“Small rodent species on pig and dairy farms: habitat selection and distribution”.

Short running title: “Habitat selection by small rodent species on livestock farms”

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Abstract

BACKGROUND:

Rodent species are common in livestock production systems, and some of them are considered serious pests because of the sanitary problems and economic losses they cause. Information about microhabitat selection by rodent species in livestock production systems is necessary for understanding rodent requirements and to contribute to effective prevention and development of control measures for pest rodent species. In this work we study microhabitat selection by rodent species that inhabit pig and dairy farms in central Argentina. Rodent trapping was conducted over three years (2008-2011) on 18 livestock farms, each one sampled seasonally during one year. To study habitat selection, microhabitat characterizations were performed describing 22 environmental variables in captured sites and random trap sites without captures.

RESULTS:

With a trapping effort of 7333 Sherman and 7026 cage live trap-nights, 444 rodents of seven species were captured (including the murine pest species *Rattus norvegicus, R. rattus* and *Mus musculus* and four native species). The three murines selected characteristics related to building structure and/or to food sources availability/proximity, while *Akodon azarae* selected sites with tall herbatious vegetation.

CONCLUSIONS:

We identified microhabitat characteristics that explain habitat distribution of small rodent species in these complex farm systems. This study contributes to broaden the integrated pest management of rodent pest species and could also contribute to the reduction of the use of rodenticides in these systems.

Key words: Rodents, habitat selection, livestock farms, integrative pest management.

1 INTRODUCTION

Intensive livestock production systems such as dairy, pig and poultry farms are plagued with rodents due to the availability of food sources, shelter and water in these systems [1-3]. Some rodent species are considered serious pests worldwide because they produced structural damages and consumption and contamination of food, causing economic losses in production [4-6]. Additionally, some rodents are potential zoonoses transmitters, being reservoirs and mechanical vectors of several diseases, infecting man and domestic animals [7-9].

In the Rolling Pampa in central Argentina, small mammals have been studied in intensive production systems such as poultry farms [2, 10, 11] and more recently on pig and dairy farms [1, 9, 12]. Small rodent communities of these systems are similar in composition and relative abundance of their species. These communities are dominated by murine species, accompanied by native rodent species and the opossums *Didelphis albiventris* and *Lutreolina crassicaudata* [1, 2, 10]. Murines have been found in all the studied environments within farms, but more commonly in or around peridomestic settings such as human buildings, food storage sheds and animal sheds, whereas native species were mostly restricted to vegetated environments with different characteristics [1]. This indicates that habitat structure and resources disponibility could be influencing habitat selection and consequently the observed species distribution [1]. Also, the three murines and some native species were found to be infected with several zoonotic pathogens (*Leptospira* spp., *Trichinella* spp. and antibodies anti-*Brucella* spp.) on several farms [9].

The success of effective pest control measures may rely not only on the knowledge of the specific composition and their habitat use, but on understanding the requirements of each particular species in these systems [13]. However, there are no studies regarding microhabitat selection by most rodent species on pig and dairy farms. The scarce works published in these systems are based on *Rattus norvegicus* movements or habitat selection, such as Montes de Oca *et al*. [12] that studied habitat selection at different scales for this rodent species on a dairy and a pig farm and Akande [14] that described movements of two Norway rats in a pig farm using a video camera (see below). Habitat selection is a hierarchical process in which habitat interrelationships with individuals may change with the spatial scale considered [15-19]. According to Morris [20], the habitat scale (or macrohabitat) represents the scale in which the home range of an individual or social group is included; while on a finest scale, the fine-grained microhabitat scale, represents the patches within a habitat where an individual forages, looks for shelter and mates, rests, etc. Microhabitat selection has direct effects on thermoregulation, in energy intake and/or predation risk, because foraging animals make tradeoffs in the use of space when exploiting the most energetically profitable places but more dangerous compared to sub-optimal microhabitats (less profitable) with no or less predation risk [21-24].

