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The effect of neighbourhood on rodent communities: an example from Pampean agroecosystems

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ABSTRACT

Pampean region agroecosystems are devoted to agricultural and farming activities, but in the crop field matrix there are remnants of natural habitats. Poultry farms mainly harbour commensal species as house mice and rats, which are rarely present in surrounding habitats. We assessed if neighbourhood to poultry farms affects the presence of *Mus musculus* in crop fields and their borders, and if rodent community in poultry farms is influenced by the species present in surrounding crop fields and borders. We found that habitat had a significant effect on the abundance of *M. musculus*. This species showed higher abundance in poultry farms than in crop field borders. *Calomys laucha* was the unique native species that was captured in farm sheds. We found higher abundance of native species in crop field borders than in crop fields independent of the proximity to the poultry farms. We conclude that rodent communities in poultry farms are little influenced by the surroundings, and show a dominance of *M. musculus* independently of the presence of native rodent species in neighbour habitats. On the other hand, farms do not export *M. musculus* to surrounding habitats, and borders only function as corridors for dispersal among farms, while crop fields are rarely used.

KEYWORDS

Pampean agroecosystem;
Mus musculus; native rodent;
neighbourhood to farms

Introduction

The composition and species abundance of local communities are not only affected by local characteristics, but also by the surroundings, that may affect the interchange of individuals among different patches and the rates of colonisation and recolonisation. Human-altered habitats show changes at many scales, ranging from local communities to a landscape scale, with increases in some habitats and decreases in others, including the disappearance of some natural patches and the incorporation of human-made habitats, as urbanisations, crops, livestock fields and farms. These changes affect the neighbourhood relations between different habitats that may affect species composition at the patch scale.

One of the effects of intensive habitat use by humans is, along with habitat loss, the fragmentation of the natural matrix or its replacement by crop fields or urbanisations. There is increasing interest, especially from the conservation point of view, in the knowledge of the 'patch context', that is, the nature of the matrix surrounding the favourable patches for predicting species persistence (Fahrig, 2001). Traditional models considered the matrix as inhospitable, homogeneous and ecologically irrelevant, but nowadays, it appears to be common sense that 'matrix matters' (Prevedello & Vieira, 2010). These

authors found that 95% of studies reviewed detected significant effects of the matrix type on different response variables (i.e. richness/abundance in patches and dispersal).

As well as being relevant from a conservation point of view, landscape effects may also influence the dynamics of expansion of introduced species. Grasslands are the most changed ecosystems worldwide (White, Murray, & Rohweder, 2000) and rodent communities are an example of how changes introduced by man in these systems promote responses that range from landscape to microhabitat scale (Angelstam, Hansson, & Pehrsson, 1987; Bilenca & Kravetz, 1995; Cole, McComb, Newton, Leeming, & Chambers, 1998; Grant, Birney, French, & Swift, 1982; Masters, Lochmiller, McMurry, & Bukehofer, 1998). Changes in habitat patches may cause an expansion, with native fauna incorporating new habitats, or may promote the invasion of non-commensal habitats by exotic species, depending on species specific habitat affinities, feeding habits, range of movements and social interactions (Bolger, Alberts, Sauvajot, Potenza, & McCalvin, 1997; Bowley & Dooley, 1991; Robinson et al., 1992).

