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Patterns of Rodent Abundance on Open-Space Grasslands in Relation to Suburban Edges

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Abstract: *Relatively little is known about the response of grassland rodent populations to urban and suburban edges. We live-trapped rodents for three summers on 65 3.1-ha grassland plots on open space of the city of Boulder, Colorado, and compared capture rates among species according to habitat type, percentage of the 40 ha surrounding each plot that was suburbanized, and proximity to a suburban edge. Deer mice (*Peromyscus maniculatus*) and hispid pocket mice (*Chaetodipus hispidus*) were more abundant on interior than on edge plots in mixed grasslands, whereas prairie voles (*Microtus ochrogaster*) were captured more often on interior than on edge plots in tallgrass/hayfields. House mouse (*Mus musculus*) abundance did not differ between edge and interior plots. Native rodents as a group were captured more often on interior than on edge plots in both habitat types. For each native species, plots with the highest capture rates were in landscapes <10% suburbanized. We conclude that proximity to suburban landscapes had a strongly negative effect on the abundance of native rodents in open-space grasslands.*

Patrones de Abundancia de Roedores en Pastizales a Espacio Abierto en Relación con los Bordes Suburbanos

Resumen: *Se conoce relativamente poco sobre la respuesta de las poblaciones de roedores de pastizales a los bordes urbanos y suburbanos. Atrapamos roedores vivos por tres veranos en 65 cuadrantes de 3.1 ha de espacio abierto en la ciudad de Boulder, Colorado y comparamos las tasas de captura entre especies de acuerdo con el tipo de hábitat, el porcentaje de las 40 ha circundantes a cada cuadrante que estaba suburbanizado y si los cuadrantes estaban o no cerca de un borde suburbano. Los ratones ciervo (*Peromyscus maniculatus*) y ratones hispido (*Chaetodipus hispidus*) fueron más abundantes en los cuadrantes del interior que en los del borde en pastizales mezclados, mientras que los ratones de campo (*Microtus ochrogaster*) fueron capturados más frecuentemente en el interior que en los cuadrantes del borde de pastizal alto/henares. La abundancia del ratón de casa (*Mus musculus*) no varió entre cuadrantes del interior y del borde. Los roedores nativos como grupo fueron capturados más frecuentemente en el interior que en los bordes en ambos tipos de hábitat. Para cada especie nativa, los cuadrantes con las tasas de captura más altas estuvieron en paisajes <10% sub-urbanizados. Concluímos que la proximidad a los paisajes sub-urbanos tienen un efecto fuertemente negativo sobre la abundancia de los roedores nativos en pastizales de espacios abiertos.*

Introduction

Landscape conversion through urbanization causes habitat alteration, edge formation, and isolation effects that can profoundly affect biodiversity (McDonnell & Pickett 1990; Grimm et al. 2000). However, most studies of these relationships have focused on wooded and shrubby ecosystems and on birds (Herkert 1994; Robinson et al. 1995; Blair 1996; Bolger et al. 1997; Mazerolle & Villard 1999). Rodents are the most abundant grassland vertebrates (Brown 1995), and field observations and experiments show that their populations can be af-

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fected by habitat edges (Diffendorfer et al. 1995; Collins & Barrett 1997; Bowers & Dooley 1999; Lidicker 1999). Relatively little is known, however, about the response of grassland rodent populations to urban or suburban edges (but see Delattre et al. 1999).

The city of Boulder, Colorado, manages over 15,000 ha of open space, the majority of which is grassland (City of Boulder Open Space and Mountain Parks 2001). Open space in Boulder is situated in one of the most rapidly suburbanizing regions on the continent (Long 1999). We compared rodent populations on plots of open-space grassland that varied in their proximity to suburban edges and in the degree to which they were embedded in suburbanized landscapes.

Study Area and Methods

Boulder, Colorado, lies at the intersection of the western Great Plains and the eastern edge of the Rocky Mountain foothills (lat. 40°00′54′′N, long. 105°16′12′′W). Boulder's open-space system includes a belt of grasslands around the northern, eastern, and southern city limits. It is interspersed with private farm and ranch land and is "perforated" (Collinge & Forman 1998) by outlying subdivisions. Habitats include tallgrass prairie and irrigated hayfields in lowland areas and various mixed grasslands on upland benches and slopes (Bennett 1997; Bock & Bock 1998). Most of the original lowland tallgrass prairies have been replaced by irrigated and mowed hayfields. All the upland prairies have been grazed historically by livestock and many are still used for this purpose.