Habitat selection studies aim to identify the environmental features that a species selects. Within the wide variety of existing methods to study microhabitat selection, one of them consists of comparing the characteristics of the “used” versus “available” space .

Microhabitat selection by rodent species has been studied around the globe in rural areas, agroecosystems and urban environments. On poultry farms, murines were frequently found in breeding animal sheds, especially *R. norvegicus* and *Mus musculus.* These species are probably associated with the constant supply of food and water in these sheds, while native species were abundant in high vegetation cover on the perimeters (edges) of farms [2, 10, 11]. Montes de Oca *et al.* [12] found, from movement studies of *R. norvegicus* on livestock farms, that this species moved along building walls while simultaneously avoiding areas with low vegetation height (below 5 cm tall). *Rattus norvegicus* also selected sites with a simultaneous closeness to food sources and potential refuges. On a higher scale, they found that this species moved mainly over food sources and cemented floors, and across water bodies (such as streams, ponds, drainage channels). In urban systems in Budapest *R. norvegicus* mainly used ground surrounding buildings and nested in courtyards, and also preferred sewerage systems which provide runways and food sources [25]. Traweger *et al.* [26] found in the city of Salzburg

(Austria) that the presence of trees and multilayer vegetation were important factors for this species, as well as patches near water and natural soil. In dwellings in England, Langton *et al.* [27], found that the prevalence of the commensal rodents' *R. norvegicus* and *M. musculus* was greater when pests or livestock were kept in gardens, in areas of low-density housing, and in dwellings in areas with problems such as litter, abandon buildings, vacant properties and unkempt gardens. Additionally, in urban systems in central Argentina, *M. musculus* was mainly found in vacant lots characterized by garbage and human deposited material, such as bricks, wood and scrap iron; while some native rodent species such as *Akodon azarae* and *Calomys musculinus* were found almost exclusively in vacant areas located in urban areas without buildings and dwellings [28]. In agricultural ecosystems of the Rolling Pampa, the distribution of native sigmodontine rodents among habitats has been well described [29-36]. *Akodon azarae* y *C. musculinus* selected microsites with tall green vegetation cover [37-39], but *A. azarae* avoided open areas rich in resources when predation risk was high [40]. *Calomys laucha* showed a wider range of use being more adapted to modified environments with anthropogenic activity [38].

The overall objective of the current work was to study microhabitat selection by rodent species that inhabit intensive production systems in central Argentina. The intents was to contribute to the ecology of these species and consequently to rodent control and prevention methods, mainly of pest rodent species.

2 MATERIALS AND METHODS

2.1 Study area

The study was conducted on 10 pig farms and eight dairy farms located in a rural landscape at the northeast of Buenos Aires province, Argentina (34º S, 58.5º W), particularly in the counties of General Las Heras, Marcos Paz, San Andrés de Giles and Exaltación de la Cruz. This area is located in the Rolling Pampa, a subdivision of the Pampas region [41] where the climate is temperate with a mean annual precipitation of 1005.2 mm [42] and mean annual temperature of 16.4ºC [43]. The Rolling Pampa includes extensive and intensive livestock farming (mainly poultry, cows and pigs) and is intensively cultivated with grain crops [41, 44]. On the study farms, different types of dwellings were found (for details, please see reference [1]) that were typically surrounded by crops, grasslands and pastures for livestock.

2.2 Trapping procedure

Rodents were live-trapped on these livestock farms for three years from spring 2008 to spring 2011. Each farm was sampled for four consecutive seasons during one year. Five habitats present on these farms were surveyed: 1. animal sheds (dairy and pig sheds), structures in which pigs or cows were present, either continuously as in pig sheds or intermittently at dairies where cows were taken for milking twice a day; 2. food storage sheds or silos, structures used to store food; 3. human buildings, dwellings with high human activity not used to store food like houses, machinery sheds, warehouses and offices; 4. vegetated areas around dwellings; 5. drainage channels with adjacent dirt mounds with tall herbaceous vegetation. Not all habitats were present on all farms.