Agroecosystems of the Pampean region are devoted mostly to agricultural activities, but within the crop field matrix, there are patches of remnant natural habitat, small tree plantations, pastures, urbanisations and breeding farms. These different habitats are differentially occupied by native rodent species: while azara's grass mouse [*Akodon azarae* (Fischer, 1829)], drylands laucha [*Calomys musculus* (Thomas, 1913)], yellow pygmy rice rat [*Oligoryzomys flavescens* (Waterhouse, 1837)], red hocicudo [*Oxymycterus rufus* (Fischer, 1814)] and brazilian guinea pig [*Cavia aperea* (Erleben, 1777)] are more abundant in crop field borders and less perturbed habitats, as railway embankments and riparian habitats, in crop fields small vesper mouse [*Calomys laucha* (Fischer, 1814)] is numerically dominant, but in some regions, *C. musculus* is also frequent (Bilenca, Cittadino, & Kravetz, 1995; Busch & Kravetz, 1992; Mills, Ellis, McKee, Maiztegui, & Childs, 1991). The increase in agriculture during the last centuries was associated with a numerical increase in both species of *Calomys*, while *A. azarae*, a typical grassland dwelling, is mainly restricted to crop field borders. Native species are occasionally found in commensal habitats (Fraschina, León, & Busch, 2014; Miño et al., 2001). In the area are also present three commensal murines, house mice [*M. musculus* (Linnaeus, 1758)], norway rat [*Rattus norvegicus* (Berkenhout, 1762)] and roof rat [*Rattus rattus* (Linnaeus, 1758)] which are mainly associated with poultry farms (Busch & Kravetz, 1992; Gómez Villafañe & Busch, 2007; Mills et al., 1991; Miño et al., 2001). In contrast to other regions, in Pampean agroecosystems, these species are not frequently found in non-commensal habitats, where they rarely reach pest levels. *M. musculus* is present in more than 95% of poultry farms (León, Guidobono, & Busch, 2007), which are isolated within a matrix of crop fields where this species is rare; suggesting that farm populations may be considered as local populations of a metapopulation (Moilanen & Hanski, 1998). Local populations are prone to extinctions due to chemical control by rodenticides and are recolonised from other farms, depending on the distance, or recover from remaining individuals that survive after control (León, Frascina, & Busch, 2009). In Australia and in many other islands, *M. musculus* is widely distributed and regularly reaches plague densities in crop fields (MacAllan, Westman, Crowther, & Dickman, 2003; Pech, Davis, & Singleton, 2003; Singleton, Krebs, Davis, Chambers, & Brown, 2001; Ylönen, Jacob, Davies, & Singleton, 2002). The competitive rank of *M. musculus* appears to vary depending on the presence and density of other species of rodents (Crespo, 1966); while in some areas, native rodent species prevent its expansion, in others *M. musculus* successfully invades and eliminates native species (Pefaur, Hermosilla, Di Castri, González, & Salinas, 1968).

León, Frascina, Guidobono, and Busch (2013) found that the presence of *M. musculus* in non-commensal habitats is negatively related to the distance to poultry farms and riparian habitats, suggesting that these last habitats may be corridors for dispersal between farm buildings, as suggested by Maisonneuve and Rioux (2001) for this species in Canadian agroecosystems.

Considering the present distribution of habitat patches, in this work, we wanted to assess if neighbourhood to poultry farms affect the presence of *M. musculus* in crop fields and their borders. Although previous works described the habitat use of this species, these studies did not take into account the effect of the surroundings. We also wanted to assess if the rodent community in poultry farms is also influenced by the species present in surrounding crop fields and borders. Therefore, we assess the following hypotheses: (1) *M. musculus* abundance is higher in crop fields and borders near poultry farms than in further habitats, (2) high abundance of *M. musculus* in poultry farms promotes

