Mastozoología Neotropical, 24(2):289-300, Mendoza, 2017

Versión impresa ISSN 0327-9383
Versión on-line ISSN 1666-0536

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Sección Especial
IMPACTO DE ACTIVIDADES PRODUCTIVAS SOBRE MAMÍFEROS DE ARGENTINA

SMALL MAMMALS IN AGROECOSYSTEMS: RESPONSES TO LAND USE INTENSITY AND FARMING MANAGEMENT

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ABSTRACT. The Province of Córdoba, Argentina, has undergone a marked transformation due to the expansion and intensification of agriculture. With almost 9 Mha under crop production from 2014-2015, this province is one of the main agricultural regions of the country. This agricultural intensification implies increasing agrochemical use, removal of border habitats, replacement of crop-grazing by a double cropping system and landscape homogenization. These factors produce alterations in habitat quality and suitability, and consequently have negative effects on biodiversity. The effects of agricultural intensification and farming management could vary with the degree of habitat specialization of different species. The objective of this work was to describe a state-of-art about the most recent responses of small mammals with different degrees of habitat specialization to land-use intensification and farming management, using data obtained by our research group in agroecosystems of the Córdoba Province. This mammalian group was used as a model due to its important contribution to the maintenance of complex food webs and the sustainability of agroecosystems. The maintenance of undisturbed linear habitat networks and implementation of organic farming in intensively managed agricultural landscapes can attenuate the effects of agricultural intensification by providing suitable habitats for small mammal populations, contributing to the maintenance of biodiversity. Moreover, organic farming has a positive effect on female reproductive activity and small mammal abundance. This research contributes to the development of a theoretical framework of Argentinean agroecosystems that combines efficient agricultural land use with biodiversity conservation.

RESUMEN. Pequeños mamíferos en agroecosistemas: respuestas a la intensidad del uso de la tierra y al manejo agrícola. La provincia de Córdoba ha sufrido una marcada intensificación y expansión de la agricultura. Con casi 9 Mha sembradas en 2014-2015, es una de las principales provincias productoras del país. Esta intensificación de la agricultura implica un incremento en el uso de agroquímicos, pérdida de hábitats naturales, destrucción de hábitats de bordes, reemplazo de un sistema cultivo-pastoreo por doble cultivo y homogeneización del paisaje. Estos factores producen alteraciones en la calidad y adecuación de los hábitats y tienen efectos negativos sobre la biodiversidad. Los efectos de la intensificación y del manejo agrícola sobre la biodiversidad pueden variar con el grado de especialización de hábitat de diferentes especies. El objetivo de este trabajo fue describir el estado del arte de la respuesta de pequeños mamíferos con diferente grado de especialización de hábitat a la intensificación en el uso de la tierra y al manejo agrícola, utilizando datos obtenidos por nuestro grupo de investigación en agroecosistemas de Córdoba. Se utilizó este grupo como modelo de estudio debido

Recibido 20 julio 2016. Aceptado 18 de abril 2017. Editor invitado: J. Priotto. Editor asociado: E. Lessa

a su importante contribución al mantenimiento de redes tróficas complejas en agroecosistemas, siendo fundamentales en el mantenimiento de su sustentabilidad. El mantenimiento de una red de hábitats lineales y la implementación del manejo orgánico en paisajes agrícolas manejados intensivamente puede atenuar los efectos de la intensificación agrícola proveyendo hábitats adecuados para las poblaciones de pequeños mamíferos, contribuyendo de esta manera al mantenimiento de la biodiversidad. Además, el manejo orgánico tiene un efecto positivo sobre la actividad reproductiva y la abundancia de especies de este grupo. El conocimiento generado contribuiría al desarrollo de un marco teórico propio para los agroecosistemas argentinos que combine un uso de la tierra eficiente con la conservación de la biodiversidad.

Key words: Conventional management. Córdoba-Argentina. Habitat generalists. Habitat specialists. Organic management.

Palabras claves: Córdoba-Argentina. Especialistas de hábitat. Generalistas de hábitat. Manejo convencional. Manejo orgánico.