Rodents were captured using Sherman traps (8x9x23cm) baited with a mixture of peanut butter, rolled oats and bovine fat, and cage live-traps (15x16x31cm) baited with beef and carrot. The two types of traps were set together every 10m along 50-100m trap-lines with 1 to 3 replicates per habitat, depending on the farm structure. In each trapping session, the location of traps was the same. Traps were active for three consecutive nights and checked daily in the morning. Trapping and handling were done following national and international guidelines for animal care [45, 46]. Rodents were identified to species based on external morphology, the sex determined, and were removed to collect tissue samples for another study (for details, see reference [9]). Individuals were humanely sacrificed following the procedures and protocols approved by the Argentine Law for Animal Care 14346 and Ethics Committee for Research on Laboratory Animals, Farm and Obtained from Natures of

National Council of Science and Technical Research (CONICET; resolution 1047, section 2, annex II).

2.3 Microhabitat selection and data analysis

Microhabitat was characterized within a 2m x 2m square around each trap, in which 19 environmental variables were recorded (Table 1). Proximity to food sources and to refuge from the center of the trap was also measured, and additionally a Shannon index was calculated as a heterogenic measure of the microsite (Table 1). This characterization (the record of 22 environmental variables) was done for all the trap stations where an individual was captured (used microsites). In addition, in order to estimate environmental availability and according to Manly *et al.* [47], on each trap-line this characterization was performed at up to three randomly selected trap stations where individuals were not captured (available microsites).

In order to summarize the microhabitat structure and the degree of association among characteristics, a Principal Component Analysis (PCA) was conducted based on a correlation matrix using the 22 environmental variables. This analysis was performed to show how the habitats are related with the environmental variables in the multivariate space. Therefore, all trap sites were ordered in a multivariate space and then identified according to the five habitats to which they belonged, to describe the differences of the site characteristics according to the habitat. Multivariate analyses were done in the *vegan* package [48-50] within the R statistical environment [51].

To analyze the environmental factors selected by each small mammal species at microhabitat scale, stepwise forward multiple regressions procedures using Generalized Linear Mixed Models (GLMM) with a binomial distribution, a logit-link function and the Laplace approximation method were used [52-54]. “Farm” was included in the model as a random effect because farms were sampled repeatedly (in each season). We tested the statistical significance of the random effect based on the change of deviance between models with and without the random factor [53]. When the random effect did not improve the model, the factor farm was removed and Generalized Linear Models (GLM) were used [53]. The response variable was binomial, with "1" representing used microsites and "0" representing available sites, following Manly *et al*. [47].We randomly selected up to three available sites for every site used on each farm and trapping session, because the number of the available sites were, in several occasions, much higher than the ratio 1:3 (used:available) as in Childs *et al*. [55]. The 22 environmental variables were used as explanatory variables and interaction terms among the significant variables were added if they contributed to a better fit of the model. We also evaluated if the effect of these variables depended on the type of production system (pig or dairy farms), the habitat and the season. For the stepwise forward selection criteria, we used the significant and greater change of deviance for a variable or interaction and the simplest significant models were reported [53]. When more than one candidate model was found, we employed the Akaike Information Criterion (AIC) for model selection, reporting models with ΔAIC<4 in relation to the best-fit model with the lowest AIC [56]. Prior to the GLMM, Pearson correlation tests were used to evaluate multicollinearity between explanatory variables. Those variables that were highly correlated ($r_{\text{Pearson}} > 0.6$ or $p<0.01$) with others that had already been included in the model were discarded [57]. Collinearity among all predicted variables included in the models were assessed with the Variance Inflation Factors (VIFs) [58]. If any VIF value was much larger than 5, the variable or interaction was dropped and the process was repeated until VIF values were smaller than the preselected threshold [58]. For the accuracy measures Kappa index (K), sensitivity, specificity and proportion of correct classifications (PCC) were reported [59]. GLMM were conducted using the *lme4* package [60], VIFs using *car* package [61] and the accuracy measures with the *PresenceAbsence* package [62] from R software [51].

