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Burrowing activity by armadillos in agroecosystems of central Argentina: Biogeography, land use, and rainfall effects

A.M. Abba [a,*], E. Zufiaurre [b], M. Codesido [b], D.N. Bilenca [b]

[a] División Zoología Vertebrados, Facultad de Ciencias Naturales y Museo, Universidad Nacional de La Plata, CONICET, Paseo del Bosque s/n, La Plata, Buenos Aires, Argentina

[b] Grupo de Estudios sobre Biodiversidad en Agroecosistemas (GEBA), Departamento de Biodiversidad y Biología Experimental, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, and IEGEBA (CONICET- UBA), Argentina

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ABSTRACT

Land use change and agricultural practices are among the main factors affecting biodiversity, and require understanding of how differing species responses shape wildlife communities in rural landscapes. During the last 2–3 decades, the Pampas of central Argentina have experienced an agricultural expansion along with rapid adoption of a non-tillage system. In some areas armadillos are increasingly considered agricultural pests, not only because they can damage and contaminate silo bags and may act as direct consumers of crops, but also their burrowing activities interfere with farming practices. Here, we describe variations in activity of armadillos in the Pampas of Buenos Aires province, central Argentina, and discuss how biogeography, land use, and rainfall may have affected these species in the rural landscape. We carried out four sampling sessions between December 2011 and June 2013 (including two periods of normal rainfall and two periods of high rainfall), surveying 392 plots (196 crop fields and 196 rangelands) at 25 different localities (covering the five different ecological units of the Pampas). In each plot, we surveyed for signs (burrows and holes) along a 600 × 6 m transect, in order to assess armadillo activity. *Chaetophractus villosus* (large hairy armadillo) showed the highest activity, with 5968 signs at 79% of the plots surveyed; whereas, 1866 signs of *Dasypus hybridus* (southern long-nosed armadillo) were found in 36% of the plots. Generalized linear mixed models revealed that *C. villosus* is more active mainly in the Inland Pampas and in cropland plots, whereas, *D. hybridus* is more active in the Flooding Pampas at plots with active livestock use. Both species showed less burrowing activity during the second year of surveys, in a period of exceptionally high rainfall. Our results suggest that the omnivorous *C. villosus* may have benefited from agriculturization and non-tillage, particularly in the Inland Pampas where sandy soils favor burrowing, whereas, the more myrmecophagous *D. hybridus* may be in retraction.

1. Introduction

Agriculture covers approximately 38% of the Earth's land surface (Foley et al., 2005, 2011; Ramankutty et al., 2008). Agricultural development impacts wildlife, affecting farmland biodiversity in several ways (Donald, 2004; Foley et al., 2005; Kareiva et al., 2007). Some wildlife populations appear to benefit from agriculture while others are reduced or eliminated (Donald, 2004; Jacob, 2003; Matson et al., 1997; Robinson and Sutherland, 2002; Tilman et al., 2001). Additionally, this kind of impacts could be associated with biogeographic aspects. Thus, there is a need to understand how differing species responses shape wildlife communities and ultimately the integrity of the ecosystem in landscapes differing in land use patterns and intensive agriculture at a regional scale.

The Argentine Pampas is one of the richest agricultural areas of the world, covering about fifty-two million hectares of productive organic soils which were originally covered by grasslands (Solbrig, 1997; Soriano, 1991). This huge flat plain was primarily a livestock-raising area but changes in land use began slowly in the 1960s and accelerated at the end of the 1970s (Ghersa et al., 1998; Manuel-Navarrete et al., 2009; Solbrig, 1997). The most dramatic technological innovation occurred in 1996 with the introduction of both genetically modified soybeans tolerant to glyphosate (Trigo and Cap, 2003) and non-tillage systems (Martínez-Ghersa and Ghersa, 2005; Satorre, 2005). Thus, pastures and annual forage

* Corresponding author. Tel.: +54 221 4226323; fax: 54 221 4257527.
E-mail addresses: abbaam@yahoo.com.ar (A.M. Abba), ezufiaurre@ege.fcen.uba.ar (E. Zufiaurre), mcodesido@ege.fcen.uba.ar (M. Codesido), dbilenca@ege.fcen.uba.ar (D.N. Bilenca).