INTRODUCTION

The conversion of natural landscapes in croplands and pastures constitutes one of the most widespread land-use activities worldwide (Foley et al. 2005). The environmental impacts of agriculture include those caused by expansion (when croplands and pastures extend into new areas, replacing natural ecosystems) and those caused by intensification (when existing lands are managed to be more productive through the use of irrigation, fertilizers, biocides and mechanization) (Foley et al. 2005). Clearance for cropland or permanent pasture has already reduced the extent of natural habitats on agriculturally usable land by more than 50% from 1985 to 2005 (Foley et al. 2011). Such intensive management to increase production can further reduce biodiversity of farmed land and subsequent ecosystems functions (Tscharntke et al. 2005). For this reason, achieving the efficient combination between agricultural land use and biodiversity conservation has become a new challenge. In the recent discussion about agriculture and biodiversity, the debate is posed between land sharing and land sparing (Perfecto & Vandermeer 2012; Tscharntke et al. 2012). Land sparing refers to the possibility of segregating land for nature from land for production. Thus, agricultural intensification for the purpose of increasing farmland productivity by area results in reducing encroachment on natural habitats. On the other hand, land sharing implies that production and conservation can be integrated in the same parcel of land (Green et al. 2005; Tscharntke et al. 2012). The last approach argues that the global application of wildlife-friendly farming methods, including the retention of patches of natural habitat and extensively farmed seminatural habitats within the countryside, as well as farming in ways that minimize the negative effects of fertilizers and pesticides on non-target organisms, would reduce the impact of agriculture on biodiversity (Green et al. 2005; Perfecto & Vandermeer 2012; Tscharntke et al. 2012). Organic farming is an environmentally friendly practice that allows for higher levels of habitat heterogeneity and greater densities of uncropped habitats compared to conventional farming (Fuller et al. 2005). Organic practices recognize the importance of providing uncropped border habitats for wildlife. In addition, insecticides, herbicides and inorganic fertilizers are largely or entirely avoided. Less treatment with these chemicals, or a lack thereof, promotes well-maintained and more suitable border habitats for wildlife (Norton et al. 2009; Coda et al. 2014).

The "conventional" (land sparing) vs. "agroecological" (land sharing) dichotomy has received much attention in Europe, where wildlife-friendly farmland has strong support due to the evidence of declines in the previously high biological value of long-established agroecosystems (Green et al. 2005; Tscharntke et al. 2005). In Europe, agricultural intensification has been recognized by scientists for almost five decades (TOPIC: [Europe] AND TOPIC:

[agricultural intensification]; published items: 1115 since 1957; Web of Science® Citation Report, 2016). In Latin America, the rates of agricultural expansion and intensification have increased considerably in the last decades due to technological changes (e.g. no-tillage techniques, genetically modified crops) and market conditions (e.g. global increase in soybean demand; Baldi & Paruelo 2008). Particularly in Argentina, the farming area dedicated to no-tillage cropping system increased from 2 Mha in 1992-1993 to 27 Mha in 2010-2011 (Aapresid 2012; Álvarez et al. 2015), and during this process, many field borders were removed to enlarge crop areas (Aizen et al. 2009). Furthermore, the area of organic farmland in this country is small; currently there are 3.6 Mha of organic farmland with only 240 000 intended for crop production, whereas the rest is dedicated to pastures for cattle production (SENASA 2014). The Córdoba Province is located in the center of Argentina and is one of the main productive regions of the country, with almost 9 Mha under crop production from 2014-2015 (MAGyA 2013). Thus, this province has undergone a marked transformation due to the expansion and intensification of agriculture. In spite of these important changes in agricultural landscapes, there are far fewer data on farmland biodiversity in less developed regions (Green et al. 2005). In Latin America, these research topics are still underrepresented and only became part of the public interest in the 1980s (TOPIC: [Latin America] AND TOPIC: [agricultural intensification]; published items: 59 since 1982; Web of Science® Citation Report, 2016).

The effects of agricultural expansion and intensification on biodiversity have been investigated in different animal taxa at local and landscape scales (Donald et al. 2001; Bilenca et al. 2007; Medan et al. 2011; Fuentes-Montemayor et al. 2012). Such effects are observed at the local scale, due to an increase in the use of pesticides and fertilizers, and at the landscape scale due to a loss, degradation or subdivision of natural or semi-natural habitats (Hole et al. 2005; Fischer & Lindenmayer 2007; Concepción et al. 2008; Geiger et al. 2010). The responses of species to these disturbances depend on their biology, behavior and habitat requirements. Thus, a given species can be more prone or more resilient to extinction in modified landscapes (Fischer & Lindenmayer 2007; Didham 2010). The responses of species to agricultural intensification could vary with their degree of habitat specialization. Specialist species are more dependent on habitat quality (Hall et al. 1997; Johnson 2007) and suffer more from habitat disturbance than generalists, which are able to use other habitats and resources (Julliard et al. 2006; Fischer et al. 2011; Fischer et al. 2013; Coda et al. 2015; Gomez et al. 2015; Schlinkert et al. 2016). Thus, the abundance of habitat generalist or specialist species can be used as an indicator for the degree of disturbance.