3 RESULTS

During the sampling period we captured 444 rodents of seven species, by means of a total trapping effort of 7333 Sherman trap-nights and 7026 cage live trap-nights. Rodents captured included introduced murines: 281 *R. norvegicus* (the dominant species in these systems), 17 *R. rattus* and 86 *M. musculus*; three native sigmodontines: 41 *A. azarae*, 6 *C. laucha* and 7 *O. flavescens*; and 6 individuals of the native caviid *Cavia aperea* (for a detailed description of the small mammal communities see reference [1]).

A total of 1198 microhabitat sites were characterized: 882 were randomly selected between the available sites, 203 sites used by *R. norvegicus*, 15 by *R. rattus*, 49 by *M. musculus*, 34 by *A. azarae*, 6 by *O. flavescens*, 5 by *C. aperea* and 4 by *C. laucha*. The number of microhabitat sites characterized per species does not match with each species captures because some individuals were captured in the same traps (double or triple captures or a single capture on consecutive days). Also, some characterized sites were discarded because some of the variables were accidentally not registered in the field.

The PCA showed association between many explanatory variables; the first two axes were retained explaining 22% of the total variance of 22 variables on 1198 observations (Fig. 1a, table 2). These associations were partially related with the different characteristics among the five habitats previously defined (see below). The first Principal Component (PC) divided microsites with some characteristics of constructions (such as walls and impervious surfaces) to the right from microsites more related with characteristics of vegetation and water bodies to the left. The trap sites belonging to the vegetated areas and drainage channels habitats were placed on the left of the multivariate space (Fig. 1a) since they were mostly covered by vegetation exceeding 6 cm tall and water bodies, respectively (Fig 1b). The trap sites belonging to the other three habitats (human buildings, animal and food storage sheds) were placed mainly on the right of the multivariate space (Fig. 1a), since they were characterized by heterogenic sites and/or a higher proportion of impervious surfaces and/or walls (Fig 1b, table 2). The second PC was positively associated with a higher proportion of food (BB F and

Spread F) and close to food sources (Prox F), and negatively associated with a higher proportion and amount of vertical hollow elements (VH and VH prop) such as wood trunks, barrels and bricks (Fig. 1b, table 2). In the second axis, the trap sites of the human buildings were placed slightly above the sites belonging to the other two habitats, since they were characterized by higher amount and proportion of degraded elements and construction materials (as wood trunks, barrels and bricks), and with lower availability of food (Fig. 1b, table 2).

Microhabitat selection analysis was restricted to the three murine species and the native sigmodontine *A. azarae*, because sample sizes for the other native species were too small for the evaluation of the microhabitat selection. Nevertheless, the few individuals captured of *C. laucha* and *O. flavescens* were mainly found at sites with a minimum of 25% of the proportion covered with vegetation between 16-50 cm tall, and *C. aperea* with more than the 50% of this cover. Microhabitat selection for *R. norvegicus* was explained by two models. For both models, this species selected sites close to food sources and/or with larger amount of vertical solid elements. The first model also showed that *R. norvegicus* avoided areas with vegetation height shorter than 5 cm and selected heterogenic sites (Table 3). The second model also showed that this species avoided sites with higher proportion of vegetation shorter than 5 cm but simultaneously selecting sites with higher proportion of water bodies (Table 3).

For *R. rattus* microhabitat selection one model was obtained. However we reported a second model with considerably less support (ΔAIC=5, according to reference [56]) because of its biological sense. The first one showed that *R. rattus* selected sites with higher proportion of impervious surfaces avoiding areas with higher proportion of bare soils. Also, they selected sites with higher proportion of horizontal hollow elements (Table 3). The second model, showed that these species selected sites with higher proportion of walls but it depended on the type of production system, with a greater association (Wall x Type, table 3) on pig farms than on dairy farms. Also a higher proportion of vertical solid elements was selected by this species (Table 3).