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crops have been progressively replaced by wheat–soybean relay cropping, maize and sunflower crops, whereas, animal stocking rate has increased in those lands with less agricultural aptitude (Paruelo et al., 2005; Viglizzo et al., 2011).

Armadillos (Mammalia: Dasypodidae) are one of the characteristic groups of medium size mammals in the Pampas, and are frequently found in agroecosystems of Buenos Aires province (Abba and Vizcaíno, 2011). Together with sloths and anteaters, armadillos form the Xenarthra, a monophyletic clade restricted to the Americas, which is considered to be one of the four major clades of placental mammals (Delsuc et al., 2002; O'Leary et al., 2013). *Chaetophractus villosus* (large hairy armadillo) and *Dasypus hybridus* (southern long-nosed armadillo) are the most widespread and abundant armadillos inhabiting the Pampas grasslands (Abba et al., 2007, 2011a, 2012; Abba and Vizcaíno, 2011). Both species of armadillos are active throughout the year and their reproductive activity focuses during spring and summer (Abba et al., 2011a,b). They are semi-fossorial, actively digging their own burrows, which they leave only to search for food by making numerous holes in the ground. *C. villosus* is present in the Gran Chaco of Bolivia, Paraguay, and Argentina and as far south as Patagonia (see Abba et al., 2012). This species is crepuscular to nocturnal and is present in a wide variety of habitat including grasslands, savanna, forest, and also in agroecosystem and some degraded habitats (Abba and Vizcaíno, 2011; Abba et al., 2012). Their food habits include many types of prey as invertebrates, small vertebrates, vegetables, and carrion (Abba and Cassini, 2008; Redford, 1985). *D. hybridus* is found in NE of Argentina, Uruguay, SE of Paraguay, and southern Brazil (see Abba et al., 2012). This species is diurnal and typically found in grasslands and is also present, but less common, in woodlands, and some degraded habitats (Abba and Vizcaíno, 2011; Abba et al., 2012). Their food habits are similar to those of *C. villosus*, even though they show a strong tendency to myrmecophagy (Abba et al., 2011a).

Studies of both recent and archeological distribution of armadillos in Buenos Aires province (covering approximately the last 10,000 years) revealed range expansions and contractions, perhaps reflecting responses to climatic events and environmental modifications (see Abba et al., 2007; Abba and Vizcaíno, 2011; Vizcaíno et al., 1995). In particular, it has been recorded that extreme rainfalls may have forced displacements of armadillo populations to avoid flooded areas (Layne and Waggener, 1984; McBee and Baker, 1982; Pacheco and Naranjo, 1978). Moreover, preliminary data suggest that distribution and abundance of armadillo species may differ among ecological (i.e., biogeographic) units in the Pampas (see Abba and Vizcaíno, 2011).

In addition, the relationship between armadillos and human activities dates from ancient times (see Martínez and Gutierrez, 2004; Vizcaíno et al., 1995). In the past, hunting was the primary relationship, since local people frequently ate armadillos, and sometimes armadillos were also considered agrarian pests. More recently, some species of armadillos are increasingly considered major agricultural pests. Armadillos can damage and contaminate silo bags and may act as direct consumers of crops. Additionally their burrowing activity can seriously affect agriculture labor and represent a serious risk for cattle, horses, and rural workers as legs can get fracture if caught in a burrow (Abba et al., 2005, 2007; Abba and Vizcaíno, 2011; Merino Tosoni and Pennisi, 2010). However, there are no activity estimates available of armadillos in the Pampas agroecosystems, nor studies investigating factors responsible for variation in activity of armadillos at different spatial scales. Based on all the above mentioned, the aim of this paper is to describe variations in activity of armadillos in the Pampas of Buenos Aires province (central Argentina), and to discuss how biogeography, land use, and rainfall, may have affected these mammals in the rural landscape.