Among species groups that coexist in agricultural landscapes, small mammals are crucial due to their contribution to well-structured food webs (Salamolard et al. 2000; Butet & Leroux 2001; Arlettaz et al. 2010), the consumption and dispersal of plant material (Kiviniemi & Telenius 1998; Kollmann & Bassin 2001; Kollmann & Buschor 2002; Baraibar et al. 2009; Fischer et al. 2011), as well as mycorrhizal fungi (Schickmann et al. 2012), and the consumption and control of invertebrates (Gliwicz & Taylor 2002). As small mammals rapidly respond to environmental change, due to their short live cycles and restricted spatial areas, such species can serve as model organisms for a better understanding of ecosystem and landscape processes (Barrett & Peles 1999). Further, small mammals show distinct degrees of habitat specialization. In central Argentinian agroecosystems, the small mammal assemblage is mainly represented by the Cricetidae rodents *Calomys musculinus*, *C. venustus*, *C. laucha*, *A. azarae*, *A. dolores*, *Oxymycterus rufus* and *Oligoryzomys flavescens* (Simone et al. 2010). Rodent species were ranked from generalists to specialists considering species-specific habitat specialization; ranging from habitat generalist (species that occur in almost all habitats within the agriculture landscape) to habitat specialist (species that occur in habitats with high vegetation cover or with specific habitat requirements): *C. musculinus*, *C. laucha*, *A. azarae*, *O. flavescens*, *C. venustus*, *A. dolores* and *O. rufus* (Martínez et al. 2014; Coda et al. 2015).

Together, the widespread environmental impacts of agricultural activity on biodiversity, and the important contribution of small mammals to the maintenance of complex food webs in agroecosystems, highlight an urgent need for the development of a new theoretical framework that considers environmental, social, political and economic characteristics of productive systems and the particular characteristics of native mammalian species. The objective of this work was to provide a state-of-art about the responses of small mammals with different degrees of habitat specialization to land-use intensification and farming managements in the Córdoba Province of Argentina.

MATERIALS AND METHODS

Study area

We conducted our research in agricultural systems in the southern Córdoba Province (**Fig. 1**), from north to south between the Elena (32° 34' S, 64° 23' W) and Washington (33° 52' S, 64° 41' W) localities, and from east to west between the Arias (33° 38' S, 62° 24' W) and Río Cuarto (33° 08' S, 64° 21' W) localities. The study area was located in Juárez Celman, Marcos Juárez, Río Cuarto and Unión Departments, which represent the 39% of the total surface area in the province with 3.3 Mha under crop production from 2014-2015 (MAyG 2016). This region corresponds to the Espinal and Pampean ecoregions; however, the vegetation has undergone marked alterations as a result of agriculture and cattle farming. At present, the landscape consists of a matrix of crop/pasture fields surrounded by field borders, railways and other types of linear habitats. These linear habitats frequently receive intentional or unintentional spraying of broad-spectrum herbicides from the neighboring crops (De la Fuente et al. 2010; Ghersa et al. 2002). Despite the influence of crop fields, linear habitats have an homogeneous plant cover throughout the year that provide more stable cover than crop fields (Gomez et al. 2011; Coda et al. 2014). Thus, the study area has different landscapes in relation to land-use intensity and farming management. Initially, to evaluate small mammal response to land-use intensity, our research was carried out considering both high and low land-use intensity landscapes (**Fig. 1**). In the former, cultivated surface (mainly with soybean and corn, and high agrochemical use) is twice the pasture surface (for livestock) and many of the linear habitats were removed to enlarge agricultural fields. In the latter, the number of hectares for pastures and for crops was similar due to the presence of dunes with native grasslands and for-