The best GLM model for *M. musculus* microhabitat selection showed that these individuals selected microsites close to food sources and simultaneously with higher proportion of walls (Table 3). In contrast, higher proportions of vegetation between 6-15 cm, between 16-50 cm and over 50 cm tall were the important variables for *A. azarae* microhabitat selection (Table 3).

According to the Kappa index, most of the microhabitat selections models had a moderate to substantial agreement with high values of the other accuracy measures, while *R. norvegicus* models had a fair agreement [63], however PCC, sensitivity and specificity indicated a better agreement (Table 3).

4 DISCUSSION AND CONCLUSIONS

In this three-year study of microhabitat selection by four rodent species inhabiting intensive production systems, we showed that the differential distribution previously found on these farms (reference [1]), can be explained by a selection of characteristics at microhabitat scale for each species. The three rodent murine species selected characteristics related to building structures and/or to the food sources availability or proximity, while the native sigmodontine *A. azarae* selected characteristics related to the vegetation structure. Even though environmental factors that explain habitat selection by rodent species in crops and their borders of the study area are well described [37, 38, 64], this is one of the first works that proposed a microhabitat characterization in livestock farms in the Rolling Pampa together with [12]. Additionally, this characterization allowed us to describe the environmental characteristics of the habitats of these anthropogenic systems.

Rattus norvegicus is the most common vertebrate pest species in livestock farms [3, 7, 65, 66], is one of the rodent species most in contact with livestock animals [1, 12], and is commonly infected with a multitude of zoonotic pathogens on farms [7, 9, 66]. At the microhabitat scale, our results for *R. norvegicus* agreed with the movements and habitat selection results obtained by a study with spool-and-lines technique combined with environmental surveys and GIS tools

[12]. This strengthens the microhabitat selection by this species, because it should be mentioned the effect of the presence of traps themselves. Traps are design to attract rodents (because of the bait) and rodents may be attracted to microsites that they would not venture into [67]. Although this expected bias, individuals were not captured independently of the microhabitat characteristics surrounding the trap stations. Habitat selection results from trapping studies should be compared with that of free-roaming animals [67, 68], that are more costly. A study on habitat selection of *R. norvegicus* using spool-and-line technique in two of the study farms yielded very similar results [12]. Our results support the hypothesis that *R. norvegicus* do not use patches regardless of their predation risk [69-73] because microsites with low vegetation height avoided by this pest species represents patches with greater predation risk (being more visible to dogs, cats and other predators); and that the availability of food sources and water are key factors for its establishment [25, 26, 74, 75]. As a result, we agree with the recommendations of concentrating efforts in maintaining short vegetation mainly around dwellings as we found this species avoided sites with low vegetation height and by reducing potential refuges such as deprecated elements that generates trash to diminish *R. norvegicus* populations [12, 65, 76]. Additionally, as we found that *R. norvegicus* together with *M. musculus* selected sites close to food sources, we recommend supporting Montes de Oca *et al*. [12], to modify some action managements on farms in relation to the storage of food, trying to reduce the availability of food for rodents. For example, on farms that food is spread on the floor or in bags not rodent-proof that rodents can damage, access and contaminate [5], we suggest the use of rodent-proof bags for the storage of food in order to diminish rodent population and food contamination [12, 77]. Lambert *et al*. [65] found that by modifying some habitat action management, the size of rat populations can be reduced. Other authors found an association of *M. musculus* with animal sheds with high availability of food, separated from native rodent species more associated with field borders, crop fields and pastures [11, 78]. Other surveys also demonstrate that abundances of this species are strongly influenced by food availability [79, 80].

