity conservation in Latin America and the Caribbean. Biodiversity Support Program, Washington, D.C.: 1–55.

White G. C and Garrot R. A., 1990. Analysis of wildlife radiotracking data. Academic Press, New York: 1–383.

Worton B. J. 1989. Kernel methods for estimating the utilization distribution in home-ranges studies. Ecology 70: 164–168.

Worton B. J. 1995. Using Monte Carlo simulation to evaluate Kernel based home range estimators. The Journal of Wildlife Management 59: 794–800.

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