We established 65 circular, 200-m diameter plots on Boulder's open space, including replicates of the various grassland habitats and the maximum available range of suburban landscape settings. Plots in tallgrass/hayfield and mixed grassland supported distinctively different and internally consistent rodent assemblages. Each plot was entirely grassland, regardless of its landscape context. Twenty-two "edge" plots were located <100 m from suburban boundaries, of which 7 were mixed grassland and 15 tallgrass/hayfield. The remaining 43 "interior" plots were at least 750 m from the nearest suburban boundary, of which 25 were mixed grassland and 18 were tallgrass/hayfield. This plot arrangement reflected the unavoidable fact that mixed grasslands tended to be farther from suburban edges than did tallgrass/hayfields in our study area.

We generated a geographic information systems (GIS) land-cover database for the study area using an August 1995 Landsat thematic mapper (TM) image, ancillary data from existing GIS coverages, and ground-truth data (Haire et al. 2000). Using this database, we calculated percentages of landscapes around each plot which consisted of urban and suburban environments (buildings, pavement, and urban vegetation), at scales ranging from 6 to 400 ha. Percent suburbanization of plot landscapes was highly similar at all scales and ranged from 0 to 31%. Patterns of rodent abundance were particularly striking at the 40-ha scale, which we chose for presentation and analysis. The landscape settings of edge plots consisted mainly of single-family residential neighborhoods, which we would classify as suburban based on the definitions of Marzluff et al. (2001).

A 20 × 20 m grid of 25 evenly spaced Sherman live traps was set out for 1 week at the center of each of the 65 plots in each of three summers (1994–1996). Trapping occurred between mid-May and mid-August, the period of peak rodent activity in the study area. We baited and held traps open for 3 nights and then trapped each grid for the following 4 nights (100 trap nights per plot per summer). Traps were baited with rolled oats, opened late in the afternoon, and closed during the day. To distinguish new from previously captured individuals, we marked each animal by clipping a small quantity of hair off its back prior to release. Because trapping results were similar each year, we computed the relative abundance of each species on each plot as the number of different individuals captured per 100 trap nights averaged over the three summers (total 3-year sample = 19,500 trap nights).

Edge plots were more common in tallgrass/hayfields than in mixed grasslands, in contrast to the numbers of interior plots in the two habitats. This sampling asymmetry necessitated control for habitat effects when we tested for edge effects. Two-way analyses of variance of trapping results were not possible for most species, because highly unequal variances among habitats precluded parametric statistics. As a nonparametric alternative, we first compared abundances between habitats within landscape settings (edge and interior) and then compared abundances between edge and interior plots within habitats with Mann-Whitney U tests.

We computed product-moment correlations between plot capture rate and percent landscape suburbanization for each species and for total native rodents combined. We also divided the abundance/suburbanization space into quartiles above and below mean values and applied the chi-square statistic to test for independence of capture rate and percent landscape suburbanization.

Results

We captured 993 individual rodents of eight different species, five of which were sufficiently abundant to warrant statistical analyses (Table 1). Captures of all native rodents together were higher on interior than on edge plots (Fig. 1) in both mixed grassland ($Z = 2.31$, $p < 0.05$) and tallgrass/hayfield habitats ($Z = 2.91$, $p < 0.01$). *Microtus* were much more abundant in tallgrass/hayfields than in mixed grasslands (Fig. 1), on both edge

Table 1. Total captures and plot occurrence of rodents on 65 open-space grassland plots in Boulder, Colorado.

Species	*No. captures*	*No. plots*
Prairie vole (*Microtus ochrogaster*)	497	38
Deer mouse (*Peromyscus maniculatus*)	304	50
Hispid pocket mouse (*Chaetodipus hispidus*)	101	30
Western harvest mouse (*Reithrodontomys megalotis*)	38	12
House mouse (*Mus musculus*)	37	15
Thirteen-lined ground squirrel (*Spermophilus tridecemlineatus*)	7	7
Meadow jumping mouse (*Zapus hudsonicus*)	5	2
Norway rat (*Rattus norvegicus*)	4	2

($Z = 2.35, p < 0.05$) and interior plots ($Z = 4.97, p < 0.001$), and they were more abundant on interior than on edge plots in tallgrass/hayfield habitat ($Z = 2.86, p < 0.01$). *Chaetodipus* were much more abundant in mixed grasslands than in tallgrass/hayfields, on both edge ($Z = 3.15, p < 0.001$) and interior plots ($Z = 4.91, p < 0.001$), and they were more abundant on interior than on edge plots in their preferred habitat ($Z = 1.99, p < 0.05$). Captures of *Peromyscus* did not differ between habitats on either edge or interior plots (Fig. 1), but they were more abundant on interior than on edge plots in mixed grasslands ($Z = 1.98, p < 0.01$). *Mus* were trapped almost exclusively on tallgrass/hayfield plots, regardless of landscape setting (edge plots: $Z = 1.98, p < 0.05$; interior plots: $Z = 3.22, p < 0.01$), and there were no edge effects. There were no significant habitat or landscape effects for *Reithrodontomys*, although this species was captured only on interior plots in mixed grasslands (Fig. 1).