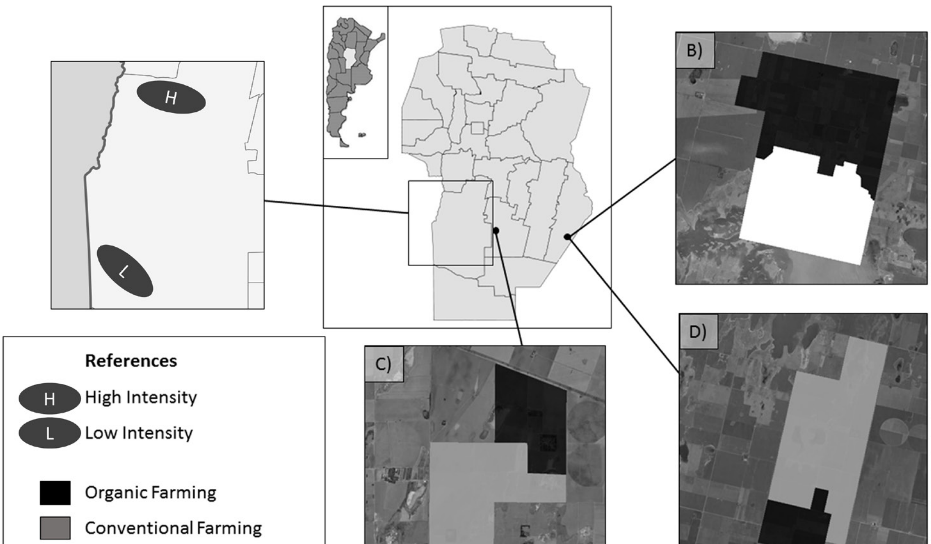

Fig. 1. Study area comprised within the agricultural systems of the center-southern region of the Córdoba province. A) High and low land-use intensity landscapes; B), C) and D) Dos Hermanas, Las Gaviotas and Altos Verdes farms, respectively.

est patches of *Prosopis* spp. (Martínez et al. 2014). Finally, to evaluate the small mammal response to farming managements, the study area focused on a landscape characterized by the presence of both organic and conventional farms. Considering the low number of hectares managed by organic farming in Argentina, and particularly in southeastern Córdoba Province, we were able to survey the entire surface area managed by organic farming. Three farms were sampled: Las Gaviotas (Postel S.A.; 33° 50' S, 62° 39' W) (1689 ha), Dos Hermanas (Foundation Rachel and Pamela Schiele; 33° 39' S, 62° 30' W; 4023 ha) and Altos Verdes (Huanqui S.A.; 33° 18' S, 63° 51' W; 1010 ha) (**Fig. 1**). The productive area of Dos Hermanas (2101 ha) has been managed through organic strategies since 1992, while Las Gaviotas and Altos Verdes fall under both organic and conventional management (LG: 330 ha organic, 1359 ha conventional; AV: 346 ha organic, 664 ha conventional). Organic plots of these two farms have been managed as such for 10 years. Weeds of plots under organic management are mechanically controlled using disk plough, chisel plough and roll and weeder machinery, whereas farms under conventional management use herbicides for weed control. Other fertilizers and insecticides are regularly used in conventional plots, while fungicides are used as required (Coda et al. 2014; 2015 and Gomez et al. 2015 to see more details).

Field work

Removal (autumn 2009) and capture-mark-recapture (from spring 2011 to autumn 2013) trap-lines were used to study land-use intensity and farming management, respectively. Both parts of our study were conducted in border habitats. Borders were defined as 1.5–2.5 m wide vegetation strips located between fields and secondary roads in the land-use intensity study and in the inner margin of fields in the farming management study. In the latter, additional trap-lines were placed parallel to border lines at 15 m within crop plots in organic and conventional farms. Each line had 20 traps similar to Sherman live-traps, with a trap every 10 m in the middle of a border (Coda et al. 2014; 2015 and Gomez et al. 2015 to see more details). Traps were active 4 consecutive nights during each sampling session. Trap-lines were considered replicates for statistical analyses. Trapped animals were identified, sexed, weighed and ear-tagged (if applicable). Body and tail length were also registered. The abundance values of each species were obtained as the number of individuals in each trap-line, and richness was calculated as the number of different species captured within each trap-line. In both studies, habitat characteristics of each trap-line were also registered. In the land-use intensity study, habitat characteristics were measured using border width, border height, and land-use on both sides of the border (crop, stubble or pasture). Additionally, a heterogeneity index was defined to assess landscape heterogeneity, and two environmental variables were estimated for each line: Normalized by Difference Vegetation Index (NDVI) and land surface temperature (LST). In the farming management study, land-use on both sides of the border and vegetation characteristics (plant litter, green cover and vegetation volume) were registered (Coda et al. 2014; 2015 and Gomez et al. 2015 to see more details).