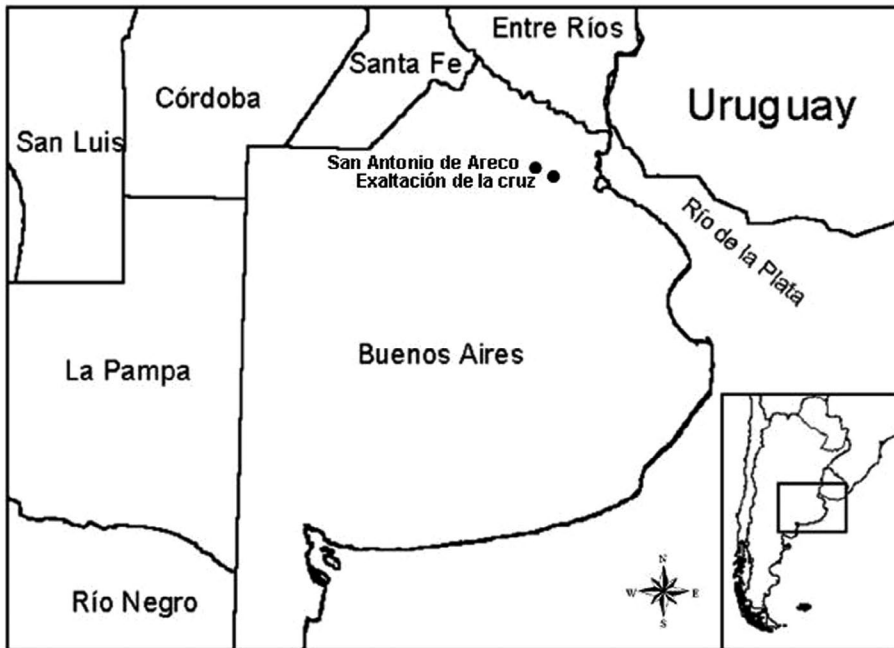


Figure 1. Location of the Exaltación de la Cruz Department, Buenos Aires Province, Argentina (Source: Authors).

its dispersion to surrounding habitats, (3) higher abundances of native species enhances their invasion of poultry farms and (4) the abundance of native species in crop fields and borders is not affected by the distance to poultry farms.

Materials and methods

Study area

The study was conducted at the Exaltación de la Cruz department, Buenos Aires Province, Argentina (34°18'S, 59°14'E; Figure 1). This area is located in the Rolling Pampa region, and is characterised by a temperate climate, with a mean annual temperature of 16 °C and an average annual precipitation of 1000 mm.

Nowadays, the study area is an agroecosystem that presents a matrix of crop fields that are frequently disturbed by agricultural activities, ploughing and herbicide application. The most frequent crops of the area include soybean, maize and wheat. Crop field size varies between 4 and 25 ha, and they are separated by wire fences along which there are thin corridors covered by a spontaneous and particular flora with both native and exotic plant species (Soriano et al., 1991). This spontaneous community is also developed along roads, railways and riparian habitats and is less disturbed by agricultural labours and livestock than fields (Bilenca & Kravetz, 1998; Busch & Kravetz, 1992). The area also has small patches of woodlots, houses and poultry farms. Crop fields cover more than 88% of the area, while their borders, which ranged between 2 and 4 m in width, cover about 2% of the area. The other natural habitats of the area, like woodlots, riparian habitats, pastures and railway embankments cover about 7% and poultry farms represent only 0.33% of the total area (Fraschina et al., 2014). Most poultry farms of the area are devoted to breeding broiler chickens and occupy about 1 ha. They are surrounded by wire fences under which there is a well-developed weed community (perimeter). Neighbouring fields are pastures, crop fields or are devoted to livestock breeding. Most poultry farms have three rectangular sheds (Gómez Villafañe et al., 2001). The distance between sheds and perimeters ranges between 2 and 20 m, depending on the size of farms and the location of sheds (Miño, Cavia, Gómez Villafañe, Bilenca, & Busch, 2007).



Figure 2. Sampling design.

Notes: PF: Poultry farm, SH: breeding sheds, IB: Internal border, defined as border of the farm perimeter, contiguous to a crop field, CFN: crop field near a poultry farm and CFA: crop field located further away from a poultry farm (Source: IMAGE © 2015, Google, Digital Globe).

Rodent sampling

We conducted seasonal rodent samplings, from July 2009 to May 2010, in 12 poultry farms, in 12 crop fields that neighbour farms (crop field near to farm: CFN) and 12 crop fields located more than 500 m away from any farm (crop field away from farm: CFA; Figure 2). This distance was based on the range of movements of the studied rodents (Chambers, Singleton, & Krebs, 2000; Witmer & Jojola, 2006). In poultry farms, we placed 10 Sherman traps along the external wall of two randomly selected breeding sheds (SH). We also placed 10 Sherman traps in the border of the farm perimeter contiguous to a crop field. This border was denominated internal border (IB) (Figure 2). In CFN and CFA, we placed three parallel lines separated by 20 m with 15 Sherman traps, one line was in the crop field border and the other two were within the crop field. All Sherman traps in each line were spaced at 10 m intervals.

