Landscape and Urban Planning 90 (2009) 11–19

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Changes in rodent communities according to the landscape structure in an urban ecosystem

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ARTICLE INFO

Article history:
Received 4 September 2007
Received in revised form 7 September 2008
Accepted 3 October 2008
Available online 11 December 2008

Keywords:
Urban landscape
Community composition
Environmental gradient
Landcover

ABSTRACT

We analyzed the relation between rodent communities composition and diversity and the landscape structure in the city of Buenos Aires. Between October 2002 and December 2005 rodent samplings were conducted in a natural reserve, three parklands, three shantytowns and two industrial–residential neighborhoods. Landscape structure at each site was characterized by the proportion of the surface occupied by different land-cover types, and the proportion covered by buildings. We caught 413 rodents of the following species: the native *Oligoryzomys flavescens*, *Deltamys kempi*, *Calomys musculinus* and *Cavia aperea*; and the introduced *Rattus norvegicus*, *R. rattus* and *Mus musculus*. Native species were dominant in the natural reserve but were also present in parklands. *R. rattus*, *R. norvegicus* and/or *M. musculus* were the dominant species in parklands, shantytowns or industrial–residential neighborhoods. Differences in landscape structure contributed to explain differences in community composition. Diversity, richness and representation of native species decreased with increasing urbanization. Our findings may be useful for planning decisions for either conservation or pest control goals, based on the rodent community composition inferred from the landscape structure.

1. Introduction

Animal community structure and the population abundance of the individual species that make up the community depend on local conditions, landscape context, historical events and evolutionary processes (Kotliar and Wiens, 1990; Levin, 1992; Ricklefs, 1987; Wiens et al., 1993). The increasing availability of Geographic Information Systems and Satellite Images, combined with complex computer methods of analysis and the capacity to deal with large datasets using multivariate analysis software, allowed the development of numerous ecological studies where the relationship among the distribution of species is modeled with environmental variables at large scales (see Rushton et al., 2004). Many of these studies have emphasized the importance of landscape-scale structure and composition in the distribution and abundance of many species. Currently, most research is focused on natural and rural environments as well as on the conservation of endangered species (Rushton et al., 2004), while models for pest species like rodents in urban environments are rare (e.g., Baker et al., 2003; Childs et al., 1998; Langton et al., 2001; Traweger and Slotta-Bachmayr, 2005).

As urban areas are expanding and replacing natural habitats worldwide, it is becoming increasingly important to understand the relationship between urban environments and their resident fauna populations. Most studies in urban areas are focused on avian species and/or iconic species (Garden et al., 2006). Less research has been focused on mammals, reptiles, amphibians, invertebrates and aquatic species (Garden et al., 2006). Information on rodent distribution in an urban landscape is valuable because rodents are known to be involved in the transmission of diseases to humans and domestic animals (Battersby and Greenwood, 2004), and cause damage to stored food, buildings and infrastructure (Battersby, 2004; Drummond, 2001). On the other hand, the knowledge of species' associations with the landscape structure may help to make planning decisions to improve urban environmental conditions for native fauna (Clergeau et al., 2001; Garden et al., 2006).

Although the conversion of natural or semi-natural ecosystems to urban ecosystems is a slow process, it is usually irreversible (Matteucci et al., 1999; Morello et al., 2000). Urban ecosystems provide fewer ecological services, such as the capacity to control animal and plant populations that may prevent pest outbreaks (Morello et al., 2000). The development of urban ecosystems

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doi:10.1016/j.landurbplan.2008.10.017

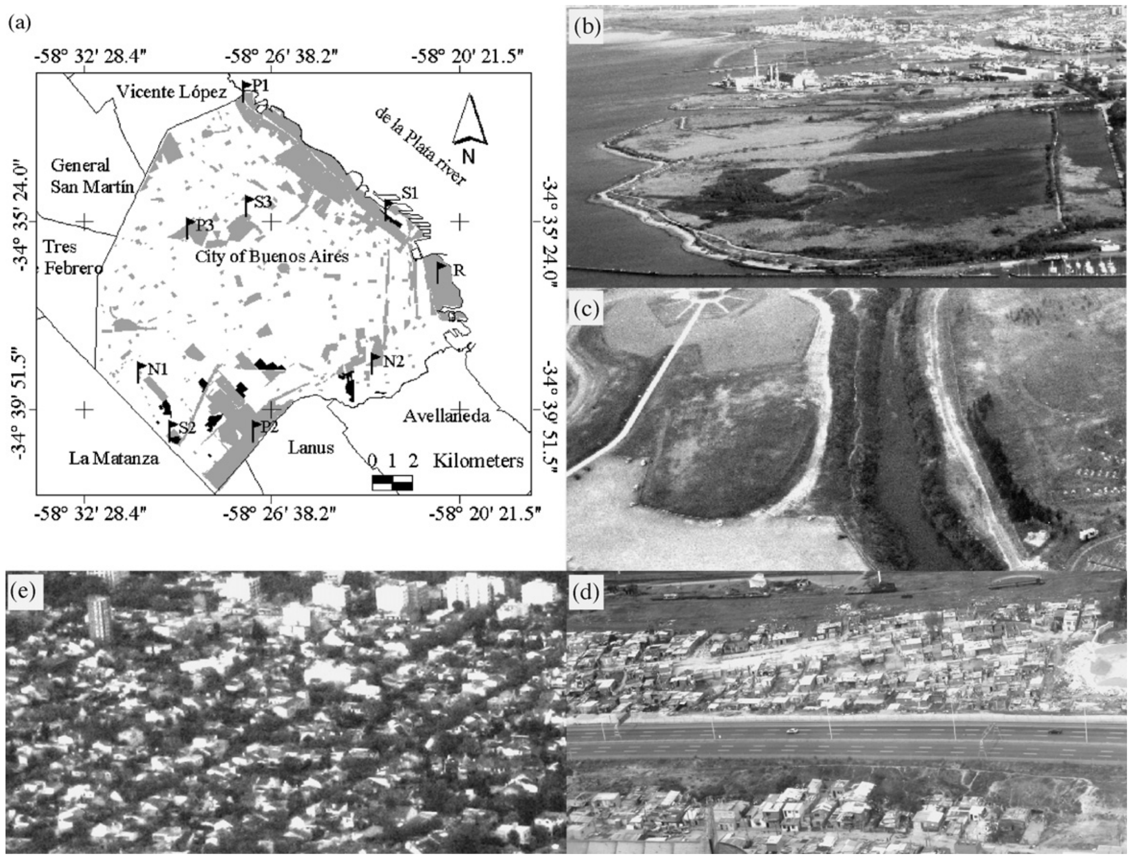


Fig. 1. (a) Map of the city of Buenos Aires showing the nine sites where rodent were sampled. Black flags indicate the location of the sampled sites. R: natural reserve, P1-3: parklands 1–3, S1-3: shantytowns 1–3 and N1-2: industrial–residential neighborhoods 1 and 2. Grey polygons indicate the location of open green spaces, black polygons indicate the location of shantytowns and the white foreground corresponds to the matrix of blocks with buildings and pavement. Aerial photographs from: (b) the reserve, (c) the parkland 1, (d) the shantytown 1 and (e) the industrial–residential neighborhoods 1.

generates new anthropic habitats. In turn, it decreases biological productivity due to a reduction in plant cover, and enhances the fragmentation, isolation and degradation of natural habitats (Marzluff, 2001). The structure of urban areas and their fringes consist of a variety of components, ranging from totally built environments to natural or semi-natural areas (McDonnell and Pickett, 1990). Natural remnants in an urban context are those not intensively managed by people, such as reserves and patches of spontaneous vegetation in parklands, lakes, ponds and streams (McDonnell and Pickett, 1990).

As a consequence of urbanization, the compositions of species (plant, bird and insect communities) tend to be simplified and homogenized (Alberti and Marzluff, 2004; Marzluff, 2001; Shochat et al., 2004), and exotic species become more prevalent (McDonnell et al., 1997; Melles et al., 2003). There is little information on the effect of urbanization on small mammal communities at a landscape scale (but see Bock et al., 2002; Delattre et al., 1999).