Plots with the highest capture rates of each native species were consistently found in surrounding 40-ha landscapes that were <10% suburbanized (Fig. 2). Because there were relatively few such "hotspots" for each species individually, we were unable to support this finding statistically for any of them. This conclusion was supported, however, in two tests performed on the data for all native rodents combined. First, there was a weak but significant negative correlation between total native rodent abundance and landscape suburbanization ($r = -0.274, p < 0.025$). Second, higher-than-average rodent capture rates (above the horizontal dashed line in Fig. 2) occurred on plots with relatively little nearby suburbanization (left of the dashed line; $\chi^2 = 5.10, p < 0.025$). The apparent consistency among the native species in this regard was not due to shared hotspots, because the top four plots for each common native species were different than any of the top four plots for any of the other species.

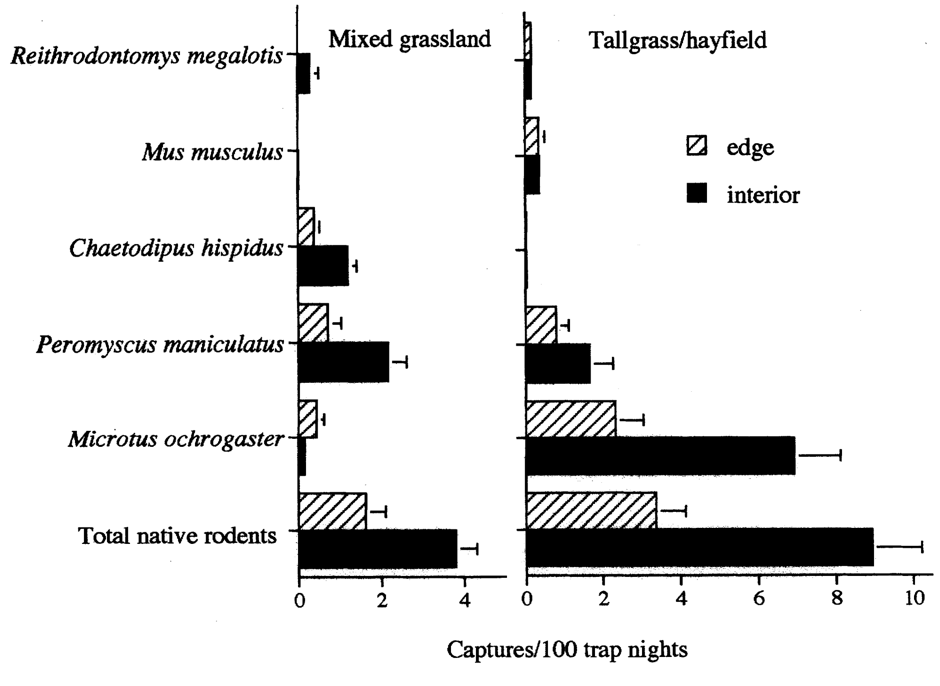

Figure 1. Captures of the five most abundant rodent species and total number of native rodents combined, per 100 trap nights on mixed grassland and tallgrass/hayfield plots at suburban edges versus interior plots at least 750 m from suburban edges.

