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Short communication

Conservation of small and medium-sized mammals following native woodland regrowth: A case study in a long-term UNESCO Biosphere Reserve, Argentina

S. Tabeni[a,b,*], F. Spirito[a,b], R.A. Ojeda[a,b]

[a] *Instituto Argentino de Investigaciones de las Zonas Áridas (IADIZA), Centro Científico Tecnológico (CCT) CONICET Mendoza, Argentina*
[b] *Grupo de Investigaciones de la Biodiversidad, Av. A. Ruiz Leal s/n, Parque General San Martín, C.C. 507, C.P. 5500, Mendoza, Argentina*

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ABSTRACT

Land uses such as cattle ranching require important decisions concerning the protection of habitats and species. This is especially true in arid lands and typically involves habitat regrowth as well as the establishment of protected areas. However, the manner in which species respond to the protected area or to the surrounding matrix may vary depending on their ecology, particularly habitat requirements. The objective of this study was to evaluate the role of one such protected dryland area (MaB Reserve of Ñacuñán) and adjacent rangelands in the central Monte Desert of Argentina. More specifically, how effective it is in ensuring the conservation of small and medium-sized mammals. Mammal richness and abundance estimated from both trapping and indirect signs were compared in different habitats inside and outside the Reserve. After over 50 years of livestock exclusion in Ñacuñán, our results showed significant changes in habitat structure and mammal diversity between protected and unprotected areas. Species associated with high plant cover were found inside the Reserve, while the surrounding areas were occupied by those adapted to open habitats. The presence of the endangered *Dolichotis patagonum* in rangelands outside the Reserve demonstrates that unprotected areas play a major role in conserving species diversity.

1. Introduction

Livestock grazing, deforestation and habitat fragmentation are the major causes of human impacts on biodiversity in drylands and have resulted in desertification, landscape homogenization and loss of plant and animal diversity (Villagra et al., 2009). South American drylands, in particular, are undergoing accelerated degradation due to grazing and deforestation (Villagra et al., 2009). Desert mammals are an important segment of biodiversity conservation showing high diversity and having important effects on the desert ecosystem (e.g., as “keystone species”) (Kelt, 2011; Ojeda et al., 1998).

In the context of land degradation, management of protected areas in which human activities are restricted or prohibited is critical. Although conservation emphasis has been placed on establishing reserves, the importance of surrounding disturbed areas for faunal conservation has been increasingly recognized since protected areas are embedded in a landscape where resource exploitation occurs. Several studies on mammals show that, although some species benefit from being protected against human disturbance, others actually meet their habitat requirements in unprotected areas (Chávez and Ceballos, 2009; Tabeni and Ojeda, 2005).

In this study, we analyzed the composition of a desert assemblage of small and medium-sized mammals and their associated habitats after 50 years of grazing exclusion in a protected area (UNESCO-MaB Reserve of Ñacuñán) and its surrounding grazed matrix (Ojeda et al., 1998). The MaB Reserve of Ñacuñán is embedded within a landscape that is strongly affected by cattle ranching (Villagra et al., 2009). After 50 year-old grazing exclusion, the recovery of the native vascular flora is remarkable, however there is currently no ecological studies that assess the ecological impacts of that protection on the surrounding unprotected rangeland and how it affects desert mammals.

2. Methods

2.1. Study area

The study was conducted in the Man and Biosphere (MaB) Reserve of Ñacuñán, Mendoza Province, Argentina (34° 02′S, 67°

* Corresponding author. Instituto Argentino de Investigaciones de las Zonas Áridas, IADIZA-CCT CONICET Mendoza, Av. A. Ruiz Leal s/n, Parque Gral. San Martín, C.C. 507, C.P. 5500, Mendoza, Argentina. Tel.: +54 261 5244144; fax: +54 261 4280080.
E-mail address: stabeni@mendoza-conicet.gob.ar (S. Tabeni).

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58′W, 12,300 ha, 119 km^2), and in an adjoining unprotected area under continuous grazing pressure. Both sites belong to the temperate Monte Desert biome, with a marked seasonality of humid summers (mean temperature > 20 °C) and dry winters (mean temperature < 10 °C). Average annual rainfall is 324 mm. It boasts a diverse mosaic of habitats that includes *Prosopis flexuosa* woodlands mixed with grasses, shrublands dominated by the evergreens *Larrea* and *Bulnesia* (Zygophyllaceae), and sand dunes with very low shrub and herb cover (dominated by *L. divaricata* and *Hyalis argentea*). From 1908 through 1937, the central Monte Desert suffered severe exploitation of *Prosopis* woodlands involving rangeland conversion on about 4,000,000 ha (Villagra et al., 2009). Ñacuñán Reserve was created in 1961 in order to conserve native woodlands and associated biota. In 1986, this protected area was included in the world network of Man and Biosphere Reserves (UNESCO).