In this work we analyzed the relation between rodent communities composition and diversity and the landscape structure in the city of Buenos Aires.

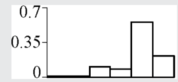
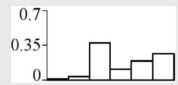
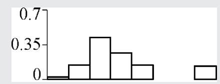
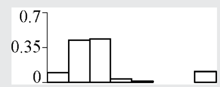
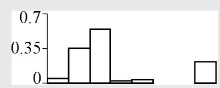
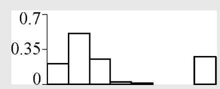
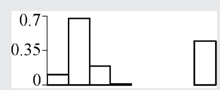
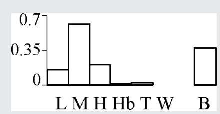
2. Materials and methods

2.1. Study area

Fieldwork was conducted in Buenos Aires, Argentina (34°37′S, 58°24′W), with a surface of around 200 km^2 and 2,776,138 inhabitants, representing 9.09% of the country's total population (INDEC, 2001). The climate is temperate with a mean annual temperature of 17.4 °C, a seasonal amplitude of 13.2 °C and a mean annual precipitation of 1014 mm. The city is situated on the rolling pampa in the shore of the de la Plata river (Soriano et al., 1991) (Fig. 1). The original vegetation consisted of 1 m high grasses, which were reduced to small relict grasslands along field borders and roads in agro-ecosystems due to intensified agriculture (Soriano et al., 1991). Trees are absent in the region, except for riverside areas where woodlands, riparian thickets and flooded grasslands co-exist (Cabrera and Zardini, 1993). The original grasslands were replaced by agro-ecosystems, which in turn are now increasingly replaced by urban habitats, along with the city growth. The matrix of the city is formed by buildings and paved streets, while parks and open green areas form patches (Fig. 1). In this work we sampled rodents in nine sites belonging to four different landscape units: a natural reserve, three parklands, three shantytowns and two industrial–residential neighborhoods (Fig. 1 and Table 1).

The natural reserve is located on the coast of the de la Plata river and has an extension of 350 ha. It is occupied by riparian habitats similar to those developed along the Paraná and de la Plata rivers, like woodlands, riparian thickets, fresh water marshes and flooded grasslands, which were developed on sediments generated by anthropogenic activity since 1970. Parklands are public areas of recreation, where areas of spontaneous vegetation and woodlots with planted species are included in a matrix of grass or ornamental lawn (Cavia, 2006). The spontaneous vegetation is developed as patches of herbs, shrubs and small woods with some species in common with the natural reserve (Cavia, 2006). Shantytowns are residential neighborhoods with low impervious surface coverage compared to other neighborhoods due to the

Table 1
Sites sampled in the city of Buenos Aires: site name, landscape unit type (mnemonic), location, season and year, total sampling effort and proportion of the surface occupied by different land-cover types and buildings.

Site Name	Landscape unit types (Mnemonic)	Land-cover and buildings proportions	Location
Reserva Ecológica Costanera Sur	Natural reserve (R)		34°36′18″S 58°20′58″W
Parque de los Niños	Parkland 1 (P1)		34°31′48″S 58°27′40″W
Parque Presidente Roca	Parkland 2 (P2)		34°40′38″S 58°26′37″W
Parque de la Facultad de Agronomía	Parkland 3 (P3)		34°35′39″S 58°29′6″W
Villa 31	Shantytown 1 (S1)		34°34′47″S 58°23′7″W
Villa Bermejo	Shantytown 2 (S2)		34°40′56″S 58°29′15″W
Villa Chacarita	Shantytown 3 (S3)		34°35′4″S 58°27′21″W
Barrio Mataderos	Industrial–residential neighborhood 1 (N1)		34°39′24″S 58°30′15″W
Colonia Solá	Industrial–residential neighborhood 2 (N2)		34°38′46″S 58°23′8″W

Site name	Season (year)	Total sampling effort
Reserva Ecológica Costanera Sur	Spring 2002, Fall 2004, Winter 2004, Summer 2004/2005	2571 Cage trap nights (CTN), 2582 Sherman trap nights (STN)
Parque de los Niños	Fall 2004, Winter 2004	272 CTN, 343 STN
Parque Presidente Roca	Spring 2004	410 CTN, 433 STN
Parque de la Facultad de Agronomía	Summer 2004/2005	258 CTN, 258 STN
Villa 31	Spring 2003, Summer 2003/2004, Fall 2004, Winter 2004	798 CTN, 759 STN
Villa Bermejo	Spring 2005	258 CTN, 264 STN
Villa Chacarita	Summer 2005/2006	175 CTN, 169 STN
Barrio Mataderos	Spring 2003, Winter 2004, Spring 2004, Summer 2004/2005, Fall 2005	1224 CTN, 1355 STN
Colonia Solá	Fall 2005	333 CTN, 183 STN

Proportion of surface occupied by highly vegetated urban cover (H), moderately vegetated urban cover (M) and low vegetated urban cover (L), tree cover (T), herb cover (Hb) and bodies of water (W); and proportion of surface occupied by buildings (B).

unpaved streets, sparsely distributed houses, and the presence of patches of spontaneous vegetation. In addition, shantytowns are characterized by precarious housing conditions and an inadequate supply of urban services, such as garbage removal, sanitation networks and/or plumbing (Cavia, 2006; Fernández et al., 2007). The industrial–residential neighborhoods studied are areas where buildings and pavement are the dominant elements in the landscape unit. Open green areas are restricted to gardens and parks. In both neighborhoods the dominant type of construction were houses of no more than two floors, but in some sections there were also industries. Department block buildings and shops were found along avenues. We named this unit as industrial–residential neighborhoods because, although houses were dominant, there were also industries present, and their presence may have an effect on rodents.

2.2. Environmental gradient proposed

The landscape units of Buenos Aires selected for this study differed in the abundance of various environments, and can be ordered along a gradient from those dominated by natural and semi-natural vegetation to those dominated by anthropogenic elements such as buildings and pavement. The natural reserve represents the most natural landscape, followed by parklands, where patches of spontaneous vegetation are included in a matrix of park grass or ornamental lawn. The urban neighborhoods, represented by shantytowns and industrial–residential neighborhoods are placed at the opposite end of the gradient. Following Morello et al. (2000), shantytowns are less urbanized than industrial–residential neighborhoods because of their low impervious surface coverage and an inadequate supply of urban services.

2.3. Rodent communities

According to their geographic distribution, 12 small rodent species may be found in the city of Buenos Aires (Galliari et al., 1991): the native caviid *Cavia aperea* (Order Rodentia, Family Caviidae, Subfamily Caviinae); the native sigmodontines (Order Rodentia, Family Cricetidae, Subfamily Sigmodontinae) *Holochilus brasiliensis*, *Scapteromys aquaticus*, *Oxymycterus rufus*, *Oligoryzomys flavescens*, *Akodon azarae*, *Deltamys kempi*, *Calomys laucha* and *Calomys musculinus;* and the introduced murines (Order Rodentia, Family Muridae, Subfamily Murinae) *Rattus rattus*, *Rattus norvegicus* and *Mus musculus*. Only eight species were reported before this study: the native species *C. musculinus*, *C. laucha*, *A. azarae*, *O. flavescens* and *C. aperea* (Massoia and Fornes, 1967; Pearson, 1967), and the introduced species *R. rattus*, *R. norvegicus* and *M. musculus* (Arango et al., 2001; Massoia and Fornes, 1967; Seijo et al., 2003).