Microhabitat selection by *A. azarae* on farms was similar to that observed in crops and borders[33, 40, 81, 82]. This species selected microsites characterized by dense and tall vegetation cover, which explains why it is mainly found in vegetation areas within farms[1]. A dense and tall vegetation cover can strongly reduce predation risk for small mammals (mainly by owls) by providing shelter[23, 40]. Additionally, this vegetation type can increase food availability for this native species that feeds mainly on insects, but also on plant material and seeds[36, 79, 83], while it can also provide thermal protection from heat and cold[79].

In contrast, *R. rattus* selected factors at microhabitat scale associated with building structures. Also this species selected other elements that provided shelter. Vertical elements would represent key elements since *R. rattus* has a great climbing ability. These vertical elements can provide access to sites in height and therefore escape from ground predators and its dominant competitor *R. norvegicus* that tend to inhabit at ground level[84, 85]. Therefore, we suggest avoiding vertical elements close to the walls so as to make farm dwellings less attractive to this climbing rodent pest species.

As already mentioned in the introduction, both *M. musculus* and *R. rattus* species were also commonly infected with several pathogens on the study farms[9], and the first one was very common on farms[1], though it is also important to focus on these species. Some of the habitat management actions herein proposed also applies for these species. However, for *R. rattus* species, other studies are required mainly because this species is common on roofs and in this study traps were placed on ground level. Regarding the native *A. azarae*, the maintenance of farm perimeter habitats with vegetation shorter than 6 cm would diminish its population and the interaction with other species inhabiting farms. Short vegetation would diminish the interspecific and intraspecific transmission of the pathogens that *A. azarae* carry[9].

This study contributes to a broadened knowledge of habitat use and selection at a micro scale of rodent species (most of them considered pests) that inhabit livestock farms in the Rolling Pampa. Understanding these aspects could help to design more sustainable rodent-control practices, supporting the ecologically-based rodent management (EBRM) of pest species [13], in order to reduce the use of rodenticides. Finally, this work gives support to Hygnstrom *et al.* [86] management handbook´s indications that many of them arise on expert observations but they are not supported with data. Some of these indications concern habitat modifications such as the use of rodent-proof food bags and diminish potential refuges for the three commensal pest species (as reported Timm [85, 87] and Marsh [84] in the mentioned handbook [86]).

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Table 1. Mnemonics and description of 22 environmental variables recorded in order to characterize the used and available microsites by rodents in livestock production systems of central Argentina from 2008 to 2011.

Mnemonics	Description
BS	- Proportion of area covered by natural bare soils.
Water	- Proportion of area covered by water bodies (such as streams, ponds, puddles, drainage channels, among others)
V<5	- Proportion of area covered by vegetation between 0-5 cm tall.
V6-15	- Proportion of area covered by vegetation between 6-15 cm tall.
V16-50	- Proportion of area covered by vegetation between 16-50 cm tall.
V>50	- Proportion of area covered by vegetation over 50cm tall.
VS prop	- Proportion of area covered by vertical – comparatively higher than longer or wider – solid elements (e.i. stacked bricks, tree trunks without hollow spaces, solid posts, etc.).
VS	- Amount of vertical solid elements within the area.
HS prop	- Proportion of area covered by horizontal – comparatively wider or longer than higher – solid elements (solid construction elements, stacked planks without hollow spaces, fallen trunks or poles without gaps, etc.).
HS	- Amount of horizontal solid elements within the area.
VH prop	- Proportion of area covered by vertical hollow elements where rodents could hide inside (e.i hollowed wood trunks, open barrels or boxes, etc.).
VH	- Amount of vertical hollow elements within the area.
HH prop	- Proportion of area covered by horizontal hollow elements where rodents could hide inside (e.i. construction open elements, fallen hollowed trees, bags, etc.).
HH	- Amount of horizontal hollow elements within the area.
Imp Surf	- Proportion of area covered by impervious surfaces (as cemented floors).
Wall	- Proportion of area covered by wall.
Spread F	- Proportion of area covered by food spread on the floor.
BB F	- Proportion of area covered by balanced bagged food.
Feeders	- Proportion of area covered by animal feeders.
Prox R	- Proximity to refuge: 1/ distance (m) to the closest potential refuge from the center of the trap.
Prox F	- Proximity to food sources: 1/ distance (m) to the closest food source from the center of the 4m^2 area. We considered as food sources, nutritionally balanced livestock food and any other type of food (bread, noodles, cookies, etc.) that was also used to feed livestock.
Sh Index	- Shannon index: Index calculated as a heterogenic measure of the microsite taking into account all the proportions covered by the different elements defined in this table.