2.2. Habitat characterization

Vegetation sampling was undertaken within small mammal trapping grids to characterize the structure of the main habitat types (*Prosopis* woodland, *Larrea* shrubland and sand dunes), inside and outside the Reserve. One 4 × 4-m plot was centered at each of 600 trapping stations, with 300 plots within and outside the Reserve (see *Mammal assemblage*). For each plot, plant cover and bare soil percentages were visually estimated. Plant species were classified into four categories: trees, shrubs, herbs and grasses to verify whether vegetation strata varied between habitats, inside and outside the Reserve. Proportions of each vegetation category were compared between protected and unprotected sites with *t* test or Welch's approximate *t* test to account for possible differences in variance among samples (Zar, 1999).

The frequency of cattle feces was also recorded on plots in grazed habitats as an indirect indicator of grazing intensity, and analyzed using a Chi-square test.

2.3. Mammal assemblage

Small mammals (i.e., <100 g) considered in this study included *Graomys griseoflavus*, *Calomys musculinus*, *Eligmodontia typus* and *Akodon molinae* (Rodentia, Cricetidae). Medium-sized mammals (i.e., ≥100 g) were *Dolichotis patagonum*, *Microcavia australis*, *Galea leucoblephara* (Rodentia, Caviidae) and *Lepus europaeus* (Lagomorpha, Leporidae).

Eight seasonal sampling efforts for small mammals were performed during 2001 and 2002 (summer: February, autumn: March–May, winter: June–August, and spring: October), in the three main habitat types. Four trapping grids, each with 25 Sherman live traps, were set in each habitat type (*Prosopis* woodland, *Larrea* shrubland and sand dunes) in protected and unprotected areas (for a total of 600 sampling points). Trapping grids were placed at least 100 m apart.

Traps were baited with rolled oats and peanut butter, and checked each morning for five consecutive days in each season. Captured animals were toe-clipped for individual identification and then released. Small mammal species abundance was determined by the minimum number known alive (MNKA).

In order to quantify space use in medium-sized mammals, indirect signs were sampled along 30 × 40-m transects established at each habitat type inside and outside the Reserve (protected and unprotected *Prosopis* woodland, $n = 20$ each; protected and unprotected *Larrea* shrubland, $n = 24$ each; protected and unprotected sand dunes, $n = 30$ each). Fecal pellets of *D. patagonum*, *G. leucoblephara* and *L. europaeus*, as well as active *M. australis* colonies, were quantified for each transect. Within the Reserve and the grazed area, trapping grids and transects were established at more than 200 m from closest fences to minimize possible edge effects. Both methods were used to estimate species richness for protected and unprotected habitats.

A Non-Metric Multidimensional Scaling (NMDS) analysis was used to examine which species combination was most closely related to habitat type within the protected or unprotected. This method is recommended as an ecological ordination technique due to its general robustness derived from lack of assumptions about the data distribution or type. The distance measure used in the NMDS analysis was Bray–Curtis distance, the number of iterations was based on Young's S-stress formula, and iterations stopped when S-stress was less than 0.005. A nonparametric Spearman rank correlation was performed between NMDS axis values and categorized habitat variables to determine the most important environment factors influencing mammal distribution. Statistical analyses were performed in R language and environment for statistical computing (R Development Core Team, 2006). We considered p values <0.05 to be statistically significant in all analyses.

3. Results

3.1. Habitat characterization

Sand dunes in the unprotected area had less herbaceous (Welch's approximate t test $= -4.71$, $p < 0.001$), shrub ($t = -6.45$, $p < 0.001$) and grass cover ($t = -2.08$, $p < 0.05$) compared to the protected area. In the *Larrea* shrubland outside the Reserve, herbaceous (Welch's approximate t test $= -5.32$, $p < 0.001$) and grass cover (Welch's approximate t test $= -7.89$, $p < 0.001$) were lower than in the Reserve, whereas bare soil cover was higher (Welch's approximate t test $= 6.15$, $p < 0.001$). The *Prosopis* woodland showed less tree (t test $= -2.28$, $p < 0.05$) and grass cover (t test $= -7.38$, $p < 0.001$) in the unprotected area than in the Reserve.

Density of cattle feces was significantly different among grazed habitats ($p < 0.001$), revealing higher activity in the *Larrea* shrubland, followed by the *Prosopis* woodland, and to a lesser extent in sand dunes.

3.2. Mammal assemblage

Species richness was higher in the *Prosopis* woodland and *Larrea* shrubland outside the Reserve, with the lowest richness occurring in the protected *Larrea* shrubland. All small mammal species were found in each habitat, although some medium-sized mammals were absent from protected habitats (e.g., *D. patagonum*) or present only in a particular habitat type (Table 1).

