

Corn mice (*Calomys musculinus*) movement in linear habitats of agricultural ecosystems

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Movement patterns of *Calomys musculinus* in linear habitats were studied in relation to sex, season, year, abundance, and width of border. Movement distances (MDs) were measured by seasonal capture, mark, and recapture samples during 2 years in wide and narrow borders in agroecosystems. The smallest MDs were registered in autumn and the highest in spring. In the breeding period MDs of males were larger than those of females. In the nonbreeding period MDs were similar between sexes. Effects of sex on MD were consistent with the promiscuous mating system of *C. musculinus*. MDs were greater in narrow than in wide borders. The narrowness of suitable habitats would force the mice to extend foraging trips in narrow borders. Opportunistic behavior of *C. musculinus* allows it to use linear habitats in a similar way to the 2-dimensional natural habitats. DOI: 10.1644/09-MAMM-A-232.1.

Key words: Argentina agricultural ecosystems, border habitats, corn mice, edges, generalized linear mixed models, movement distances

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Fragmentation of natural landscapes as a result of agriculture, increasing urbanization, and other human activities is a current global concern. Many spatial parameters are involved in these landscape changes, including the composition (e.g., habitat patches), spatial configuration (e.g., fragmentation and isolation), and shape (geometry) of landscape elements (Forman 1995; Forman and Godron 1986; Kareiva and Wennergren 1995). Habitat remnants persist as linear strips along rivers, property borders, roads, and railways as a consequence of large areas of continuous wildlife habitats (e.g., forest and grassland areas) that are converted to urban and agricultural areas (Forman 1995). Wildlife species are restricted to such linear habitats in many heavily altered landscapes. Therefore, the functioning of populations in linear as opposed to 2-dimensional habitat area has become a concern in environmental management (Bennett 1990; Fauske et al. 1997; Hobbs 1992), with the emphasis on the role of linear habitats as dispersal corridors (Bennett 1990; Forman and Godron 1986). However, linear habitat structures also may contain potential resources for long-term survival and reproduction (Fauske et al. 1997). Thus, these habitats play a role as buffer zones where width and vegetation height in relation to surrounding habitats determine the attractiveness

of these zones to herbivores and the extent to which permanent populations can exist (Yletyinen and Norrdahl 2008).

One of the most important consequences of agricultural ecosystem development is fragmentation by roads. Roads act as barriers to small mammal movements (Cittadino et al. 1998; Clarke et al. 2001; Garland and Bradley 1984; Kozel and Fleharty 1979; Mader 1984; Oxley et al. 1974; Swihart and Slade 1984). These barriers can affect the colonization of habitat patches and consequently population persistence (Kozakiewicz 1993).

Agricultural ecosystems in central Argentina consist of a matrix of crop areas (corn, soybean, sunflower, wheat, and flax) surrounded by a network of roadsides and fencelines, railways, and other edge habitats that support a plant community with some remnants of native flora and many introduced weeds that provide a more stable cover than crop fields (Bonaventura and Cagnoni 1995; Busch et al. 1997, 2000). These noncrop linear areas provide habitat for a variety of small mammal species and their predators, including birds of prey. One of the most abundant species in these habitats is



the corn mouse, *Calomys musculinus* (Cricetidae: Sigmodontinae). This species has been studied mainly for its role as a reservoir of Junin virus, an etiologic agent of Argentine hemorrhagic fever (Mills and Childs 1998). *C. musculinus* can live in a variety of habitats including natural pastures, crop fields, cultivated fields undisturbed after harvest, border areas protected by wire fences with little agricultural disturbance, road borders, borders between cultivated fields or pastures, and railway banks (Busch et al. 2000; Castillo et al. 2003). Individuals live primarily in border habitats, and they use crop fields only with high weed cover and density of vertical vegetation (Ellis et al. 1997). However, at present, weed cover is almost nonexistent in crop fields due to the increasing use of agrochemicals (Bilenca et al. 2007). Populations of *C. musculinus* are characterized by seasonal density changes, with low density during winter (16 individuals/ha) and peaks during late summer or early autumn (260 individuals/ha); a 1:1 sex ratio is usual (Mills and Childs 1998). The reproductive period has an average length of 8 months (from mid-September to April—Mills and Childs 1998).