In agro-ecosystems near the city of Buenos Aires the rodent community includes *C. aperea*, *A. azarae*, *O. flavescens*, *C. musculinus*, *C. laucha* and *M. musculus*. *C. aperea*, *A. azarae* and *O. flavescens* are more abundant in less disturbed habitat like road and crop field borders. *Calomys* species are more abundant in crop fields and *M. musculus* and *Rattus* species are rare in these habitats and are common in farms (Busch and Kravetz, 1992; Gómez Villafañe and Busch, 2007; Mills et al., 1991; Miño et al., 2007). In crop borders systems sigmodontine species exhibit variations in abundance with a minimum in spring, peaks in late autumn, and decreases in winter (Busch and Kravetz, 1992; Mills et al., 1991). In farms introduced species abundances do not vary seasonality (Gómez Villafañe and Busch, 2007; Miño et al., 2007).

In the coastal area of the de la Plata and Paraná rivers near the city of Buenos Aires the rodent community includes *C. aperea, A. azarae*, *O. flavescens, O. nigripes, D. kempi, O. rufus, H. brasiliensis* and *S. aquaticus.* Except *C. aperea, A. azarae* and *O. flavescens* which are also present in agro-ecosystems, the other species are typically present in riparian habitats like woodlands, thickets, marshes and flooded grasslands (González and Pardiñas, 2002; Massoia, 1964). *O. nigripes* occupies mainly woodlands making its nests in trees (Massoia and Fornes, 1964b). *C. aperea, D. kempi* and *O. flavescens* use sites dominated by trees, shrub marshes or flooded grasslands in riparian areas (Bonaventura et al., 2003a,b; Cassini, 1991; Gómez Villafañe et al., 2005; González and Pardiñas, 2002). *O. rufus* uses patches with shrubs or tall grasses patches in marshes (Cueto et al., 1995; Dalby, 1975; Suárez and Bonaventura, 2001). *S. aquaticus* and *H. brasiliensis* have semiaquatic habits and are restricted to grasslands located near bodies of water (Gómez Villafañe et al., 2005; Massoia and Fornes, 1964a). Many of these species are seasonal breeders (Barlow, 1969; Bonaventura et al., 2003a, 2003b; Cueto et al., 1995; Dalby, 1975; Kravetz, 1972), but those species that live a year or more, like *O. rufus* and *C. aperea*, do not show seasonal variations in abundance (Bonaventura et al., 2003a,b; Cueto et al., 1995; Dalby, 1975). In riparian habitats *A. azarae, O. flavescens, O. nigripes* and *D. kempi* show seasonal variations in abundance with a minimum in winter-spring and a peak in summer (Bonaventura et al., 1991; Cavia, 2006).

2.4. Rodent surveys

Sampling was performed between October 2002 and December 2005. Rodent samplings were conducted in each of the nine sites using Sherman and cage traps. Both are single capture live traps. The Sherman trap is an aluminum box-trap (8 cm × 9 cm × 23 cm) with a door open at one end leading to a weight-sensitive treadle. As the animal walks along the weight-sensitive treadle, it closes the spring-loaded door. Cage traps are wire mesh traps (15 cm × 16 cm × 31 cm) with one door that is locked open with a pin connected to a trigger device holding the bait. Although we set a ratio of 1:1 Sherman trap per cage trap at each of the studied sites, the trapping effort was similar but not equal because some traps were sprung without capturing animals or were stolen. In sites dominated by vegetation (the natural reserve and parklands) Sherman and cage traps, which were 5 m apart, were placed on lines. Following Aplin et al. (2003), there were a fixed number of traps per house, shop or factory in areas with numerous constructions or buildings (i.e. shantytowns and industrial–residential neighborhoods). Two Sherman and two cage traps were set in each house, shop or factory whose owners volunteered for the research project. Traps were placed inside buildings and in their yards or gardens. One to 23 blocks were sampled in each neighborhood. Sherman traps were baited with a mixture of peanut butter and cow fat, and cage traps with carrot and raw meat; they were monitored for three consecutive nights and checked every morning. The species, sex, weight and body and tail lengths were recorded for each animal caught. In the natural reserve each individual captured was marked and released at the site of capture. In all the other sites, animals captured were removed because tissues sampled were also collected for parasitological studies.

2.5. Landscape variables

Landscape structure was based on a land-cover classification from De Pietri and Karszenbaum (2000). The total area of the city of Buenos Aires was classified into five classes using a numerical procedure with a NDVI dynamic range computed from a LANDSAT TM image obtained on December 4, 1997. Each one of the pixels of 30 m × 30 m of the LANDSAT TM image was assigned to one of the five land-cover types defined by De Pietri and Karszenbaum (2000): tree cover when >75% of the pixel was covered by trees, herb cover when >75% of the pixel was covered by herbs, highly vegetated urban cover when 75–50% of the pixel was vegetated and <50% was built up, moderately vegetated urban cover when 5–50% of the pixel was vegetated and 50–80% was built up, and low vegetated urban cover when <5% of the pixel was vegetated and >80% was built up. Built up are all surfaces in which buildings, paved roads, or other constructions replaced the natural substrate. Gardens, parks or other open areas with natural or implanted vegetation are excluded from this category. We also included two digital maps: one of bodies of water and the other contained all buildings of the city of Buenos Aires. We checked the information provided by the land-cover classification and the digital maps by field observations. The classification of De Pietri and Karszenbaum (2000) did not consider the bodies of water, which were misclassified. We modified this classification in order to include the bodies of water as a new land-cover type replacing the assignment of pixels misclassified, according to the digital map of bodies of water. The new classification has 6 classes that cover 100% of the surface of the city. The digital map of buildings was considered independently.

At each site, we selected a 75 ha hexagonal window in which we quantified the relative proportion of the surface occupied by the different land-cover types, and the proportion covered by buildings. The size of these windows was determined according to the area needed to include the trap lines or blocks where rodents were sampled. In the industrial–residential neighborhood 1 we used three windows to contain the 23 blocks sampled, while in the other sites we used only one window because the area sampled was smaller. Using only one window of greater size in all sites would have included a large proportion of non-sampled area in eight sites. The three windows of the industrial–residential neighborhood 1 were considered as a single observation for the statistical analysis on the basis of their contiguity. A Geographic Information System was used to process all data (ArcView GIS 3.2a and ArcView Spatial Analyst: ESRI, 1999).

2.6. Data analysis

We estimated species richness, species diversity and community composition at each site. Diversity was determined using the Shannon–Wiener (H) diversity index (Krebs, 1989; Magurran, 1988). Finally, the community composition was described by the relative abundance of each rodent species (p_i), which was calculated as the number of individuals of a given species divided by the total number of individual rodents captured. We assumed that the different capture rates, that the species could have, do not bias the results.

The similarity in the composition of the rodent community among sites was evaluated with the Czekanowski's quantitative index (Matteucci and Colma, 1982; Pielou, 1984). The Czekanowski's index is calculated as the total sum of the lower relative abundance of each species between two compared communities. If p_{i1} and p_{i2} are the relative abundances of species i in communities one and two respectively and S the total number of species, then the Czekanowski's $index_{1,2} = \sum_{i=1}^{S} minimum(p_{i1}, p_{i2})$. The similarity matrix of rodent community was expressed as a dendrogram, constructed with a cluster analysis using the simple linkage method (Pielou, 1984). The simple linkage method (also called nearest neighbors) joins two clusters, on basis of the two most similar communities in the different clusters (Pielou, 1984).

We analyzed the relation between species richness, diversity and the proportion of introduced species at each site and its location in the proposed environmental gradient by means of non-parametric rank correlations. We assigned the rank: 0 to the reserve, the most natural landscape unit, 1 to parklands, 2 to the shantytowns and 3 to the most urban landscape unit, the industrial–residential neighborhoods.

The association between species composition and landscape structure was analyzed using Euclidean distance matrices obtained from landscape data. These were compared with the similarity matrix based on rodent composition using simple and partial Mantel tests (Legendre and Legendre, 1998). Significance of the association was tested by 1000 Monte Carlo permutations (using zt 1.0: Bonnet and de Peer, 2001–2002). Because the relationships between rodent community and landscape structure may be masked by spatial autocorrelation, a matrix based on the actual distances between sampled sites was calculated and also compared with the other distance matrices using the Mantel tests (Legendre and Legendre, 1998).