2. Materials and methods

2.1. Study area

Our study area extends ≈225,000 km^2 (500 km north to south, 450 km east to west; 33–39°S, 57–63°W; Fig. 1B) in the Pampas region of Buenos Aires province (central Argentina), and includes five ecological units which show some differences in geomorphology, soils, drainage, physiography, and vegetation: the Rolling, Flat Inland, West Inland, Flooding, and Southern Pampas (Soriano, 1991). These ecological units also differ in land use patterns (LART-MAAyP, 2004; Fig. 1B): whereas, cropland has replaced more than 75% of the native vegetation in the Rolling Pampas, most of the Flooding Pampas still remains as grassland (>85%). The Inland Pampas (Flat and West) and the Southern Pampas have mixed production systems devoted to both crops and animal husbandry. In the Rolling and the Inland Pampas, summer crops [soybean (*Glycine max*), maize (*Zea mays*), and sunflower (*Helianthus annuus*)] are dominant, whereas, in the Southern Pampas winter crops such as, wheat (*Triticum aestivum*) prevail (INDEC, 2006).

The climate is warm-temperate, with mean temperatures varying between 15 °C in the south and 18 °C in the north. Annual rainfall decreases from 1000 mm in the NE to 800 mm in the SW (see Fig. 1C), although inter-annual variability of rainfall is quite frequent in the Pampas with extensive rainfall or drought (Labraga et al., 2002; Scian et al., 2006). According to data provided by the Servicio Meteorológico Nacional of Argentina (SMN, Exp_144540), the first year of our study was considered as a normal period (≈800–900 mm, see Fig. 1C black arrow), whereas, the second year was considered as a wet period of exceptionally high rainfall (≥1200 mm, see Fig. 1C gray arrow); thus, we considered inter-annual rainfall variation in our analyses (see Section 2.3).

2.2. Sampling of armadillos

We studied the two most common armadillos species of the Pampas: *C. villosus* and *D. hybridus*. We randomly selected 25 areas distributed evenly throughout our study area, five in each ecological unit of Buenos Aires Pampas (Fig. 1B). In each of these areas we selected four plots, two crop fields, and two rangelands with livestock activity. In each plot we searched for burrowing signs (burrows and holes, see Abba et al., 2007) along a 600 × 6 m transect, in order to assess armadillos activity. Signs of burrowing activity could be distinguished at species level, considering width and shape of the entrance (see Abba et al., 2007; a third armadillos species, *Chaetophractus vellerosus* – little or screaming hairy armadillo – was excluded from analyses due to low frequency of occurrence; see Section 3). Additionally, we could confirm several cases of indirect signs through direct observations of animals digging.

We did four surveys to estimate armadillo activity: two during spring–summer (December 2011–2012 and January 2012–2013) and two during fall (April–May 2012 and May–June 2013). Thus, each site was surveyed twice each season throughout two years, but each sampling was carried out in different plots, so that, we avoided dependence among data.

We surveyed pastures and natural or semi-natural grasslands in plots with livestock use, and surveyed winter crop stubble (wheat, barley, rye, etc.) during spring–summer and summer crop stubble (soybean, corn, sunflower, etc.) during fall. In total, we surveyed 392 plots (196 of each land use type), since during December 2011 we could not survey in two sampling sites of one ecological unit (the West Inland Pampas) due to logistical problems.