In studies performed in natural grasslands (2-dimensional habitat), *C. musculinus* has a promiscuous mating system; females typically mate with more than 1 male during each estrous period (Steinmann et al. 2009). During the breeding period females keep exclusive home ranges and are territorial, whereas males have home ranges that are more than twice as large as those of females and are shared fully with both sexes. In the nonbreeding period male and female home-range sizes are similar (Steinmann et al. 2005, 2009).

Calomys musculinus is one of the most abundant species in linear habitats, and it shows a wider habitat and trophic niche than other coexisting rodent species in rural habitat (Busch et al. 2000). Its space-use pattern has been studied principally in 2-dimensional habitats (Steinmann et al. 2005, 2006a, 2006b). The aim of our study was to explore movement patterns of *C. musculinus* in linear habitats of agricultural ecosystems in central Argentina. The following questions were addressed: Do males have higher movement distances (MDs) than females? Do MDs depend on the reproductive period? Does the width of linear habitat (border) affect MDs of mice? Do rural roads act as barriers to movement by *C. musculinus*?

MATERIALS AND METHODS

Field methods.—This study was carried out from November 2005 to August 2007 in linear habitats of agricultural ecosystems in Río Cuarto Department (Córdoba Province, Argentina). Phytogeographically, this region corresponds to “Provincia del Espinal, Distrito del Algarrobo” (Cabrera 1953), which is a low-elevation plain (600–900 m) with vegetation dominated by algarrobo (*Prosopis alba* and *P. nigra*), accompanied by quebracho blanco (*Aspidosperma quebracho-blanco*), mistol (*Zizyphus mistol*), and itin (*Portulaca kuntzie*). However, the vegetation has undergone marked alterations as a result of agriculture and cattle farming. At present, the landscape consists mainly of individual crop fields

surrounded by wire fences, with borders dominated by weedy species. Despite the influence of crop fields, borders have a homogeneous plant cover of about 85% throughout the year and a high availability of seed in soil (Priotto et al. 2002).

Four sampling transects located in field borders were used as study sites, 1 placed in a wide border (range of width: 10–30 m; transect A) and 3 placed in narrow borders (≤ 2 m; transects B, C, and D). Sampling transects were set up on opposite sides of 7-m-wide secondary roads (A opposite to B; C opposite to D). Each transect was composed of 300-m traplines with 30 traps similar to Sherman live traps. Traplines were separated by 500 m. Transects A and B each had 4 traplines (A1, A2, A3, A4, B1, B2, B3, and B4) and transects C and D each had 2 traplines (C1, C2, D1, and D2; Fig. 1). Seasonal samplings were carried out during 2 consecutive years. Capture, mark, and recapture trapping sessions were conducted for 5 consecutive days in November (spring), March (summer), May (autumn), and July–August (winter). Trapped animals were weighed and marked with self-piercing ear tags with numerical codes (National Band & Tag Company, Newport, Kentucky). Sex and reproductive state (males: scrotal or abdominal testes; females: perforated or imperforated vulva, evidence of pregnancy, nipples visible or not) also were recorded. Small pieces of the tail tip were taken and preserved in ethanol for other studies that include DNA analyses. Research on live animals was performed in a humane manner and followed guidelines for the care and use of animals approved by the American Society of Mammalogists (Gannon et al. 2007).

We calculated the largest MD among capture points of an individual captured at least twice during a trapping session. MD was considered to provide an index of home-range size (Gaines and Johnson 1982; Pusenius and Viitala 1995). Because of small sample sizes for juveniles, all analyses used only adult males and females.

Data analysis.—The primary focus of this study was to investigate the influence of sex, season, and year on MDs of *C. musculinus* in linear habitats. We also tested for the effects of an abundance index as a covariate because this variable could potentially influence MDs. Subsequently we analyzed the effect of border width on MDs, considering separately those individuals captured in wide and narrow borders.