Traps were baited with rolled oats mixed with peanut butter. Each trap was checked in the morning during three subsequent days at each trapping session. The location and habitat of capture, species, sex, external measures (body and tail length), body weight and external evidence of reproductive condition were recorded for each animal captured. Only the individuals captured in crop fields and their borders were marked and released at the site of capture, the rest of individuals captured were euthanized by cervical dislocation after a dose of Isoflurane (2-chloro-2-(difluoromethoxy)-111-trifluoro-ethane).

Statistical analysis

Rodent abundance was estimated by a Trapping Success Index (TSI) = number of different individuals captured/number of traps x number of nights.

The distribution of the TSI of *M. musculus* and native species among habitats was studied by Generalised Linear Mixed Models (GLMM) with binomial error structure and a logit-link function (Bolker et al., 2009; Crawley, 2012; Zuur, Ieno, Walker, Saveliev, & Smith, 2009). The TSI of each species were the response variables, the habitat an explanatory fixed factor and a block defined by two sheds of a poultry farm, its internal border, the crop field contiguous to it and a crop field located further away was considered a random factor (Figure 3). GLMM were conducted using the lme4 (Bates, Maechler, Bolker, & Walker, 2015) and MASS packages (Venables & Ripley, 2002) from the R software (R Core Team, 2013). If the effect of habitat was significant, we conducted Tukey tests in order to find which of them differed.

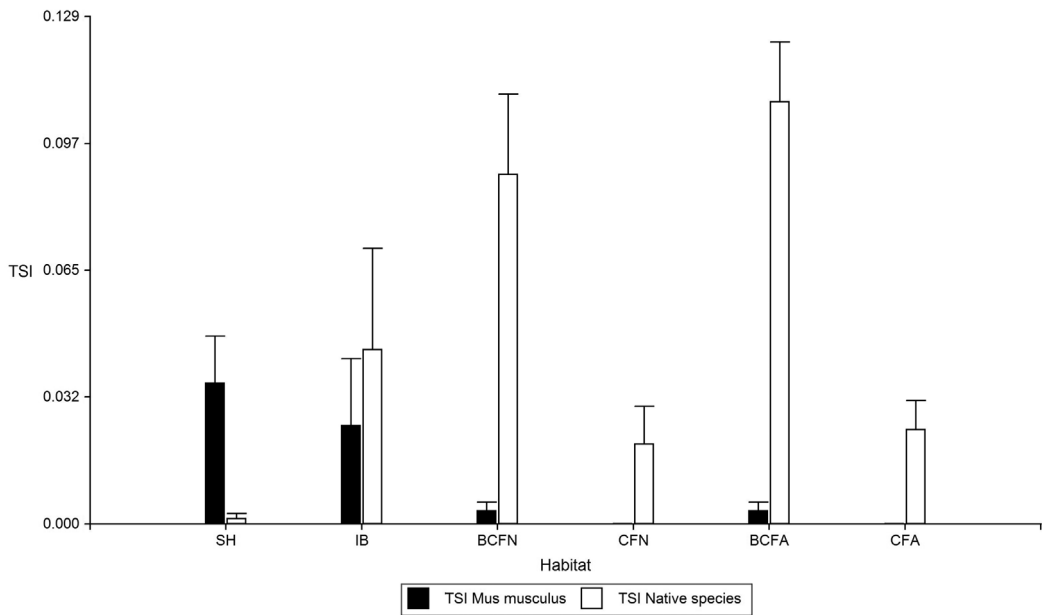


Figure 3. Trap success index (TSI) and standard errors of *M. musculus* (grey bars) and all native species (white bars) in sampled habitats. Notes: SH: breeding sheds, IB: Internal border, BCFN: border of CFN, CFN: crop fields near a poultry farm, BCFA: border of CFA and CFA: crop fields located further away of any poultry farm.

In order to test whether high numbers of *M. musculus* in breeding sheds of the poultry farms promote its expansion to other habitats, we conducted a Spearman rank correlation between the TSI of *M. musculus* in sheds and the number of habitats with presence of this species for each defined block.