We analyzed the association between the relative abundance of each rodent species from the nine studied sites and landscape structure using Generalized Linear Models (McCullagh and Nelder, 1999), with a forward stepwise multiple regression procedure (Nicholls, 1991). The response variables were the relative abundance of each species in the community, and the explanatory variables were the proportions of the different land-cover types and buildings. The S-plus 6.0 software was used to fit the model (Insightful, 2002). On the basis that the response variables are proportions, we assumed a binomial distribution of errors and applied the logistic function as a link for the response variable (Crawley, 1993). This function constrains the predicted values to lie between zero and one. We computed the Pearson correlation coefficient between pairs of explanatory variables to test for colinearity between them. Whenever two variables were strongly associated (with $p < 0.01$), the one accounting for the greatest change in variance was kept, whereas the other one was excluded from further analysis.

3. Results

We caught 413 rodents belonging to seven species during 5462 Sherman trap-nights and 5211 cage trap-nights. Of these, four were native species (*O. flavescens, D. kempi, C. musculinus* and *C. aperea*), and three were introduced species (*R. norvegicus, R. rattus* and *M. musculus*). Native rodents were exclusively found in vegetated environments, whereas introduced rodents were also captured in dwellings, shops and factories. The distribution of species was not homogeneous among sites ($\chi^2 = 755.48$, d.f. = 40; $P = 0.000$; *C. musculinus* was not included in the analysis because of the small number of captures). In the natural reserve, the rodent community was dominated by the native species *D. kempi* and *O. flavescens*; this site showed the highest species richness, Shannon–Wiener diversity index and number of native rodent species (*D. kempi, O. flavescens, C. musculinus* and *C. aperea*, Fig. 2). Parklands 1 and 2 ranked second in the Shannon–Wiener diversity index, and also had native rodents (Fig. 2). *M. musculus* was caught in all three parklands, *R. norvegicus* and *C. aperea* in two of them, *O. flavescens* was exclusively captured in parkland 2, and *R. rattus* in parkland 3. In shantytowns, the dominant species were *R. norvegicus* and *M. musculus*, and *R. rattus* was also found. In contrast with Arango et al. (2001), Coto (2001), and Seijo et al. (2002, 2003), *M. musculus* was

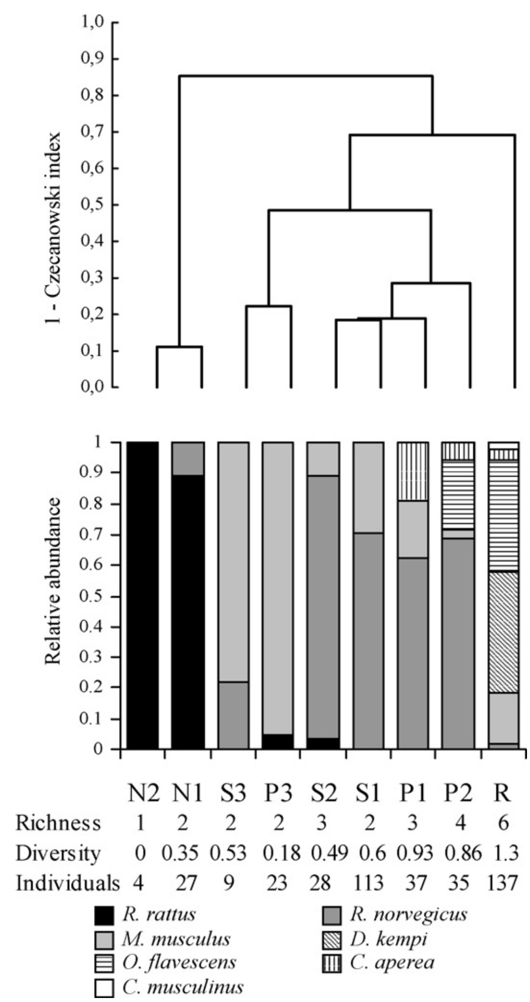


Fig. 2. Rodent community composition, richness, diversity, total rodents captured (individuals) and similarity among sites sampled in the city of Buenos Aires. The dendrogram depicts clustering of the Czekanowski's quantitative index. Diversity: Shannon–Weaner diversity index. R: natural reserve, P1-3: parklands 1–3, S1-3: shantytowns 1–3 and N1-2: industrial–residential neighborhoods 1 and 2.

an important component of rodent communities in shantytowns. In the two urban industrial–residential neighborhoods, *R. rattus* dominated the captures, accompanied by *R. norvegicus*. According to the Czekanowski's index, the two industrial–residential neighborhoods were the most similar in rodent composition, and differed from shantytowns, parklands and the natural reserve. The rodent community of the natural reserve was different from all others. Parklands and shantytowns were similar, but did not constitute a homogeneous group (Fig. 2).

Rodent communities showed a decrease in species diversity (Spearman $r = -0.710$, $n = 9$, $p = 0.032$), richness (Spearman $r = -0.777$, $n = 9$, $p = 0.014$) and native species representation (Spearman $r = -0.782$, $n = 9$, $p = 0.013$) with increasing urban conditions according to the environmental gradient proposed (Fig. 3). Along the environmental gradient the different land-cover types change their proportion, from a dominance of tree cover in the reserve to moderate vegetated urban cover in the industrial–residential neighborhoods (Table 1). There was a strong association only between the proportions of buildings and moderately vegetated urban cover ($r_P = 0.944$, $p = 0.000$).

According to the Mantel test, there was no spatial correlation in species composition or in landscape structure ($p > 0.05$ for all cases). Species composition of sites was associated with the proportion of surface occupied by buildings (simple $r_M = 0.455$, $p = 0.012$) and highly vegetated urban cover (simple $r_M = 0.345$, $p = 0.035$). Significant associations were also found between rodent community composition and the proportion of surface occupied by buildings, when the effect of the proportion of highly vegetated urban cover was partialled out (partial Mantel test $r_M = 0.44$, $p = 0.017$), and between rodent community composition and the proportion of highly vegetated urban cover, when the effect of the proportion of surface occupied by buildings was partialled out (partial $r_M = 0.324$, $p = 0.033$).

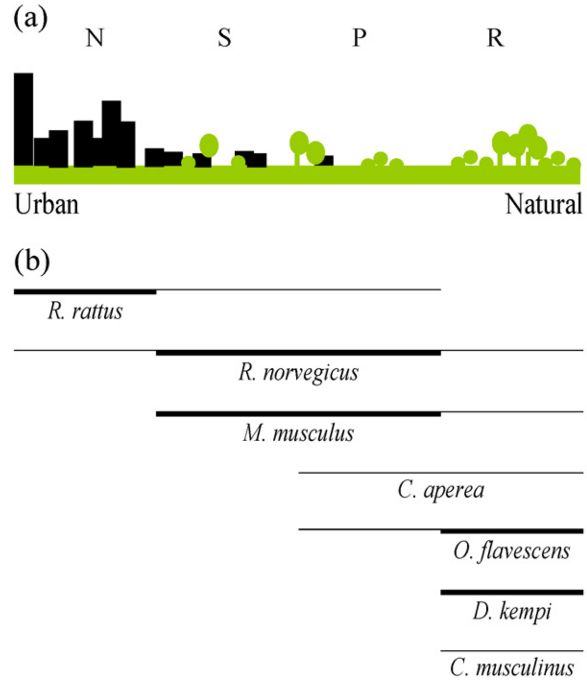


Fig. 3. (a) Landscape units studied in the city of Buenos Aires ordered according to a proposed environmental gradient and (b) rodent species' distribution among them. Black elements represent artificial elements like buildings, and green elements represent natural elements like vegetation. N: industrial–residential neighborhoods, S: shantytowns, P: parklands and R: natural reserve. Horizontal lines over rodent species' names indicate the relative abundance of rodent species in the different landscape units: dominant (thick line), not dominant (thin line), and absent (no line). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Table 2
Forward stepwise multiple regression analyses conducted between the relative abundance of *R. rattus*, *R. norvegicus*, *M. musculus*, *C. aperea* and *O. flavescens*; and the abundance of land-cover types (see text).