2.3. Statistical analyses

We compared the occupation rates of plots by each species on each type of land use by means of tests of difference of proportions (Zar, 2010). We described and compared variations in armadillo activity (number of burrowing signs) by considering the following explanatory variables: land use (use two levels: cropland and livestock), ecological unit (Pampas ecological unit, unit, five levels: Southern, Flooding, Flat Inland, West Inland, and Rolling), and year (two levels: year 1 = normal and 2 = wet). All these variables were specified as a fixed effect, whereas, season (two levels: spring–summer and fall) was treated as a random effect, in order to control for possible seasonal differences in armadillos activity (Abba et al., 2011a,b). To test the effects of these variables on armadillo activity we used a negative binomial generalized mixed model to account for overdispersed count data (Zuur et al., 2009). Moreover, in all cases we checked for normality and homogeneity of variance of residuals by means of graphical validation tools for the negative binomial GLMM (Zuur et al., 2009).

We developed two independent analyses, taking into account the number of burrowing signs of each species. Models were evaluated with information-theoretic procedures (Burnham and Anderson, 2002). We considered models with all possible combinations of predictor variables, resulting in eight candidate models for analyzing variation in armadillo activity by plot. Akaike's information criterion corrected for small sample size (AICc) was calculated for each model (Burnham and Anderson, 2002). Model comparisons were made with ΔAICc, which is the difference between the lowest AICc value (i.e., best of suitable models) and AICc from all other models. The AICc weight of a