Results

During the study, we captured a total of 157 individuals: 39 *M. musculus*, 69 *A. azarae*, 43 *Calomys* spp., 4 *O. flavescens* and 2 *O. rufus* with a total capture effort of 4320 trap-night. The TSI of the different species captured in each sampled habitat are shown in Table 1.

According to the GLMM, the habitat had a significant effect on the abundance of *M. musculus* ($\chi^2 = 30.228$, $df = 3$, $p < 0.0001$). This species was present in poultry farms, both in sheds and in the internal border which did not differ significantly ($Z = 0.983$, $p = 0.743$) and showed higher abundance than crop field borders ($Z = 3.177$, $p = 0.007$ for the comparison SH—BCFN; $Z = 3.177$, $p = 0.007$ for the comparison SH—BCFA; $Z = 2.481$, $p = 0.057$ for the comparison IB—BCFN and $Z = 2.481$, $p = 0.057$ for the comparison IB—BCFA). There was not a significant effect of the distance to farms in the abundance in crop field borders ($Z = 0$, $p = 1$). It was not captured in fields.

There was not a significant relationship between *M. musculus* abundance in poultry farm sheds and the number of habitats in which it was present ($p = 0.2$, $R^2 = 0.4$).

C. laucha was the unique native species that was captured in farm sheds, while in internal borders was also found *A. azarae*. *O. flavescens* and *O. rufus* were only captured in crop field borders and *C. laucha* and *A. azarae* were found in crop fields (Table 1 and Figure 3).

According to GLMM, the habitat had a significant effect on the abundance of all native species ($\chi^2 = 43.345$, $df = 4$, $p < 0.0001$). We found higher abundance of these species in crop field borders than within crop fields ($Z = -4.774$, $p < 0.001$ for the comparison CFN—BCFN; $Z = -5.270$, $p = 0.001$ for the comparison CFN—BCFA; $Z = -4.080$, $p < 0.001$ for the comparison CFA—BCFA and $Z = -3.499$, $p = 0.004$ for the comparison CFA—BCFN). We did not find statistical differences between the abundance of all

Table 1. Trap success index (TSI) for all rodent species in each sampled habitat.

Species	TSI (\pm SE) per habitat							
	SH	IB	CFN	BCFN	CFA	BCFA	CFN	BCFN
<i>A. azarae</i>	0	.0250 \pm .0131	.0056 \pm .0046	.0426 \pm .0165	.0074 \pm .0037	.0426 \pm .0172	0	.0074 \pm .0042
<i>O. flavescens</i>	0	0	0	.0074 \pm .0042	0	0	0	0
<i>O. rufus</i>	0	0	0	0	0	0	0	0
<i>Calomys laucha</i>	.0014 \pm .0014	.0028 \pm .0028	.0046 \pm .0025	.0019 \pm .0019	.0102 \pm .0040	.0037 \pm .0037	.0037 \pm .0037	.0037 \pm .0037
<i>Calomys musculus</i>	0	.0057 \pm .0057	.0028 \pm .0020	.0056 \pm .0029	.0056 \pm .0038	.01481 \pm .0096	.0056 \pm .0038	.0056 \pm .0038
Total native species	.0013 \pm .0013	.044 \pm .025	.0204 \pm .0096	.0889 \pm .0205	.0241 \pm .0073	.107 \pm .0152	.0241 \pm .0073	.0889 \pm .0205
<i>M. musculus</i>	.0361 \pm .011	.0250 \pm .017	0	.0037 \pm .0025	0	.0037 \pm .0025	0	.0037 \pm .0025

Notes: SH: breeding sheds, IB: Internal border, CFN: crop fields near a poultry farms, BCFN: border of CFN, CFA: crop fields located further away of any poultry farm and BCFA: border of CFA.

native species in CFN with respect to CFA ($Z = 1.779, p = 0.380$) neither between their borders ($Z = 0.517, p = 0.985$). We neither found differences between their abundance in IB with respect to both types of crop fields and their borders ($Z = -2.459, p = 0.097$ for the comparison IB—CFN; $Z = -1.068, p = 0.820$ for the comparison IB—CFA; $Z = -1.668, p = 0.450$ for the comparison IB—BCFN and $Z = -2.080, p = 0.223$ for the comparison IB—BCFA).