	Coefficient	t	p	Residual variance	d.f.	Change in variance	d.f.	p
R. rattus ($R_L^2 = 0.943$)								
Null model				179.41	8			
Intercept	−8.46	−6.57	0.000					
Buildings	23.98	6.57	0.000	10.23	7	169.18	1	0.000
R. norvegicus ($R_L^2 = 0.967$)								
Null model				248.17	8			
Intercept	−5.53	−8.51	0.000					
Highly vegetated	16.41	9.86	0.000	64.44	7	183.73	1	0.000
Herbs	−17.62	−5.86	0.001	27.05	6	37.40	1	0.000
Bodies of water	7.47	3.95	0.028	8.11	5	18.94	1	0.000
M. musculus ($R_L^2 = 0.670$)								
Null model				105.59	8			
Intercept	−1.71	−7.54	0.000					
Herbs	12.85	4.55	0.003	85.19	7	20.40	1	0.000
Bodies of water	−23.50	−4.31	0.005	53.42	6	31.77	1	0.000
Trees	7.41	3.56	0.016	31.72	5	21.71	1	0.000
C. aperea ($R_L^2 = 0.998$)								
Null model				28.13	8			
Intercept	−0.76	−1.24	0.250					
Moderately vegetated	−38.20	−1.49	0.180	8.55	7	19.58	1	0.000
Trees	−3.79	−2.88	0.028	0.07	6	8.49	1	0.004
O. flavescens ($R_L^2 = 0.808$)								
Null model				117.72	8			
Intercept	−4.28	−8.89	0.000					
Trees	6.84	7.23	0.000	22.60	7	95.12	1	0.000

Proportion of the surface occupied by tree cover (trees), herb cover (herbs), highly vegetated urban cover (highly vegetated), moderately vegetated urban cover (moderately vegetated) and low vegetated urban cover (low vegetated), bodies of water and buildings. R_L^2 statistics: the proportional reduction in the absolute value of the log-likelihood, t: Student's statistics for the coefficients.

According to multivariate regression analysis, the relative abundance of *R. rattus* increased with increasing the surface occupied by buildings (Table 2). *R. norvegicus* was most abundant in the communities at sites with a larger proportion of highly vegetated urban cover, a larger proportion of bodies of water, and a lower proportion of herb cover. The relative abundance of *M. musculus* increased with increasing proportion of surface occupied by herbs and trees, and with decreasing proportion of surface occupied by bodies of water. The relative abundance of *C. aperea* increased with decreasing proportion of moderately vegetated urban cover and tree cover. The relative abundance of *O. flavescens* increased with increasing proportion of tree cover**.** These models explained almost all the variance for *R. rattus, R. norvegicus*, *C. aperea* and *O. flavescens,* and a great amount of it for *M. musculus* (Table 2).

4. Discussion

We found seven rodent species in the studied landscape units of Buenos Aires. According to previous works (Castillo et al., 2003; Chernousova, 2001; Dickman and Doncaster, 1987) native rodents can be common in urban landscapes. In the present work, native species were dominant in the natural reserve but were also present in parklands. *R. rattus, R. norvegicus* and/or *M. musculus* were the dominant species in parklands, shantytowns or industrial–residential neighborhoods (Fig. 3). *R. norvegicus* and *M. musculus* were the most common species, being present in seven of the nine sites studied, probably because of their high ability of adaptation to different environments (Timm, 1994a,b). *R. rattus* was mainly restricted to the industrial–residential neighborhoods, whereas *D. kempi* and *C. musculinus* were restricted to the natural reserve. *D. kempi* was not reported previously for the city of Buenos Aires, while *A. azarae* and *C. laucha* were cited by Massoia and Fornes (1967) and Pearson (1967) and were not found in our work. The growing urbanization that took place in the city during the last 35 years resulted in the disappearance of remnant grasslands, which are the appropriate environments for these species (Busch et al., 2001). Currently, rodent communities of Buenos Aires are composed of a few species that likely lived in the area before the foundation of the city, and of introduced species. The disappearance of the remaining native species, as for *A. azarae* and *C. laucha*, would also have resulted from the disappearance of appropriate environments due the urbanization.

At a landscape scale, the abundance of organisms is determined by the existence of different environments and spatial heterogeneity (Kotliar and Wiens, 1990; Levin, 1992; Wiens et al., 1993). As was observed in other studies on small mammals and birds (Cueto and López de Casenave, 1999; Jeganathan et al., 2004; Macdonald and Rushton, 2003; Rushton et al., 2004; Sauvajot, 1998; Savard et al., 2000; Smart et al., 2004), we found that the community composition was associated to the landscape structure, characterized by different proportions of land-cover types. The existence of different environments within the landscape units allowed the species present in the region to occupy the urban ecosystem, as proposed by Alard and Poudevigne (2002). As was observed for bird communities (Melles et al., 2003; Palomino and Carrascal, 2006), we also found that rodent communities showed a decrease in species diversity, richness and native species representation with increasing urban conditions.

The natural reserve, may function as an island habitat for rodents because it is isolated from other similar environments; colonization may have involved random processes, and new species are expected to appear in the future. We report the first record of *O. flavescens, D. kempi* and *C. musculinus* populations in the reserve. In contrast, no *A. azarae* and *C. laucha* were detected, despite the fact that they have been cited previously (Narosky et al., 1996). Although *D. kempi* was one of the dominant species at this site (Fig. 2), it is generally rare in rodent communities from Argentina (González and Pardiñas, 2002). The absence of *A. azarae,* which is competitively dominant in other communities (Bonaventura et al., 1991; Busch and Kravetz, 1992), probably favored the dominance of *D. kempi*.

C. aperea showed a negative association with the proportion of moderately vegetated urban cover and with the proportion of tree cover. This is in accordance with the idea that this species prefers open areas like grasslands and ornamental lawns (Gómez Villafañe et al., 2005). *O. flavescens* was positively associated with sites showing a high proportion of tree cover like the one provided by riparian thickets in the natural reserve, and by patches of vegetation with high cover of trees and/or shrubs in parklands, where this species was commonly captured (Cavia, 2006).

R. norvegicus was associated with sites showing a large proportion of highly vegetated urban cover, which are abundant in shantytowns (Table 1). In contrast to areas with high abundance of buildings, shantytowns would provide suitable conditions for the construction of ground burrows. In parklands, *R. norvegicus* was abundant in patches with high cover of trees and/or shrubs (Cavia, 2006), as shown by the inclusion of tree cover in the regression model. The presence of *R. norvegicus* in parklands could be associated with bodies of water, based on its occurrence along riversides in other cities (Bajomi and Sasvári, 1986; Castillo et al., 2003; Ieradi et al., 1996). This environmental association, reflected by the inclusion of the proportion occupied by bodies of water in the regression model, would be related to the need of free water by *R. norvegicus* (Timm, 1994b).

M. musculus, in contrast, has been reported to have a low requirement for free water (Timm, 1994a) and to be a poor competitor (Busch et al., 2005), and its high abundance in parklands lacking bodies of water may be related to the absence of *R. norvegicus*. This may also explain the negative association observed between bodies of water and the relative abundance of *M. musculus*. However, in the other landscape units studied herein, lack of bodies of water does not mean lack of available water. In shantytowns, for example, rodents obtain water from the commonly found puddles and trenches, and from drinking troughs for pets. Cavia (2006) has reported the presence of *M. musculus* in patches with high cover of herbs, trees and/or shrubs in the natural reserve and parklands. In the present work this environmental association is reflected by the inclusion of herb and tree cover in the regression model.