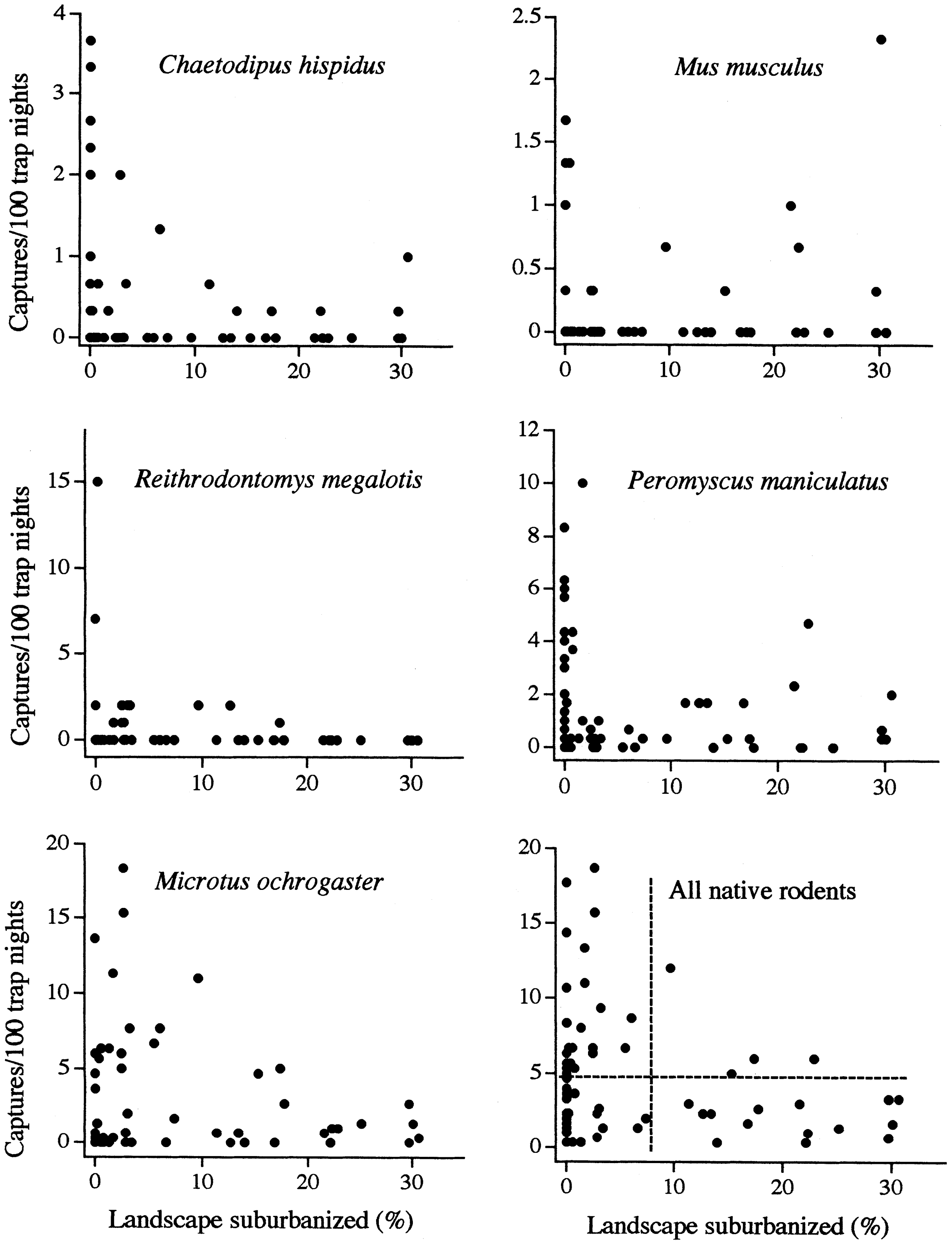

Figure 2. Captures per 100 trap nights versus percentage of the surrounding 40-ha landscape that was suburbanized for the five most abundant rodent species and total native rodents combined on 65 plots in Boulder open-space grasslands. Dashed lines divide the plot of total native rodents into quartiles based on mean capture and suburbanization variables.

Discussion

Proximity to suburban edges had strongly negative effects on abundances of native grassland rodents (Fig. 1), yet many interior plots also supported few rodents during our three summers of trapping (Fig. 2). We conclude that distance from suburban edge was a necessary but not a sufficient condition for rodents to achieve high densities, with other unmeasured factors such as habitat quality and predator abundance also likely to be involved.

Native grassland songbirds and diurnal birds of prey are also relatively uncommon at the suburban edges of Boulder open space (Berry et al. 1998; Bock et al. 1999; Haire et al. 2000). Scarcity of avian and mammalian prey may explain in part why the raptors tend to avoid the suburban boundaries. We found no evidence, however, that grassland-suburban boundaries represent any sort of refuge from predatory risk for rodents or songbirds, as may be the case in certain wooded ecosystems (Gering & Blair 1999).

We do not know why rodents were relatively scarce near suburban edges on open-space grasslands around Boulder, but three possible explanations can probably be eliminated. First, habitat condition apparently was not involved, because edge and interior grasslands did not differ in vegetative attributes such as bare ground, vegetation height, species composition, or presence of exotics (Bennett 1997). Second, competition with exotic house mice appears not to have been a factor because they were equally abundant on edge and interior plots. Third, scarcity of rodents could not have been a result of patch size and isolation effects, as it clearly is for rodents in California shrub habitats (Bolger et al. 1997), because Boulder's open-space grasslands consist of a highly connected belt around the city's limits rather than a series of isolated parcels.

A plausible explanation for our results is the effect of domestic and human-commensal predators on grassland rodents at urban and suburban edges. We have no proof of this, but studies elsewhere document the impacts of urban and suburban predators, particularly house cats (*Felis catus*), on rodent populations (Barratt 1997; Hall et al. 2000).

Whatever causal factors were involved, our results suggest that the principle of minimizing urban or suburban edge in relation to natural area is as relevant to conserving grasslands and rodents as it is to conserving forests and birds.

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