Discussion and conclusions

Our results suggest that *M. musculus* abundance in crop fields and borders are not affected by the distance to poultry farms (reject hypothesis 1) and that neighbourhood to poultry farms does not promote the presence of *M. musculus* in crop fields and their borders (reject hypothesis 2). As in previous studies (León et al., 2013), we found this species in borders of crop fields but not within them, suggesting that *M. musculus* dispersal occurs along borders or riparian habitats, but not through crop fields. The highest plant cover and the stability of borders and riparian habitats enhances survival during dispersal movements, probably because of the lower predation risk. Busch and Burroni (2015) found that this species behaviour changes according to predation risk, reducing its foraging activity during high moonlight. An alternative explanation for the absence of *M. musculus* captures in crop fields may be that the capture effort performed in this habitat (2160 traps-night in 24 crop fields) was not enough to detect this species, although in crop field borders the capture effort was half than in crop fields and we captured four mice (1080 traps-night in 24 crop fields borders). Agreeing with this, several samplings with a high capture effort within crop fields also showed that this species is rarely captured in this habitat (Busch, Miño, Dadon, & Hodara, 2000, 2001). This suggests that *M. musculus* is unable to use the crop field matrix of the study area, nor use this habitat to disperse, in contrast to Australian agricultural ecosystems where there are feral populations of *M. musculus* that on occasions reach pest levels (Brown & Singleton, 2002). This difference is mainly attributed to the absence of interspecific competition from other granivores, and the occasional occurrence of favourable climatic conditions in Australia that enable mice to breed, as mild winters, spring rainfall and occasional summer storms can decrease the effect of aridity on breeding performance (Jacob, Ylönen, Runcie, Jones, & Singleton, 2003; Singleton & Redhead, 1990; Ylönen et al., 2002). In agricultural environments of Argentina, the low winter temperatures and the competitive exclusion by native species (Busch, Bilenca, Cittadino, & Cueto, 2005; Fox & Pople, 1984) may limit the establishment and abundance of *M. musculus* in this type of habitats.

Our results confirm that in the study region *M. musculus* has only established populations in poultry farms and does not form stable populations in non-commensal habitats. The population dynamic of this species in poultry farms is mainly determined by the characteristics of the farms (where anthropogenic circumstances may provide the necessary resources for mice, particularly within structures and with sufficient food during the colder months) and human management (chemical control and environmental arrangement). Crop field borders and other corridors may be used by this species for dispersal among farms, while the cropfield matrix is an unsuitable habitat with low permeability.

With respect to the hypothesis (3) we found that although poultry farms provide potential good conditions for native species, they are seldom used by them, even when densities in surrounding habitats are high. Among these native species, in this work, we only found *C. laucha* in breeding sheds, in agreement with Miño et al. (2001) who also found this species in poultry farms. *C. laucha* is probably more adapted to perturbed habitats than *A. azarae* and *O. flavescens*, which are mainly found in crop field borders. The low abundance of native species in farms may be related to the high human interventions in these habitats and the periodic application of anticoagulant baits (especially bromadiolone), to which they can be more susceptible than *M. musculus*, which was found to be resistant to bromadiolone (Guidobono, León, Gómez Villafaña, & Busch, 2010). Finally, our results support the hypothesis (4) which indicates that the abundance of native species in crop fields or their borders is independent of the presence of poultry farms.

In summary, we conclude that rodent communities in farms are little influenced by the surroundings, and show a dominance of *M. musculus* independently of the presence of native rodent species in neighbour habitats. On the other hand, farms do not export *M. musculus* to surrounding habitats, the borders only functions as corridors for dispersal among farms, while the crop fields are rarely used by this species. Among native species, *C. laucha* may probably increase the use of poultry farms in absence of *M. musculus*, which is suggested to be competitive dominant (Busch et al., 2005).

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Disclosure statement

No potential conflict of interest was reported by the authors.

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