R. rattus was more abundant at sites with high proportion of constructions, in agreement with Marsh (1994), who stated that residential or industrial areas provide suitable habitats for this species. The ability of this rat to climb and build nests with artificial materials inside buildings (Marsh, 1994) may have contributed to its spread in areas of high construction density in Buenos Aires.

According to our models, the most common species in Buenos Aires may be *R. rattus*, because buildings and moderately vegetated urban cover are dominated in the city. This is in disagreement with observations in other cities where *R. norvegicus* is the most common rat, as in New York (Childs et al., 1998), Baltimore (Davis, 1951; Jackson, 1998), Rome (Ieradi et al., 1996), Budapest (Bajomi and Sasvári, 1986), Salzburg (Traweger and Slotta-Bachmayr, 2005) and many cities in England (Langton et al., 2001). This difference may be attributed to the *R. rattus* worldwide geographic distribution, which suggests that it is much more suited to warm climates (Marsh, 1994), and in consequence it may be the most common species in cities with mild temperature conditions, while *R. norvegicus* dominates in cities with cold climates. The differences between the two species of rats may be taken in account to the design of control measures.

Parklands may provide refuge for native flora and fauna in urban ecosystems (Cornelis and Hermy, 2004). The presence of native species in parklands may suggest that they can be, along with reserves, potential sites for their conservation. There could be a conflict, however, between conservation goals and the need of control of some rodent species. In the present study, native rodents were captured in patches of spontaneous vegetation within parklands, but these patches may also harbor introduced species that may be involved in the transmission of pathogens to human, such as *Leptospira* spp. (Seijo et al., 2002) and hantavirus Seoul (Cueto et al., 2008). On the other hand, *O. flavescens*, one of the native species captured in parklands, is associated with the transmission of a severe pulmonary disease in the region, the Hantavirus Pulmonary Syndrome (Levis et al., 1995; Rivera et al., 2007). The use of recreation areas as parklands for the conservation of native rodents may increase the risk of zoonoses transmission to the visitors.

In our study not all sites were sampled simultaneously and/or in all seasons. However, the associations observed could not be attributed to the different dates of sampling because communities were similar when the landscape structure of the sites was similar independently of the moments in which they were sampled. The noise associated to different dates of sampling did not unmask the effect of landscape structure probably because the effect of urbanization on rodent communities is stronger than the seasonal or inter annual changes.

Based on the strong association observed between rodent community composition and environmental characteristic at the landscape scale, it is possible to identify areas where native fauna is potentially present, determining which areas could be of interest for conservation purposes. Our results also allow us to suggest that in the reserve and parklands proactive actions are needed to reduce the potential risk of transmission of hantavirus by *O. flavescens* to the visitors. In residential areas, when rodent poison campaigns are decided, the product used could be selected (the chemical, bait bases and formulation) in accordance to the species that are going to be controlled, such as *R. rattus* in industrial–residential neighborhoods or *R. norvegicus* and *M. musculus* in shantytowns. However, the association observed between rodent community composition and environmental characteristic may be integrated in a multi-scale approach, because factors that affect community characteristics act at different scales, and a landscape scale approach may not be sufficient to elucidate ecological outcomes of community composition (Cornelis and Hermy, 2004; Corry and Nassauer, 2005). Finally, a similar approach can be useful to map the distribution of rodent species in other cities, in order to make management decisions for either conservation or pest control goals.

Acknowledgements

We want to be grateful especially to María Busch for her valuable comments that have helped to improve this work. We are grateful to Emiliano Muschetto, María Soledad Fernández, Martín Zamero, Analía Andrade, Pablo Teta and Carina Hercolini for their assistance in the field; to Diego Martínez, Silvia Fisher, the employees of Gobierno de la Ciudad de Buenos Aires and Reserva Ecológica Costanera Sur, and the neighbors of Villa 31, Villa Chacarita, Villa Bermejo, Mataderos and Colonia Solá for their help. We want to thank Anibal Carbajo for his help in the data analysis and Haydee Karszenbaum for the land cover classification of Buenos Aires City. Aerial photographs from Fig. 1 were taken by G.R. Cueto. The handling of the animals throughout the study followed the Argentine Law for Animal Care, National Law 14346 (see http://www.sarem.org.ar). This research was supported with grants from CONICET (Argentina), Universidad de Buenos Aires and Gobierno de la Ciudad de Buenos Aires.

References

Alard, D., Poudevigne, I., 2002. Biodiversity in changing landscapes: from species of patch assemblages to system organization. In: Leuven, R.S.E.W., Poudevigne, I., Teuw, R.M. (Eds.), Application of Geografic Information Systems and Remote Sensing in River Studies. Backhuys, Leiden.

Alberti, M., Marzluff, J.M., 2004. Ecological resilience in urban ecosystems: linking urban patterns to human and ecological functions. Urban Ecosyst. 7, 241–265.

Aplin, K.P., Brown, P.R., Jacob, J., Krebs, C.J., Singleton, G.R., 2003. Field methods for rodent studies in Asia and the Indo-Pacific. Australian Center for International Agricultural Research, Camberra.

Arango, J., Cittadino, E., Agostini, A., de Mazzonelli, G.D., Alvarez, C., Colusi, M., et al., 2001. Prevalence of leptospirosis in *Rattus rattus* and *Rattus norvegicus* of the Buenos Aires Metropolitan Area, Argentina. Ecol. Austral 11, 25–30 (in Spanish).

Bajomi, D., Sasvári, K., 1986. Results of eight years examination of the habitats of residual urban Norway rat populations after eradication. In: Paper presented at the Twelfth Vertebrate Pest Conference, San Diego, California.

Baker, P.J., Dodds, P.A.A., Webber, C.E., Harris, S., 2003. Factors affecting the distribution of small mammals in an urban area. Mammal Rev. 33 (1), 95–100.

Barlow, J., 1969. Observations on the Biology of Rodents in Uruguay. Royal Ontario Museum, Ontario.

Battersby, J.E., 2004. Public health policy—can there be an economic imperative? An examination of one such issue. J. Environ. Health Res. 3 (1), 19–28.

Battersby, J.E., Greenwood, J.J.D., 2004. Monitoring terrestrial mammals in the UK: past, present and future, using lessons from the bird world. Mammal Rev. 34 (1–2), 3–29.

Bock, C.E., Vierling, K.T., Haire, S.L., Boone, J.D., Merkle, W.W., 2002. Patterns of rodent abundance on open-space grasslands in relation to suburban edges. Conserv. Biol. 16 (6), 1653–1658.

Bonaventura, S.M., Piantanida, M.J., Gurini, L.B., Sánchez López, M.I., 1991. Habitat selection in population of cricetine rodents in the region Delta (Argentina). Mammalia 55 (3), 339–354.

Bonaventura, S.M., Pancotto, V., Vicari, R., Madanes, N., Bellocq, M., 2003a. Demography and microhabitat use of the wild guinea pig (*Cavia aperea*) in freshwater *Spartina densiflora* marshes in Argentina. Acta Zool. Sin. 49 (1), 20–31.

Bonaventura, S.M., Pancotto, V., Madanes, N., Vicari, R., 2003b. Microhabitat use and density of sigmodontine rodents in *Spartina densiflora* freshwater marshes, Argentina. Mammalia 67 (3), 367–377.

Bonnet, E., de Peer, Y.V., 2001–2002. zt (Version 1.0). Free Software Foundation, Inc., Boston.

Busch, M., Kravetz, F.O., 1992. Competitive interactions among rodents (*Akodon azarae, Calomys laucha*, *C. musculinus* and *Oligoryzomys flavescens*) in a two-habitat system. I. Spatial and numerical relationships. Mammalia 56, 45–56.

Busch, M., Miño, M.H., Dadon, J.R., Hodara, K., 2001. Habitat selection by *Akodon azarae* and *Calomys laucha* (Rodentia, Muridae) in pampean agroecosystems. Mammalia 65, 29–48.