RESULTS AND DISCUSSION

Species richness

A total of 634 individuals belonging to 7 small mammal species were trapped in 3200 trap-nights located in the high land-use intensity landscape, whereas a total of 233 individuals belonging to 10 small mammal species were captured in 1280 trap-nights located in the low land-use landscape (**Table 1**). *Necromys lasiurus*, *Graomys griseoflavus*, *Monodelphis dimidiata* and *Thylamys pallidior* were only found in trap-lines placed in the low land-use intensity landscape. In this zone, there were greater proportions of grasslands and xerophytic woodlands, characteristics of the Espinal ecoregion. This fact possibly explains the presence of these species, considered distinctive species of the abovementioned ecoregion, since these species are not usually captured in our studies. *Calomys laucha* was only captured in trap-lines within the high land-use intensity landscape. *Calomys musculinus* and *A. azarae* were the most frequently captured rodent species in trap-lines under high and low land-use intensity landscapes, respectively (**Table 1**). Considering that these small mammal species belong to Cricetidae family (the most abundant group), a clear trend of increasing relative abundance of the specialist species was observed in the low land-use intensity landscape. Conversely, a downward trend in abundance of the more generalist species was observed in the same landscape.

Table 1

Species richness and abundances of each species by high and low land-use intensity landscapes.

	High land-use intensity		Low land-use intensity	
	Mean ± SE	**Rank**	**Mean ± SE**	**Rank**
Richness	3.60±0.9	2-5	3.3±1.7	1-7
	N = 40		N = 20	
Species abundance	**Mean ± SE**	**Total (Capture %)**	**Mean ± SE**	**Total (Capture %)**
Calomys musculinus	7.6±7.0	303 (47.8)	2.4±3.9	45(19.3)
Akodon azarae	5.2±3.9	206 (32.5)	5.1±4.5	96(41.2)
Oxymycterus rufus	0.9±1.1	34 (5.4)	2.2±2.4	42(18.0)
C. venustus	1.4±1.8	55 (8.7)	0.1±0.3	2(0.9)
Oligoryzomys flavescens	0.5±0.9	21 (3.3)	0.3±0.6	6(2.6)
Necromys lasiurus	-	-	1.2±2.7	22(9.4)
A. dolores	0.1±0.5	4 (0.6)	0.5±1.7	9(3.9)
C. laucha	0.3±0.7	11 (1.7)	-	-
Graomys griseoflavus	-	-	0.3±0.9	5(2.1)
Monodelphis dimidiata	-	-	0.3±0.6	5(2.1)
Thylamys pallidior	-	-	0.1±0.2	1(0.4)

Standard error (SE).

Table 2

Species richness and abundances of captured species in organic and conventional border habitats.

	Organic		Conventional	
	Mean ±SE	**Rank**	**Mean ±SE**	**Rank**
Richness	1.3±1.1	0-5	1.2±0.9	0-4
	N_{total} = 104 trap-lines		N_{total} = 118 trap-lines	
Species abundance	**Mean ±SE**	**Total**	**Mean ±SE**	**Total**
Calomys musculinus	1.6±2.3	203	1.7±2.5	168
C. laucha	0.8±1.9	80	0.7±1.0	78
Akodon azarae	0.4±1.0	42	0.3±0.8	32
Oligoryzomys flavescens	0.2±0.6	21	0.04±0.2	5
Oxymycterus rufus	0.01±0.1	1	0.02±0.1	2
C. venustus	0	0	0.03±0.2	3

Standard error (SE).