Because distance measurements are likely to be nonnormal, a generalized linear mixed model with negative binomial distribution in R 2.9.0 software (R Development Core Team 2009; www.r-project.org) was used to identify the factors that determined MDs. We used repeated-measure analysis. The repeated measures were transects (in each transect individual MDs were registered in 3 seasons and 2 years). Individuals were not considered as repeated measures because we recorded no MDs of the same individual in different seasons and years. The Akaike information criterion, corrected for small sample size (AIC_c), was used as a measure of the fit of a model (the smaller the AIC_c, the better the fit—Burnham and Anderson 1998). Because we wanted to identify the effect of abundance, season, and sex on MDs, we considered sex,

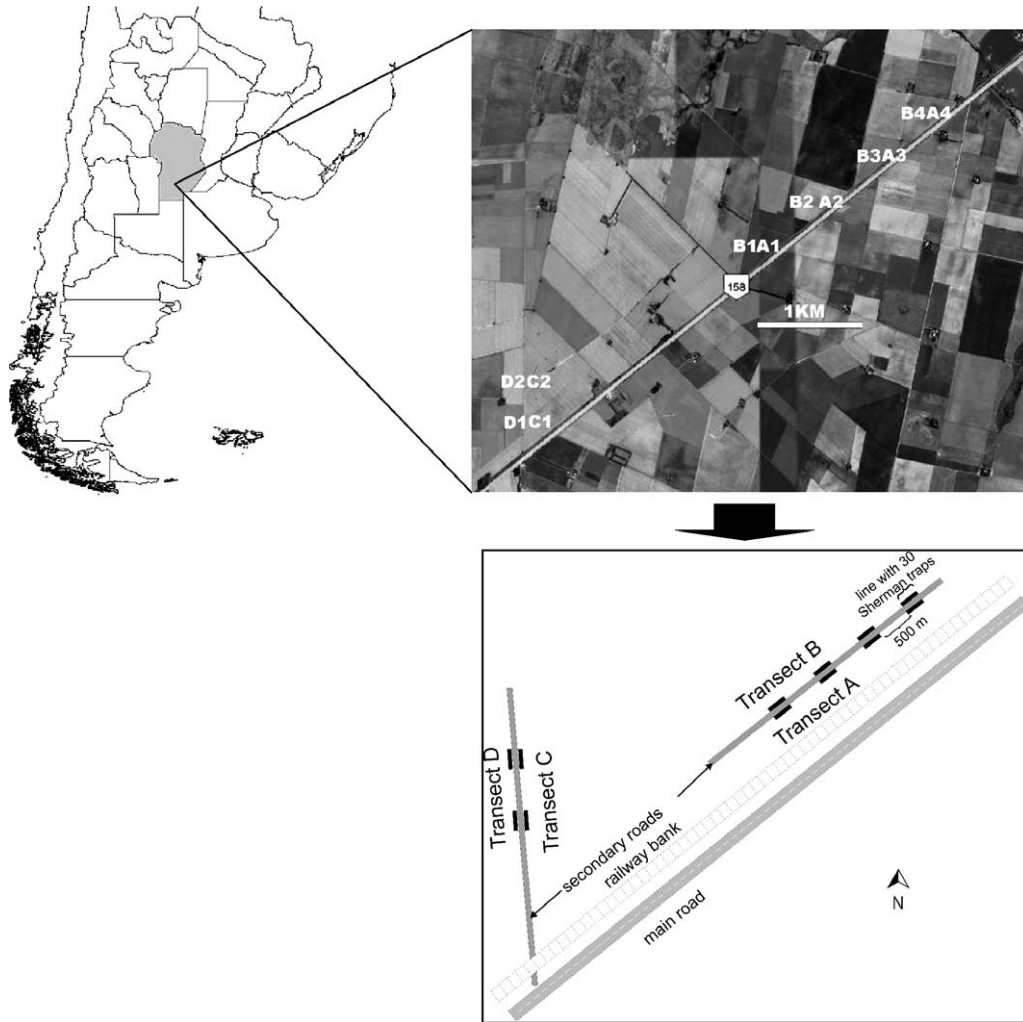


FIG. 1.—Distribution and schema of transects studied across an agricultural ecosystem in Río Cuarto Department (Córdoba Province, Argentina). From 2009 Map Link/Tele Atlas (<http://earth.google.es/>). Fig. 1 is reprinted from Gomez et al. (in press).

season, abundance, and year as main effects and their 2-way interactions. Seasonal analyses of MDs were based on the following categories: spring (November), summer (March), and autumn (May). Winters were discarded from statistical analyses because few MDs could be calculated during the 1st winter, and borders were burned during the 2nd one. The low number of recaptures for each individual did not allow us to obtain reliable results in the abundance estimations using capture, mark, and recapture analysis. For this reason the number of individuals captured in the line where each MD was calculated was used as an index of abundance.