Busch, M., Bilenca, D.N., Cittadino, E.A., Cueto, G.R., 2005. Effect of removing a dominant competidor, *Akodon azarae* (Rodentia, Sigmodontinae) on community and population parameters of small rodent species in Central Argentina. Austral Ecol. 30, 168–178.

Cabrera, A.L., Zardini, E.M., 1993. Manual de la flora de los alrededores de Buenos Aires. Acme S.A.C.I, Buenos Aires.

Cassini, M., 1991. Foraging under predation risk in the Wild Guinea pig *Cavia aperea*. Oikos 62 (1), 20–24.

Castillo, E., Priotto, J., Ambrosio, A.M., Provensal, M.C., Pini, N., Morales, M.A., et al., 2003. Commensal and wild rodents in an urban area of Argentina. Int. Biodeter. Biodegr. 52 (3), 135–141.

Cavia, R., 2006. Rodents in the city of *Buenos Aires*: an approach to their control. Unpublished Doctoral Thesis, University of Buenos Aires, Buenos Aires (in Spanish).

Chernousova, N.F., 2001. Specific features of the dynamics of murine rodent communities under the effects of urbanization. 1. Dynamics of species composition and abundance. Russian J. Ecol. 32 (2), 122–125.

Childs, J.E., McLafferty, S.L., Sadek, R., Miller, G.L., Khan, A.S., DuPree, E.R., et al., 1998. Epidemiology of rodent bites and prediction of rat infestation in New York city. Am. J. Epidemiol. 148 (1), 78–87.

Clergeau, P., Jokimäki, J., Savard, J.-P.L., 2001. Are urban bird communities influenced by the bird diversity of adjacent landscapes? J. Anim. Ecol. 38 (5), 1122–1134.

Cornelis, J., Hermy, M., 2004. Biodiversity relationships in urban and suburban parks in Flanders. Landscape Urban Plan. 69 (4), 385–401.

Corry, R., Nassauer, J., 2005. Limitations of using landscape pattern indices to evaluate the ecological consequences of alternative plans and designs. Landscape Urban Plan. 72 (4), 265–280.

Coto, H., 2001. Risk area determination associated with rodent presence in the Autonomous city of *Buenos Aires*. Unpublished Mastery Thesis, University of San Martín, Buenos Aires (in Spanish).

Crawley, M.J., 1993. GLIM for Ecologists. Blackwell Scientific Publications, Oxford.

Cueto, V., López de Casenave, J., 1999. Determinants of bird species richness: role of climate and vegetation structure at a regional scale. J. Biogeogr. 26, 487–492.

Cueto, V., Piantanida, M., Cagnoni, M., 1995. Population demography of *Oxymycterus rufus* (Rodentia: Cricetidae) inhabiting a patchy environment of the delta of the Paraná River, Argentina. Acta Theriol. 40, 123–130.

Cueto, G.R., Cavia, R., Bellomo, C., Padula, P.J., Suárez, O.V., 2008. Prevalence of Infection with Hantavirus in wild *Rattus norvegicus* and *R. rattus* populations of Buenos Aires City, Argentina. Trop. Med. Int. Health 13 (1), 46–51.