The NMDS ordinations based on similarity matrices of species abundance identified two important dimensions that explained habitat use by mammals and differences between the habitat features selected (Fig. 1a and b). All small mammal species were present both in protected and unprotected areas, but in different proportions (Fig. 1a). Vegetation features such as grass and herbaceous cover were the only variables correlated with NMDS axis 1 ($r_{herbs} = 0.07$; $p_{herbs} = 0.01$ and $r_{grasses} = 0.99$; $p_{grasses} = 0.04$). Herbaceous cover was the only related variable in axis 2 ($r_{herbs} = 0.87$; $p_{herbs} = 0.02$). For both axes, all variables were positively correlated. Cattle feces were negatively correlated with both axes ($r_{feces\ axis\ 1} = -0.18$; $r_{feces\ axis\ 2} = -0.98$; $p < 0.05$). For small mammals, *G. griseoflavus* and *E. typus* occupied areas with high density of cattle feces, whereas *A. molinae* and *C. musculinus* were found in areas with increasing grass and herbaceous cover (Fig. 1a).

For medium-sized mammals, the ordination unambiguously separated two groups, those at sites outside the Reserve, and those

Table 1
Total number of small mammals captured during 2001 and 2002; feces/ha recorded for medium-sized mammals and colonies/ha (only for *Microcavia australis*); and species richness for each habitat type in protected and unprotected areas, Ñacuñán, Monte Desert.

	Protected area			Unprotected area		
	Prosopis woodland	*Larrea* shrubland	Sand dunes	*Prosopis* woodland	*Larrea* shrubland	Sand dunes
Small mammals						
Akodon molinae	40	113	41	68	39	29
Graomys griseoflavus	62	69	56	53	46	41
Calomys musculinus	21	47	21	17	42	18
Eligmodontia typus	7	7	21	9	18	31
Medium-sized mammals						
Dolichotis patagonum	0	0	0	202	18	0
Microcavia australis	25	0	0	128	25	13
Galea leucoblephara	75	142	3	59	21	8
Lepus europaeus	0	0	5	154	21	30
Species richness	7	6	7	9	9	8

at sites inside it (Fig. 1b). *D. patagonum*, *M. australis* and *L. europaeus* were species more associated with unprotected habitats, whereas *G. leucoblephara* was associated with protected habitats (Fig. 1b). A significant positive correlation was found between axis 1 and grass cover ($r_{grasses} = 0.78$; $p_{grasses} = 0.02$), whereas axis 1 had negative

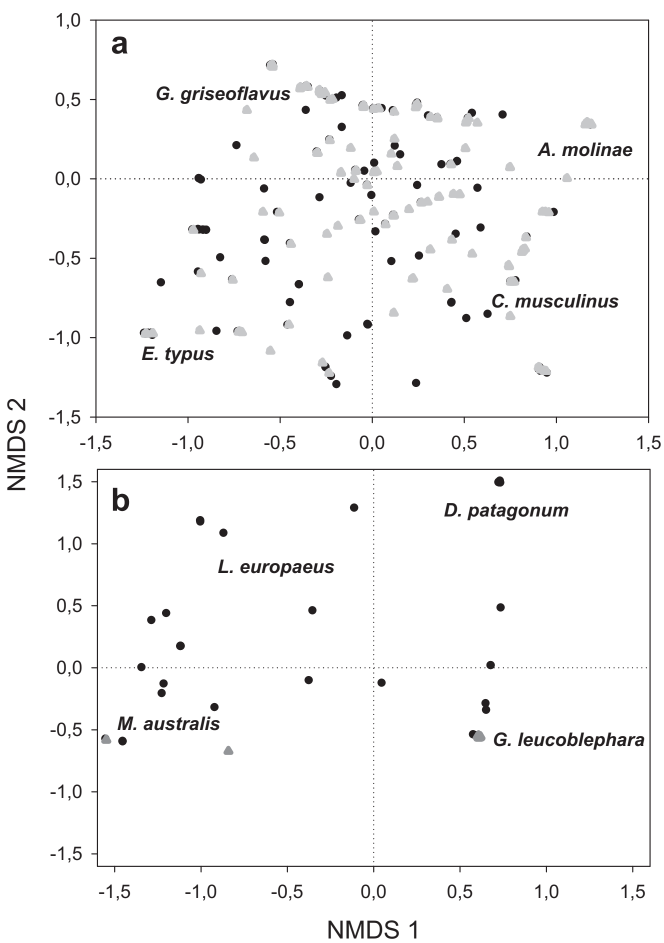

Fig. 1. Non-Metric Multidimensional Scaling (NMDS) ordination based on Bray Curtis matrix of small mammal (a) and medium-sized mammal (b) abundances in the protected (▲) and unprotected (•) areas. Stress values are 0.08 and 0.10, respectively.

correlations with bare soil and density of cattle feces ($r_{bare\ soil} = -0.34$; $r_{feces} = -0.67$; $p < 0.05$). We interpreted axis 1 as a situation of degraded landscape because of the significant relationships between bare soil and grazing. Only the density of cattle feces was positively related to axis 2 ($r_{feces} = 0.81$; $p_{feces} = 0.04$). The other categorical variables were non-significant.