RESULTS

From November 2005 to August 2007 we obtained 1,152 captures of 808 individual *C. musculus*. We ear-tagged 412 females and 396 males. The abundance index for *C. musculus* was greater during the 2nd year, and the mean number of individuals varied among seasons, with a peak in summer and a minimum in winter (Fig. 2).

A total of 82 and 97 MDs were calculated for females and males, respectively. Individuals moved within the limits of

each line; we observed no long-distance movements (among lines within a transect). This species was reluctant to cross roads; only 8 (4 males and 4 females) marked individuals crossed roads. Generalized linear mixed model analysis based

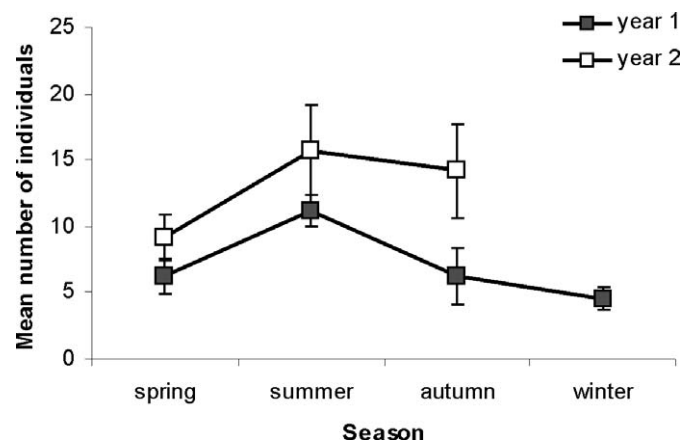


FIG. 2.—Number of individuals ($\bar{X} \pm SE$) of *Calomys musculus* by season and year in linear habitats.

TABLE 1.—Analysis for the generalized linear mixed model describing movement distances of *Calomys musculus*. The best model is indicated in boldface type.

Variable	AIC _c	ΔAIC _c	No. parameters	Deviance
Season × sex	1,327.994	0.000	7	1,313.994
Season	1,330.768	2.774	4	1,322.768
Season + sex	1,330.806	2.812	5	1,320.806
Season + year	1,332.230	4.236	5	1,322.230
Abundance + sex	1,332.622	4.628	4	1,324.622
Abundance × sex	1,332.962	4.968	5	1,322.962
Abundance	1,335.122	7.128	3	1,329.122
Season × year	1,335.608	7.614	7	1,321.608
Sex	1,337.746	9.752	3	1,331.746
Year	1,340.744	12.750	3	1,334.744

on AIC_c revealed that sex and season were the most important factors affecting MDs. AIC_c never decreased in any model that included abundance or year with or without interactions (Table 1). The best model included the interaction between sex and season (Table 2). The greatest MDs for both sexes were in spring. Male movements were larger than those of females in spring and summer, whereas the opposite pattern was observed in autumn (Fig. 3). In spite of these divergences, only the difference between spring and autumn was statistically significant (Table 2). Having examined the effect of sex, season, and year, we investigated the effect of border width on MDs using the same analysis. Because of the low number of MDs obtained from the single wide transect (A) we could not include width in the previous analysis. For this reason we performed other analyses including width, season, and sex as predictors. We included only seasons with high numbers of individuals (spring and summer). MDs were greater in the narrow than in the wide border, and AIC_c was lower in the model including width. However, the coefficient for border width was not statistically significant: β (SE) = 0.531 (0.29); $z = 1.804$, $P = 0.071$ (Fig. 4).

TABLE 2.—Coefficients (β) for the best model of generalized linear mixed model analysis of movement distances of *Calomys musculus*. Standard errors (in parentheses) and the significance of the coefficients also are shown; $P < 0.05$ shown in boldface type. The effect of each term in the model is tested. P -values tested the null hypothesis that $\beta = 0$. The terms with $P < 0.05$ have some discernable effect. Because an intercept term exists, the 3rd level of season (spring) and the 2nd of sex (male) are redundant. The estimates for the first 2 levels contrast the effects of the first 2 seasons to the 3rd, and the estimates for the females contrast their effects to males.