Dalby, P., 1975. Biology of pampa rodents Balcarce Area, Argentina. Publublications of the Museum, Michigan State University. Biol. Series 5, 149–272.
Davis, D.E., 1951. The relation between level of population and size and sex of Norway rats. Ecology 32, 459–461.
De Pietri, D.E., Karszenbaum, H., 2000. Teledetection contributions to the urban vegetation distribution and characterization of the city of Buenos Aires. In: Paper Presented at the IX Latin-American Symposium of Remote Sensing, Misiones, Argentina (in Spanish).
Delattre, P., De Sousa, B., Fichet-Calvet, E., Quéré, J.P., Giraudoux, P., 1999. Vole outbreaks in a landscape context: evidence from a six year study of *Microtus arvalis*. Landscape Ecol. 14 (4), 401–412.
Dickman, C.R., Doncaster, C.P., 1987. The ecology of small mammals in urban habitats. I. Populations in a patchy environment. J. Anim. Ecol. 56, 629–640.
Drummond, D.C., 2001. Rodents and biodeterioration. Int. Biodet. Biodegr. 48 (1), 105–111.
ESRI, 1999. ArcView GIS (Version 3.2a). Environmental Systems Research Institute, Inc., New York.
Fernández, M.S., Cavia, R., Cueto, G.R., Suárez, O.V., 2007. Implementation and evaluation of an integrated program for rodent control in a shanty town of Buenos Aires city, Argentina. EcoHealth 4, 271–277.
Galliari, C.A., Berman, W.D., Goin, F.J., 1991. Mammals. In: Resources and Natural Features in the Environmental Evaluation. Environmental Situation or the Province of Buenos Aires, vol. 5. Comisión de Investigaciones Científicas, La Plata, pp. 1–35 (in Spanish).
Garden, J., McAlpine, C., Peterson, A., Jones, D., Possingham, H., 2006. Review of the ecology of Australian urban fauna: a focus on spatially explicit processes. Austral Ecol. 31 (2), 126–148.
Gómez Villafañe, I.E., Busch, M., 2007. Spatial and temporal patterns of brown rat (*Rattus norvegicus*) abundance in poultry farms. Mamm. Biol. 72 (6), 364–371.
Gómez Villafañe, I.E., Miño, M.H., Cavia, R., Hodara, K., Courtalón, P., Suárez, O.V., et al., 2005. Guide of Rodents from *Buenos Aires* Province. LOLA, Buenos Aires (in Spanish).
González, E.M., Pardiñas, U.F.J., 2002. *Deltamys kempi*. Mamm. Species 711, 1–4.
Ieradi, L.A., Cristaldi, M., De Angelis, R., 1996. Rodent pest management. Biological and anthropological aspects. In: Paper Presented at the Fifth International Conferenci Rodens and Spatium. Biodiversity and Adaptation, Maroc.
INDEC, 2001. National census of population and housing. Secretaría de Planeación: Presidencia de la Nación, República Argentina (in Spanish).
Insightful, C., 2002. S-plus (Version 6.1 Proffesional), Seattle.
Jackson, W.B., 1998. Ecology of pest rodents in the urban environment. In: Ambasht, R.S. (Ed.), Modern Trends in Ecology and Environment. Blackhuys, Leiden, pp. 101–113.
Jeganathan, P., Green, R.E., Norris, K., Vogiatzakis, I.N., Bartsch, A., Wotton, S.R., et al., 2004. Modelling habitat selection and distribution of the critically endangered Jerdon's courser *Rhinoptilus bitorquatus* in scrub jungle: an application of a new tracking method. J. Appl. Ecol. 41 (2), 224–237.
Kotliar, N.B., Wiens, J.A., 1990. Multiple scales of patchiness and patch structure: a hierarchical framework for the study of heterogeneity. Oikos 59, 253–260.
Kravetz, F.O., 1972. Study on diet, activity periods and other ecological aspects in a population of "long-snouted mice" (*Oxymycterus rufus platensis* Thomas) of Punta Lara. Acta Zool. Lilloana XXIX, 201–212 (in Spanish).
Krebs, C.J., 1989. Ecological Methodology. Harper & Row, New York.
Langton, S.D., Cowan, D.P., Meyer, A.N., 2001. The occurrence of commensal rodents in dwellings as revealed by the 1996 English House Condition Survey. J. Appl. Ecol. 38 (4), 699–709.
Legendre, P., Legendre, L., 1998. Numerical Ecology, Second English Edition ed. Elsevier Science B.V., Amsterdam.
Levin, S.A., 1992. The problem of pattern and scale in ecology. Ecology 73 (6), 1943–1967.
Levis, S.C., Briggiler, A.M., Cacass, M., Peters, C.J., Ksiazek, Cortes, J., et al., 1995. Emergence of hantavirus pulmonary syndrome en Argentina. Am. J. Trop. Med. Hyg. 53, 233.
Macdonald, D.W., Rushton, S., 2003. Modelling space use and dispersal of mammals in real landscapes: a tool for conservation. J. Biogeogr. 30 (4), 607–620.
Magurran, A.E., 1988. Ecological diversity and its measurement. Croom Helm, London.
Marsh, R.E., 1994. Roof rats. In: Hygnstrom, S.E., Timm, R.M. Larson, G.E. (Eds.), Prevention and Control of Wildlife Damage, California, pp. B-125–B-132.
Marzluff, J.M., 2001. Worldwide urbanization and its effects on birds. In: Marzluff, J.M., Bowman, R., Donnelly, R. (Eds.), Avian ecology and conservation in an urbanizing world. Kluwer Academic, Norwell, pp. 19–47.
Massoia, E., 1964. Systematic, geographical distribution and etho-ecological characteristics of *Akodon* (*Deltamys*) *kempi* (Rodentia: Cricetidae). Physis 24 (68), 299–305 (in Spanish).
Massoia, E., Fornes, A., 1964a. Notes about the genus *Scapteromys* (Rodentia–Cricetidae). I. Systematic, geographical distribution and etho-ecological characteristics of *Scapteromys tumidus* (Waterhouse). Physis 24 (68), 279–297 (in Spanish).
Massoia, E., Fornes, A., 1964b. New information of systematic, biology and etho-ecology of *Oryzomys* (*Oligoryzomys*) *nigripes* Thomas (Rodentia, Cricetidae). Paraná Delta. Invest. Agríc. 12 (1) (in Spanish).
Massoia, E., Fornes, A., 1967. Rodents collected in the Federal Capital City (Caviidae, Cricetidae y Muridae). IDIA, 47–53 (in Spanish).
Matteucci, S.D., Colma, A., 1982. Study of Vegetation Methodology, vol. 22. Secretaría General de la Organización de los Estados Americanos, Washington (in Spanish).
Matteucci, S.D., Morello, J., Rodriguez, A., Buzai, G.D., Baxendale, C.A., 1999. Metropolitan growth and biodiversity changes: the case of Buenos Aires. In: Biodiversity and Land Use. Concepts and Examples from Latinamerica, vol. 24. EUDEBA, Buenos Aires, pp. 549–580 (in Spanish).
McCullagh, P., Nelder, J.A., 1999. Generalized Linear Models. CRC Press, Boca Raton.
McDonnell, M.J., Pickett, S.T.A., 1990. Ecosystem structure and function along urban-rural gradients: an unexploited opportunity for ecology. Ecology 71 (4), 1232–1237.
McDonnell, M.J., Pickett, S.T.A., Groffman, P., Bohlen, P., Pouyat, R.V., Zipperer, W.C., et al., 1997. Ecosystem processes along an urban-to-rural gradient. Urban Ecosyst. 1, 21–36.
Melles, S., Glenn, S.M., Martin, K., 2003. Urban bird diversity and landscape complexity: species–environment associations along a multiscale habitat gradient. Conserv. Biol. 7 (1), 5.
Mills, J.N., Ellis, B.A., Mckee, K.T., Maiztegui, J.I., Childs, J.E., 1991. Habitat associations and relative densities of rodent populations in cultivated areas of central Argentina. J. Mammal. 72 (3), 470–479.
Miño, M.H., Cavia, R., Gómez Villafañe, I.E., Bilenca, D.N., Busch, M., 2007. Seasonal abundance and distribution among habitats of small rodents on poultry farms. A contribution for their control. Int. J. Pest Manage. 12, 1–6.
Morello, J., Buzai, G.D., Baxendale, C.A., Rodriguez, A.F., Matteucci, S.D., Godagnone, R.E., et al., 2000. Urbanization and the consumption of fertile land and other ecological changes: the case of Buenos Aires. Environ. Urbaniz. 12, 119–131.
Narosky, T., Henschke, C., Yzurieta, D., 1996. Birds of the Costanera Sur and the city of de Buenos Aires, guide for their identification. Vazquez Mazzini, Buenos Aires (in Spanish).
Nicholls, A.O., 1991. Examples of the use of generalised linear models in analysis of survey data for conservation evaluation. In: Margules, C.R., Austin, M.P. (Eds.), Nature conservation: cost effective biological surveys and data analysis. CSIRO Australia, East Melbourne, pp. 54–63.
Palomino, D., Carrascal, L., 2006. Urban influence on birds at a regional scale: a case study with the avifauna of northern Madrid province. Landscape Urban Plan. 77 (3), 276–290.
Pearson, O.P., 1967. Age structure and reproductive dynamic in a population of meadow mice, *Akodon azarae*. Physis XXVII (74), 53–58 (in Spanish).
Pielou, E.C., 1984. The Interpretation of Ecological Data: A Primer on Classification and Ordination. John Wiley Sons, New York.
Ricklefs, R.E., 1987. Community diversity: relative roles of local and regional processes. Science 235, 167–171.
Rivera, P., González Ittig, R., Rossi Fraire, H., Levis, S., Gardenal, C., 2007. Molecular identification and phylogenetic relationships among the species of the genus *Oligoryzomys* (Rodentia, Cricetidae) present in Argentina, putative reservoirs of hantaviruses. Zool. Scr. 36 (3), 231–239.
Rushton, S.P., Ormerod, S.J., Kerby, G., 2004. New paradigms for modelling species distributions? J. Appl. Ecol. 41 (2), 193–200.
Sauvajot, R.M., 1998. Patterns of human disturbance and response by small mammals and birds in chaparral near urban development. Urban Ecosyst. 2, 279–297.
Savard, J.-P.L., Clergeau, P., Mennechez, G., 2000. Biodiversity concepts and urban ecosystems. Landscape Urban Plan. 48 (3–4), 131–142.
Seijo, A., Coto, H., San Juan, J., Videla, J., Deodato, B., Cernigoi, B., et al., 2002. Lethal leptospital pulmonary hemorrhage: an emerging disease in Buenos Aires, Argentina. Emerg. Infect. Dis. 8 (9), 1004–1005.
Seijo, A., Enría, D., Levis, S., Pini, N., Coto, H., Deodato, B., et al., 2003. Study of hantavirus Seoul, in human and rodent populations in a shantytown of the city of Buenos Aires. Medicina (Buenos Aires) 63, 193–196 (in Spanish).
Shochat, E., Stefanov, W.L., Whitehouse, M.E.A., Faeth, S.H., 2004. Urbanization and spider diversity: influences of human modification of habitat structure and productivity. Ecol. Appl. 14 (1), 268–280.
Smart, J.C.R., Ward, A.I., White, P.C.L., 2004. Monitoring woodland deer populations in the UK: an imprecise science. Mammal Rev. 34 (1–2), 99–114.
Soriano, A., León, R., Sala, O., Lavado, R., Deregibus, V., Cauhepe, M., et al., 1991. Río de la Plata Grassland. In: Coupland, R. (Ed.), Ecosystems of the world 8A. Natural Grasslands. Introduction and Western Hemisphere. Elsevier, Amsterdam, pp. 367–407.
Suárez, O.V., Bonaventura, S.M., 2001. Habitat use and diet in sympatric species of rodents of the low Paraná delta, Argentina. Mammalia 65 (2), 167–176.
Timm, R.M., 1994a. House mice. In: Hygnstrom, S.E., Timm, R.M., Larson, G.E. (Eds.), Prevention and Control of Wildlife Damage, California, pp. B-31–B-46.
Timm, R.M., 1994b. Norway rats. In: Hygnstrom, S.E., Timm, R.M. Gary, E.L. (Eds.), Prevention and Control of Wildlife Damage, California, pp. B-105–B-120.
Traweger, D., Slotta-Bachmayr, L., 2005. Introducing GIS-modelling into the management of a brown rat (*Rattus norvegicus* Berk.) (Mamm. Rodentia Muridae) population in an urban habitat. J. Pest Sci. 78 (1), 17–24.
Wiens, J.A., Stenseth, N.C., Van Horne, B., Ims, R.A., 1993. Ecological mechanisms and landscape ecology. Oikos 66, 369–380.