We trapped a total of 312 and 323 individuals corresponding to 6 species in 8320 and 9440 trap-nights in organic and conventional farms, respectively (**Table 2**). The total abundance of rodents was similar in organic and conventional farms in both years (**Table 2**). Nine *C. musculinus* and 3 *C. laucha* were captured in 640 trap-nights within crop plots in organic farms, and 1 *A. azarae*, 3 *C. musculinus* and 6 *C. laucha* were captured in 560 trap-nights in conventional crop plots. Richness was not associated with farming practices, rather the lowest richness values were registered in spring corresponding to the lowest vegetation volumes (**Fig. 2a** and **d**). Fischer et al. (2011) found that organic farming had a positive effect on species richness in simple landscapes (>80% of arable land) at a small spatial scale (100 m). In our study, the percentages of arable land were always lower in organic than in conventional farms; however, this was not enough to produce an effect on species richness at the spatial scale considered in our study. In European landscapes, small mammals respond to both local and landscape scale effects (Fischer et al. 2011; Fischer & Schröder 2014), with higher small mammal abundance, species richness and diversity in conventional fields of complex landscapes and organic fields of simple landscapes (Fischer et al. 2011). The landscape complexity and its interaction with farming practices have not yet been assessed in Argentina. Complex landscapes appear to support small mammal colonization of crop fields and may increase habitat connectivity (Alain et al. 2006; Fischer et al. 2011). In Argentina, mean plot sizes of agricultural systems are larger than those of European systems (in our study, mean plot size >30 ha versus <10 ha on average in European systems, e.g. Fischer et al. 2011), fully exceeding the dispersal scale of rodent species (Sommaro et al. 2010; Gomez et al. 2011). Thus, crop fields in conventional farms with scarce weed cover could not connect suitable habitats for small mammals nor provide shelter from predators, reinforcing the importance of border habitats

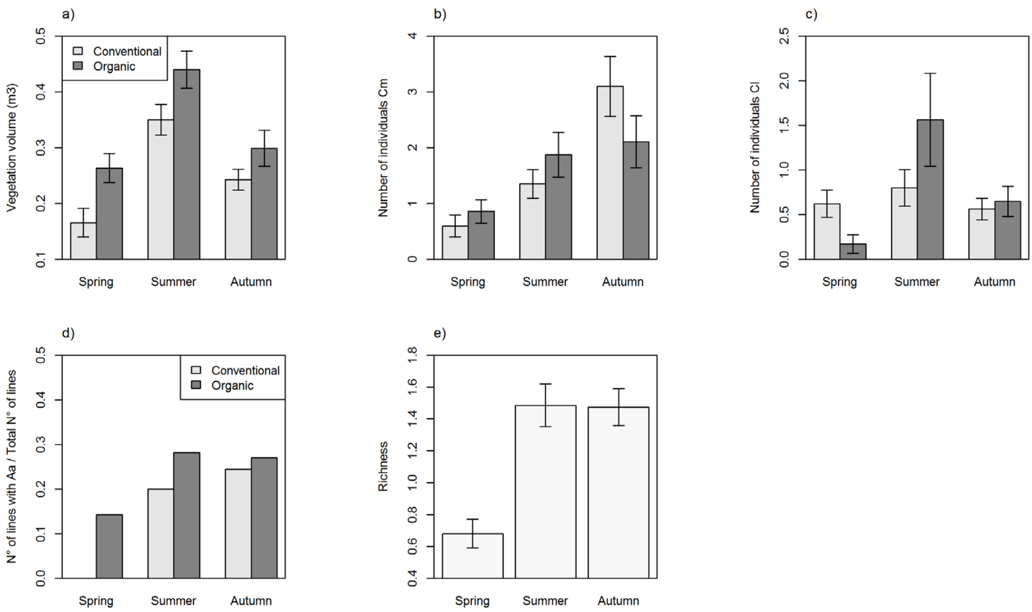

Fig. 2. (a) Vegetation volume (mean ± SE) in border habitats under organic or conventional managements by season. Number of individuals (b) *Calomys musculinus*, (c) *Calomys laucha* in border habitats under organic and conventional managements by season. (d) Number of lines where *Akodon azarae* individuals were captured in relation to the total number of trap-lines by management and season. (e) Small mammal species richness in border habitats by season. N = 35, 32 and 37 trap-lines in organic and N = 37, 40 and 41 in conventional farms by season.