Table 2. Factor loadings of the 22 variables of the first two components (PC) for the Principal Component Analysis (PCA).

Mnemonics	PC1 (13.3%)	PC2 (8.7%)
BS	0.21	-0.25
Water	-0.20	0.02
V<5	-0.05	-0.09
V6-15	-0.20	-0.02
V16-50	**-0.61**	0.03
V>50	-0.43	0.03
VS prop	0.10	-0.31
VS	-0.02	-0.26
HS prop	0.31	-0.17
HS	0.29	-0.25
VH prop	0.33	**-0.56**
VH	0.35	**-0.56**
HH prop	0.25	0.26
HH	0.25	0.21
Imp Surf	**0.63**	0.13
Wall	**0.74**	0.02
Spread F	0.24	**0.49**
BB F	0.16	**0.53**
Feeders	0.10	0.08
Prox R	-0.34	0.00
Prox F	0.34	**0.55**
Sh Index	**0.65**	0.01

Values above 0.5 in bold

Table 3. Summary of the simplest Generalized Linear Mixed Models for microhabitat selection of rodent species captured on 18 livestock farms in central Argentina from 2008 to 2011. Model predictors included 22 environmental variables (mnemonics in table 1) recorded within the 2m x 2m square used to characterize the used and available microsites described in table 1. Also we evaluated the effect of the type of production system (type: pig or dairy farms), season and habitat. "Farm" was included as a random effect, and when this random effect did not improve the model, it was removed and a Generalized Linear Model was used. *d.f.*: residual degrees of freedom; K: Kappa index; Sens: sensitivity, Spec: specificity; PCC: proportion of correct classifications. For *Rattus rattus* and *Akodon azarae* the AICc for small sample size was used (please see text).

				Accuracy measures			
Models	***df***	**AIC**	**Null AIC**	**Kappa**	**PCC**	**Sens**	**Spec**
Rattus norvegicus							
V<5 + Sh I + Prox F + VS + (Farm)	572	713.5	737.9	0.34	0.71	0.49	0.83
V<5*Water + Prox F + VS + (Farm)	571	716.4	737.9	0.31	0.69	0.55	0.77
R. rattus							
Imp Surf*BS + HH prop	55	54.2	69.5	0.64	0.87	0.73	0.91
Wall*Type + VS prop	55	59.4	69.5	0.47	0.80	0.60	0.87
Mus musculus							
Wall*Prox F	195	180.5	224.2	0.46	0.81	0.55	0.89
Akodon azarae							
V16-50 + V>50 + V6-15	132	126.9	155.0	0.43	0.72	0.91	0.66