Factors	β (SE)	z	P -value
Intercept	3.443 (0.23)	0.148	0.000
Summer	-0.306 (0.36)	-0.846	0.398
Autumn	-2.028 (0.46)	-4.280	0.000
Female	-0.337 (0.37)	-0.979	0.328
Summer × female	-0.522 (0.52)	-0.966	0.334
Autumn × female	1.407 (0.74)	1.788	0.074

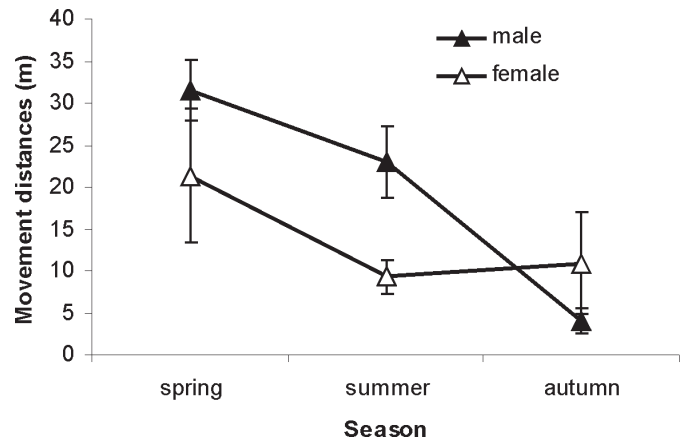


FIG. 3.—Seasonal movement distances ($\bar{X} \pm SE$) of male and female *Calomys musculus* in linear habitats.

DISCUSSION

Generally home-range size is regarded as 1 indicator of habitat quality (Tufto et al. 1996). Because lengths of movements are a good index of home-range size in small mammals (Slade and Russell 1998), and length of foraging trips affects both the energetic cost of food acquisition and the risk to be predated (Banks et al. 2000; Norrdahl and Korpimäki 1998; Yletyinen and Norrdahl 2008), MDs can be used as indicators of habitat quality. Habitat quality is affected heavily by the shape of habitat patch because this affects width and length of a given habitat area; the length increases as the habitat becomes more linear. Habitat quality would increase in relation to habitat width because natural 2-dimensional habitats have higher quality than crop borders of agricultural ecosystems (1-dimensional habitats).

The factors that influenced the movement patterns of *C. musculus* in linear habitats were similar to those observed in 2-dimensional habitats (grasslands) by de Villafañe and Bonaventura (1987) and Steinmann et al. (2005). MDs varied seasonally, being smallest in autumn and highest in spring. They were determined mainly by sex and reproduction. The

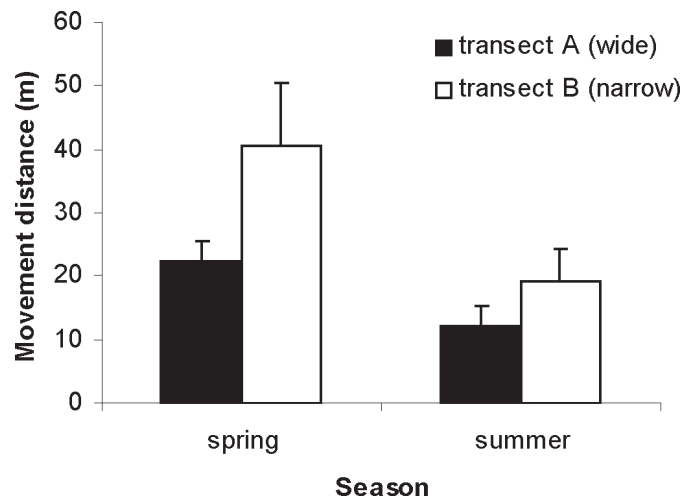


FIG. 4.—Movement distances ($\bar{X} \pm SE$) of *Calomys musculus* in wide and narrow linear habitats.

autumn trapping session was conducted in May, the nonbreeding period, when the 1st frosts were registered. Cold periods are energetically demanding for small mammals, and energetic costs can be reduced by restricting to a minimum the movement activities outside the insulated nest (Yletyinen and Norrdahl 2008). During the breeding period MDs of males were larger than those of females, whereas in the nonbreeding period MDs were similar between sexes. Main effects of sex on MDs of *C. musculus* were consistent with the promiscuous mating system of the species. In promiscuous rodents longer MDs of males reflect a strategy that maximizes access to fertile females, whereas lower movements of females reveal territorial behavior directed at protection of nestlings from infanticidal females (Bond and Wolff 1999; Steinmann et al. 2005, 2009; Wolff and Peterson 1998) or defense of food resources (Ims 1987; Ostfeld 1985, 1990). During the breeding period differences in MDs between spring and summer can be explained by spacing behaviors of males and females. At low population densities (spring) many vacant areas exist in borders where females can establish sparse and exclusive reproductive spaces. Thus, larger MDs of males would be in relation to an active search for estrous females. Meanwhile, in summer (high population densities) few vacant areas are found in borders because all spaces are occupied by estrous females. Thus, MDs of males searching for females would be diminished.