4. Discussion

After nearly over 50 years of large herbivore exclusion, our results show significant differences in habitat structure and mammal diversity between areas, suggesting that the mammal assemblage studied is partially protected in the Reserve. Some small rodents like *A. molinae* and *C. musculinus* seem to have benefited from this exclosure as it has led to higher plant density and reduced predation risk (Tabeni and Ojeda, 2005). However, the protected area shows a decrease in richness and abundance of medium-sized mammals. For instance, *M. australis* occupies habitats under a grazing regime where the vegetation structure allows the species to build its colonies under plants with an umbrella-like pattern (Tognelli et al., 1995). Another example is *D. patagonum*, whose adaptations for running and communicating in open habitats (long limbs, clavicle reduction and well-developed sensory organs; Campos et al., 2001) have led to its preferential use of the relatively more open unprotected sites. Our results illustrate how a protected area becomes an unsuitable landscape for this vulnerable species, and raise conservation concerns given the hunting pressure historically exerted on it as well as its competition for food with livestock (Campos et al., 2001).

For small mammal species, the patterns found here are consistent with those in other grazing lands in which grazed areas are occupied by species that inhabit open areas with low plant cover. They show specialized morphologies to detect predators (e.g. inflated tympanic bullae, long hind limbs for bipedal locomotion) that are also present in some species (e.g., *Eligmodontia*) similar to members of the family *Heteromyidae* in North America (Jones et al., 2003) and subfamily *Gerbillidae* in Africa (Eccar et al., 2000) and India (Wada et al., 1995). In contrast, Jones et al. (2003) pointed out that some genera such as *Baiomys*, *Reithrodontomys* and *Sigmodon* predominate in mesic grasslands/shrublands with dense cover before being reduced by grazing.

On the other hand, there is little evidence of the effects of grazing exclusion on medium-sized mammals. Adler and Lauenroth (2000) observed that the burrow density of rodents such as *Spermophilus tridecemlineatus* was significantly higher in ungrazed areas in Colorado shortgrass steppe. Some lagomorphs, such as the pygmy rabbit (*Brachylagus idahoensis*), have had drastic population reductions in the presence of cattle in sagebrush steppe of North America (Thines et al., 2004). Evidence for other taxa has shown that maintaining a diverse mosaic of grazed and protected areas in South Africa enables the persistence of reptiles and arthropods adapted to both xeric and mesic environments (Fabricius et al., 2003).

Our results indicate that environmental heterogeneity plays a major role in understanding species responses to landscape changes caused by livestock exclusion. Protected areas are often managed as islands immersed in a surrounding matrix without considering functional linkages with the context, conversely, surrounding lands are strongly linked to the ecological processes occurring in the core-protected areas, mediating fluxes between patches and enabling long-term persistence of biota (Wiens, 2009).

Protection from livestock disturbance and regrowth of *Prosopis* woodlands were the primary goals in establishing a protected area within the study region, seeking a return to natural conditions free from human interference, eventually leading to a notable recovery of native plant cover and a reduction in bare soil. Nevertheless, such natural conditions are totally or partially unknown in most cases (Fleischner, 1994). In semiarid regions of South America, coevolutionary relationships between herbivores and vegetation have scarcely been addressed. Despite the current scarcity of large herbivores in the semiarid areas of Argentina (Bucher, 1987), the diversity of species composing the megaherbivore fauna during the Pleistocene is remarkable (Bucher, 1987; Mac Fadden, 2000). These herbivores must have had exerted important selective pressures on the arid and semiarid land vegetation (Bucher, 1987). Historically, the guanaco (*Lama guanicoe*) has been the largest native herbivore in the semiarid eco-regions of Argentina (e.g. Chaco, Patagonia and Monte) before colonizers introduced domestic herbivores (Bucher, 1987). However, the guanaco is currently locally extinct in our study area, being present until the late 19th century (Rusconi, 1967).

In view of the mammal responses found in this study, we highlight that unprotected parts of the landscape, although largely ignored, may play a critical role in the conservation of some species. The mosaic of protected and unprotected areas possesses important resources for the persistence of the regional pool of species with different attributes and habitat requirements.

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