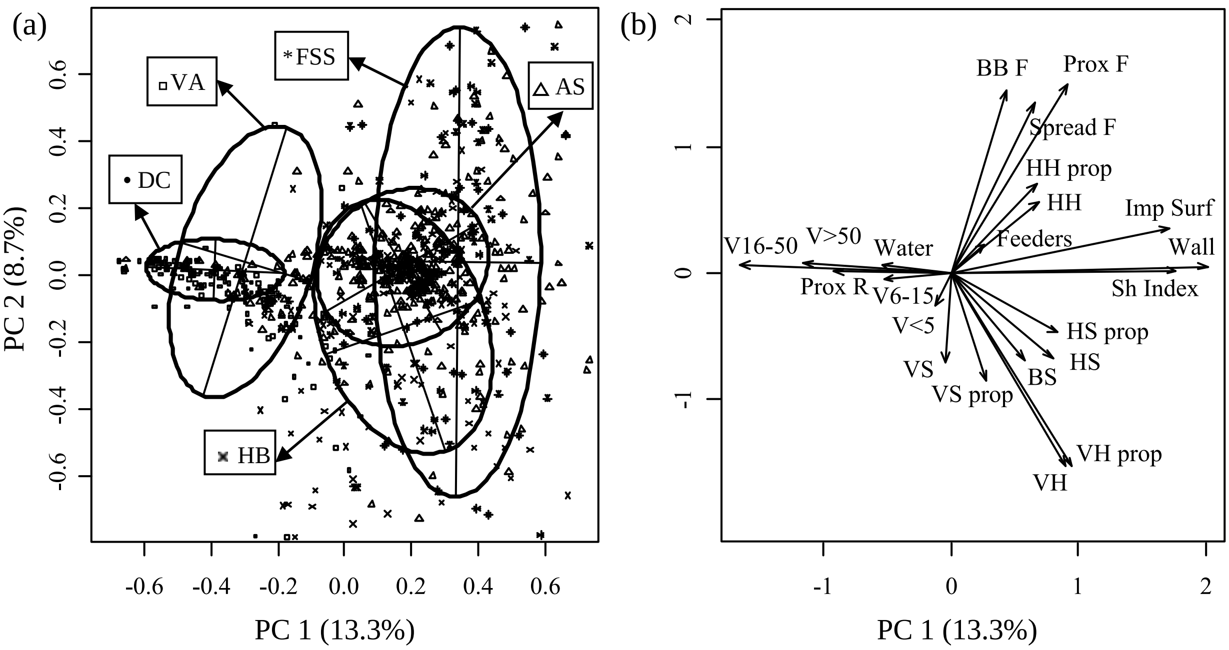
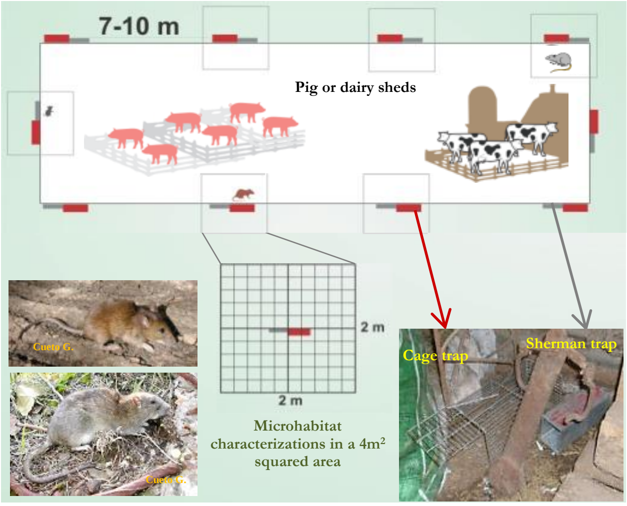


Figure 1. (a) Ordination of the 1198 microsites (2m x 2m square; see text) on 18 livestock farms in central Argentina from 2008 to 2011, produced by the Principal Component Analysis according to the five habitat they belonged (ellipses), based on (b) the 22 environmental variables recorded in the microsites. PC: Principal Component; the proportional variance explained for the two PC retained is shown in parentheses. The mnemonics of the environmental variables are described in table 1. Habitats: FSS, Food storage sheds; VA, Vegetated areas; DC, Drainage channels; HB, Human buildings; AS, Animal sheds. The mnemonics of the environmental variables in (b) are described in table 1.


7-10 m
Pig or dairy sheds
2 m
2 m
Microhabitat characterizations in a 4m² squared area
Cage trap
Sherman trap
Cueto G.
Cueto G.

Murine pest rodents selected characteristics related to building structure and food sources availability, while native species selected sites with tall herb vegetation, helping farmer´s decisions where to control pests protecting non-target species.