Taking into account that the length of movement can be considered an index of habitat quality in relation to energetic costs of food acquisition and predation risk (Banks et al. 2000; Norrdahl and Korpimäki 1998; Yletyinen and Norrdahl 2008), longer MDs of mice in narrow borders than in wide borders indicate that the latter were better habitats for *C. musculus*. Because mice reside mainly in borders, the narrowness of suitable habitat could force mice to extend foraging trips in narrow borders whereas in wide borders movements in several directions are possible. Similar results were found for *Microtus agrestis* in agricultural ecosystems of Finland (Yletyinen and Norrdahl 2008). However, the movement pattern related to habitat shape is not clear in *C. musculus*. MDs in 2-dimensional habitats (30 m on average—de Villafañe and Bonaventura 1987; Steinmann et al. 2005) are similar to those observed in narrow borders in our study, which was characterized by fewer recaptures per individuals. Movement length could be used as an indicator of quality in linear habitats, but it could not allow us to differentiate between 1- and 2-dimensional habitats. Future research should use similar methodologies to evaluate the effect of habitat shape (1- versus 2-dimensional habitats) in movement length.

Roads acted as barriers to movements of *C. musculus*, as observed in many other small mammal species (Cittadino et al. 1998; Clarke et al. 2001; Garland and Bradley 1984; Kozel and Fleharty 1979; Mader 1984; Oxley et al. 1974; Swihart and Slade 1984). Mice would be averse to crossing areas without cover to avoid predation (Cittadino et al. 1998; Sheffield et al. 2001).

Ecological changes, together with the agricultural development of the Pampa Humeda, have favored *C. musculus* because this species is captured in higher proportion in the current rodent

assemblage than it was in the undisturbed original grassland assemblage (Bilenca and Kravetz 1995; Crespo 1966). This is because *C. musculus* has a wider habitat and trophic niche than other coexisting rodent species in agrarian systems of central Argentina (Busch et al. 2000). The opportunistic behavior of this species allows it to use linear habitats in a similar way to 2-dimensional natural habitats.

RESUMEN

Se estudiaron los patrones de movimiento de *Calomys musculus* en hábitat lineales en relación al sexo, la estación, el año, la abundancia y el ancho del borde. Las distancias de movimiento (DM) fueron registradas a través de muestreos estacionales de captura marcado y recaptura durante 2 años en bordes anchos y angostos de agroecosistemas. Las menores DM fueron registradas en otoño y las mayores en primavera. En el periodo reproductivo las DM de los machos fueron mayores que las de las hembras. Las DM fueron similares entre sexos en el periodo no reproductivo. El efecto del sexo sobre las DM es consistente con el sistema de apareamiento promiscuo de *C. musculus*. Las DM fueron mayores en los bordes angostos que en los anchos. La estrechez de los hábitats adecuados forzaría a los ratones a extender los viajes de forrajeo en los bordes angostos. El comportamiento oportunista de *C. musculus* le permite utilizar los hábitats lineales de una manera similar a los hábitats naturales bidimensionales.