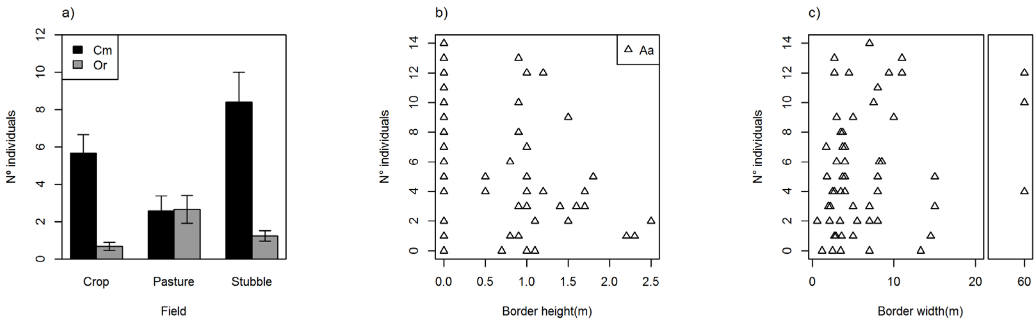

Fig. 3. a) Number of individuals of *Calomys musculinus* (Cm) and *Oxymycterus rufus* (Or) in relation to the land use on both sides of the border (Mean ± SE); Relationship between *Akodon azarae* (Aa) abundance and b) border height, c) border width.

as corridors and sources of resources for long-term survival and reproduction in these agroecosystems (Sommaro et al. 2010; Gomez et al. 2011; Coda et al. 2014). Although mean plot sizes of organic farms are similar to those of conventional ones, the former could provide more resources (coverage and food) for small mammals in both border habitat and crop fields, which could be related to the exclusion of external inputs (Coda et al. 2014). If this is the case, we expect that organic farming has positive effects on abundance and richness of small mammals in simple landscapes such as intensively managed Argentinian farmland.

Specialist species

Analyses of abundance were performed using the most abundant species. In relation to land-use intensity study, *A. azarae* abundance decreased with border height (**Fig. 3b**) and increased with border width (**Fig. 3c**). There were no effects of land-use intensity on *A. azarae* abundance. In relation to farming management, *A. azarae* was captured more often in border habitats of organic rather than conventional farms (**Fig. 2 d**). During spring, vegetation volume reached a low point and we only captured *A. azarae* in border habitats of organic farms. During summer, *A. azarae* had a higher frequency of occurrence in organic farms, making up 28.13% of the total trap-lines captures (N = 32), whereas individuals of this species represented only 20% of the total trap-line captures in conventional farms (N = 40). During autumn, *A. azarae* individuals represented 27.03% (N = 37) and 24.39% of the total trap-line captures (N = 41) in organic and conventional farms, respectively.

Oxymyxterus rufus was more abundant in the landscape with low land-use intensity and its abundance varied in relation to the land-use on both sides of the border, being more abundant in pasture fields (**Fig. 3a**). It was not possible to use this species in the analyses of farming management due to its low numbers. The low abundance of this species could be due to the type of sampling design used in this study where borders were located in the inner margin of fields. These types of borders would not have stable vegetation cover similar to borders between fields and secondary roads, since they go through permanent interventions of agricultural practices (Coda et al. 2014; 2015).

Specialist species as *O. rufus* and *A. azarae* may suffer more from environmental stress and declining population numbers with high levels of land-use intensity and conventional management. The highest habitat quality of organic farm borders explains the higher capture rates of the specialist *A. azarae* in this land management type. It is expected that this type of management renders crop fields and border habitats of organic farms more suitable habitats for a variety of taxa. Particularly, our findings showed that habitat quality of organic farm borders was the highest due to the increased vegetation volume mainly comprised of green cover. On the other hand, border habitat quality on conventional farms was the lowest, as a consequence of the small vegetation volume, mainly comprised of plant litter (Coda et al. 2014; 2015). The higher captures of the specialist species *A. azarae* in more vegetated and less disturbed habitat is in line with previous studies of this species (Busch et al. 2001; Andreo et al. 2009; González Fischer et al. 2012). *Oxymycterus rufus* is considered the most specialized within the four abovementioned species due to its semifossorial habits, and the fact that it is exclusively captured in grasslands often associated with watercourses (Pardiñas et al. 2001).

Generalist species

Calomys musculinus was more abundant in the landscape with high land-use intensity and its abundance varied in relation to land-use on both sides of the border. The highest abundance of *C. musculinus* was registered in stubbles, and the lowest was detected in pasture fields (**Fig. 3a**). Although *C. laucha* was only captured in the high land-use intensity landscape, it was not possible to analyze the data due to low capture rates. Generalist species as *C. musculinus* may benefit and increase abundance under high land-use intensity. Different studies reported that agricultural intensification and expansion over Espinal and Pampean regions have favored generalist species as *C. musculinus* since it is a good settler of disturbed habitats as agricultural systems due to its habitat and trophic niche width (Bilenca & Kravetz 1995; Busch et al. 2000; Sommaro et al. 2010).

The most captured species in border habitats of organic and conventional farms were generalist *C. musculinus* and *C. laucha*. During the summer, the responses of generalist species were similar to the specialist species, since their abundances were higher in border habitats of organic than of conventional farms. These findings could be related to the highest reproductive activity associated with this season and the best habitat quality of organic border habitats (highest values of vegetation volume; Coda et al. 2014). Also, such higher habitat quality may be accompanied by a higher movement rate towards more suitable border habitats of organic farms. In all other seasons, the relationship between management and abundance varied by species. In spring, *C. laucha* was more captured in borders under conventional management, and *C. musculinus* showed little difference between farming practices. On the contrary, during autumn *C. laucha* did not show differences of abundance between managements and *C. musculinus* was more abundant in borders of conventional farming (**Fig. 2d** and **e**). During these seasons, when border habitat quality decreases, organic management appears to have less influence on the abundance of the generalist species studied.

CONCLUSIONS AND PERSPECTIVES

Habitat specialization has been outlined as a key concept to predict the adaptive response of populations to fluctuating environments, such as agroecosystems (Levins 1968). In our study, the effects of land-use intensification on population abundances were species-specific. While specialist species may mostly be affected by environmental stressors such as habitat fragmentation or chemicals utilized in agroecosystems, generalist species may benefit from the relaxation of competition in agroecosystems. The absence of species characteristic of the Espinal ecoregion in high land-use intensity landscapes suggests that specialist species are more sensitive to habitat deterioration and loss. Variable land-use intensity was a good predictor of species abundance and allowed a clear separation of species with different habitat specialization grades. High land-use intensity landscapes seem to favor more opportunistic and generalist species, while specialist species may be more frequently associated to less disturbed and unmodified habitats. Our results showed that organic management in farmlands under intensive agriculture has a positive influence on specialist species abundance. Given that small mammal specialist species are more dependent on habitat quality (measured as green cover), their abundances would be a good indicator of habitat quality in farmlands. The characteristics related to linear habitats, such as border width and height, and land-use on both sides of borders would be relevant variables to explain species abundances.

Considering the important positive role that small mammals have on food webs in agricultural ecosystems, the maintenance of high population numbers may be important for biodiversity conservation. Based on our data, we show support for the idea that the implementation of some minor practices, such as the preservation of wide border habitats with characteristics similar to natural habitats, would be crucial to ensure sustainable management of agricultural systems. In intensively managed agricultural landscapes, the maintenance of undisturbed linear habitat networks can attenuate the effects of agricultural intensification by providing suitable habitats for small mammal populations, contributing to the maintenance of agroecosystem biodiversity. Furthermore, in Argentinean agroecosystems the implementation of organic farming may be a good conservation strategy for small mammals since this management has a positive effect on female reproductive activity and abundance of small mammals (Coda et al. 2014; 2015). However, landscape complexity and its interaction with farming practices have not yet been considered in Argentina. Our research group is currently working in order to assess the interaction between landscape complexity and farming practices at different spatial scales in central Argentinean agricultural ecosystems.

Given current trends in the constant demand for food and biofuel, the reversion of the current trend of agricultural intensification and expansion is a utopia. One of the greatest challenges facing humanity is the transformation of agriculture to provide food for growing human populations while maintaining farmland biodiversity and the associated ecosystem services that biodiversity provides. To achieve this goal it is critical to focus research towards tackling gaps in our knowledge about the impacts of agricultural intensification and expansion at local and landscape scales on abundance, species richness and composition of species communities. As key players in agricultural ecosystems, small mammals are ideal model organisms that can bring us to a better understanding of agroecosystems and associated landscape processes. Our research with small mammal communities in Argentinean agroecosystems, combined with studies by other groups focused on birds and soil fauna, will contribute to the development of a cutting-edge theoretical framework for this South American region that combines efficient agricultural land use with biodiversity conservation.

ACKNOWLEDGMENTS

We thank all field assistants and Foundation Rachel and Pamela Schiele, as well as Las Gaviotas and Altos Verdes farms. Financial support was provided by Consejo Nacional de Investigación Científica y Técnica (CONICET) (PIP CONICET No. 11220100100003) and Fondo para la Investigación Científica y Tecnológica (PICT 838/11 Préstamo BID).

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