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LITERATURE CITED

- BANKS, P., K. NORRDAHL, AND E. KORPIMÄKI. 2000. Nonlinearity in the predation risk of vole mobility. *Proceedings of the Royal Society of London, B. Biological Sciences* 267:1621–1625.
- BENNETT, A. 1990. Habitat corridors and the conservation of small mammals in a fragmented forest environment. *Landscape Ecology* 4:109–122.
- BILENCA, D. N., C. M. GONZALEZ-FISCHER, P. TETA, AND M. ZAMERO. 2007. Agricultural intensification and small mammal assemblages in agroecosystems of the Rolling Pampas, central Argentina. *Agriculture, Ecosystems and Environment* 121:371–375.
- BILENCA, D. N., AND F. O. KRAVETZ. 1995. Patrones de abundancia relativa en ensambles de pequeños roedores de la Región Pampeana. *Ecología Austral* 5:21–30.
- BONAVENTURA, S. M., AND M. CAGNONI. 1995. La vegetación de los bordes de caminos en agroecosistemas. *Physis (Buenos Aires Sección C)* 50:63–71.
- BOND, M. L., AND J. O. WOLFF. 1999. Does access to females or competition among males limit male home-range size in a promiscuous rodent? *Journal of Mammalogy* 80:1243–1250.

- BURNHAM, K. P., AND D. R. ANDERSON. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York.
- BUSCH, M., M. R. ALVAREZ, E. A. CITTADINO, AND F. O. KRAVETZ. 1997. Habitat selection and interspecific competition in rodents in pampean agroecosystems. *Mammalia* 61:167–184.
- BUSCH, M., M. MIÑO, J. R. DADON, AND K. HODARA. 2000. Habitat selection by *Calomys musculus* (Muridae, Sigmodontinae) in crop areas of the pampean region, Argentina. *Ecología Austral* 10:15–26.
- CABRERA, A. 1953. Esquema fitogeográfico de la República Argentina. *Revista Museo de La Plata, Botánica* 8:87–168.
- CASTILLO, E., ET AL. 2003. Commensal and wild rodents in an urban area of Argentina. *International Biodeterioration and Biodegradation* 52:135–141.
- CITTADINO, E. A., M. BUSCH, AND F. O. KRAVETZ. 1998. Population abundance and dispersal in *Akodon azarae* (pampa grassland mouse) in Argentina. *Canadian Journal of Zoology* 76:1011–1018.
- CLARKE, B. K., B. S. CLARKE, L. A. JOHNSON, AND M. T. HAYNIE. 2001. Influence of roads on movement of small mammals. *Southwestern Naturalist* 46:338–344.
- CRESPO, J. A. 1966. Ecología de una comunidad de roedores silvestres en el partido de Rojas, provincia de Buenos Aires. *Revista del Museo Argentino de Ciencias Naturales e Instituto Nacional de Investigación en Ciencias Naturales, Ecología* 1:79–134.
- DE VILLAFANE, G., AND S. M. BONAVENTURA. 1987. Ecological studies in crop fields of the endemic area of Argentine hemorrhagic fever. *Calomys musculus* movements in relation to habitat and abundance. *Mammalia* 51:233–248.
- ELLIS, B., ET AL. 1997. Structure and floristics of habitats associated with five rodent species in an agroecosystem in central Argentina. *Journal of Zoology (London)* 243:437–460.
- FAUSKE, J., H. P. ANDREASSEN, AND R. A. IMS. 1997. Spatial organization of the root vole *Microtus oeconomus* in linear habitat. *Acta Theriologica* 42:79–90.
- FORMAN, R. T. T. 1995. *Land mosaics*. Cambridge University Press, Cambridge, United Kingdom.
- FORMAN, R. T. T., AND M. GODRON. 1986. *Landscape ecology*. John Wiley & Sons, Inc., New York.
- GAINES, M. S., AND M. L. JOHNSON. 1982. Home range size and population dynamics in the prairie vole, *Microtus ochrogaster*. *Oikos* 39:63–70.
- GANNON, W. L., R. S. SIKES, AND THE ANIMAL CARE AND USE COMMITTEE OF THE AMERICAN SOCIETY OF MAMMALOGISTS. 2007. Guidelines of the American Society of Mammalogists for the use of wild mammals in research. *Journal of Mammalogy* 88:809–823.
- GARLAND, T., JR., AND W. G. BRADLEY. 1984. Effects of a highway on Mojave Desert rodent populations. *American Midland Naturalist* 111:47–56.
- GOMEZ, D., L. SOMMARO, A. STEINMANN, M. CHIAPERRO, AND J. PRIOTTO. In press. Movement distances of two species of sympatric rodents in linear habitats of Central Argentine agro-ecosystems. *Mammalian Biology*.
- HOBBS, R. J. 1992. The role of corridors in conservation: solution or bandwagon? *Trends in Ecology & Evolution* 7:389–392.
- IMS, R. A. 1987. Responses in spatial organization and behaviour to manipulations of the food resource in the vole *Clethrionomys rufocanus*. *Journal of Animal Ecology* 56:585–596.
- KAREIVA, P., AND U. WENNERGREN. 1995. Connecting landscape patterns to ecosystem and population processes. *Nature* 373:299–302.
- KOZAKIEWICZ, M. 1993. Habitat isolation and ecological barriers—the effect on small mammal populations and communities. *Acta Theriologica* 38:1–30.
- KOZEL, R. M., AND E. D. FLEHARTY. 1979. Movements of rodents across roads. *Southwestern Naturalist* 24:239–248.
- MADER, H. J. 1984. Animal habitat isolation by roads and agricultural fields. *Biological Conservation* 29:81–96.
- MILLS, J. N., AND J. E. CHILDS. 1998. Ecologic studies of rodent reservoirs: their relevance for human health. *Emerging Infectious Diseases* 4:529–537.
- NORRDAHL, K., AND E. KORPIMÄKI. 1998. Does mobility or sex of voles affect risk of predation by mammalian predators? *Ecology* 79:226–232.
- OSTFELD, R. S. 1985. Limiting resources and territoriality in microtine rodents. *American Naturalist* 126:1–15.
- OSTFELD, R. S. 1990. The ecology of territoriality in small mammal. *Trends in Ecology & Evolution* 5:411–415.
- OXLEY, D. J., M. D. FANTON, AND G. D. CARMODY. 1974. The effects of roads on populations of small mammals. *Journal of Applied Ecology* 11:51–59.
- PRIOTTO, J., A. STEINMANN, AND J. POLOP. 2002. Factor affecting home range size and overlap in *Calomys venustus* (Muridae: Sigmodontinae) in Argentine agroecosystems. *Mammalian Biology* 67:97–104.
- PUSENIUS, J., AND J. VIITALA. 1995. Familiarity of breeding field vole (*Microtus agrestis*) females does not affect their space use and demography of the population. *Annales Zoologici Fennici* 32:217–223.
- SHEFFIELD, L. M., C. R. CRAIT, W. D. EDGE, AND G. WANG. 2001. Response of American kestrels and gray-tailed voles to vegetation height and supplemental perches. *Canadian Journal of Zoology* 79:380–385.
- SLADE, N. A., AND L. A. RUSSELL. 1998. Distances as indices to movements and home-range size from trapping records of small mammals. *Journal of Mammalogy* 79:346–351.
- STEINMANN, A. R., J. PRIOTTO, E. CASTILLO, AND J. POLOP. 2005. Size and overlap of home range in *Calomys musculus* (Muridae: Sigmodontinae). *Acta Theriologica* 50:197–206.
- STEINMANN, A. R., J. W. PRIOTTO, AND J. POLOP. 2009. Territorial behaviour in corn mice, *Calomys musculus* (Muridae: Sigmodontinae), with regard to mating system. *Journal of Ethology* 27:51–58.
- STEINMANN, A. R., J. PRIOTTO, L. SOMMARO, AND J. POLOP. 2006a. The influence of adult female absence on the spacing behaviour of juvenile corn mice, *Calomys musculus*: a removal experiment. *Annales Zoologici Fennici* 43:366–372.
- STEINMANN, A. R., J. PRIOTTO, L. SOMMARO, AND J. POLOP. 2006b. Spacing behaviour of juveniles corn mice, *Calomys musculus* at the beginning of the breeding period, in absence of adult males. *Acta Oecologica* 29:305–310.
- SWIHART, R. K., AND N. A. SLADE. 1984. Road crossing in *Sigmodon hispidus* and *Microtus ochrogaster*. *Journal of Mammalogy* 65:357–360.
- TUFTO, J., R. ANDERSEN, AND J. LINNELL. 1996. Habitat use and ecological correlates of home range size in a small cervid: the roe deer. *Journal of Animal Ecology* 65:715–724.
- WOLFF, J. O., AND J. A. PETERSON. 1998. An offspring-defense hypothesis for territoriality in female mammals. *Ethology Ecology and Evolution* 10:227–239.
- YLETYNEN, S., AND K. NORRDAHL. 2008. Habitat use of field voles (*Microtus agrestis*) in wide and narrow buffer zones. *Agriculture, Ecosystems and Environment* 123:194–200.

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