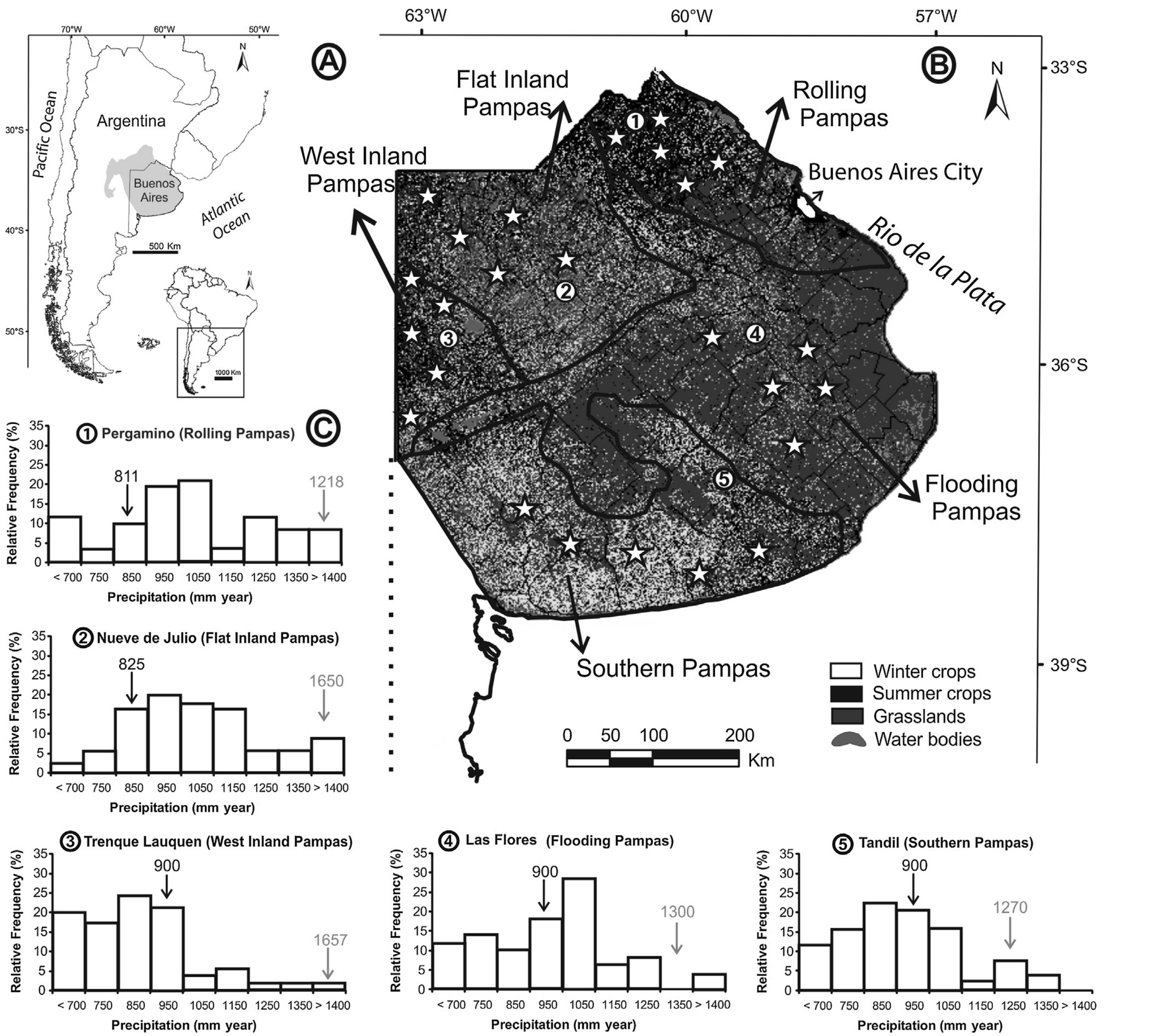

Fig. 1. (A) General location of the Argentinean Pampas Region (gray shading) and Buenos Aires province. (B) Detail of the study area indicating land use cover types and limits of the ecological units considered in our analysis (Rolling Pampas, Flat Inland Pampas, West Inland Pampas, Flooding Pampas and Southern Pampas), stars indicate approximate locations of the survey sites. (C) Histograms with annual rainfall recorded over the last 50 years at five locations: Pergamino (Rolling Pampas), Las Flores (Flooding Pampas), 9 de Julio (Flat Inland Pampas), Trenque Lauquen (West Inland Pampas), and Tandil (Southern Pampas); black arrows indicate average annual rainfall during the first year of our armadillos surveys (normal) and gray arrows indicate average annual rainfall during the second year of our armadillos surveys (wet). Land use cover was extracted from LART-MAAyP (2004); rainfall data were provided by the Servicio Meteorológico Nacional (SMN, Exp_144540).

Table 1
Mean number (and standard error) of burrowing activity of armadillos (*Chaetophractus villosus* and *Dasypus hybridus*) and occupancy rate of plots by each species according to land use (cropland and rangeland) in the Pampas of Buenos Aires province, central Argentina,during spring–summer and fall. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; test for difference of proportions.

Burrowing activity (number of signs per transect)								
Species	Spring–summer				Fall			
	Mean	SE	Range	*n*	Mean	SE	Range	*n*
C. villosus	14.6	2.2	0–297	192	15.8	1.6	0–149	200
D. hybridus	5.6	1.3	0–187	192	4.1	0.9	0–97	200
	Occupancy rate (%)							
	Spring–summer				Fall			
	Cropland		Rangeland		Cropland		Rangeland	
C. villosus	83	*	70		93	***	71	
D. hybridus	27	**	46		26	**	47	

model (wi) means the relative likelihood that the specific model is the best of the suite of all models. We evaluated the support for predictor variables summing wi across all models that contained the parameter being considered (parameter likelihood; Burnham and Anderson, 2002). Coefficients estimates were calculated using model-averaged coefficients estimates based on wi from all candidate models. To supplement parameter-likelihood evidence of important effects, we calculated 95% confidence interval limits (CL) of parameter estimates. For statistical analyses, we used the glmmADMB and MuMIn package from R software, Version 3.1.0 (R Core Team, 2014).

3. Results

A total of 7834 armadillo signs were found in 89.5% (351) of the plots surveyed. *C. villosus* was the most active species irrespective of land use type, with 5968 signs at 79% of the plots surveyed, whereas, a total of 1866 signs of *D. hybridus* were found in 36% of the plots. On average, occupancy rates by *C. villosus* were higher in crop field plots (88%) than rangeland plots (70.5%), whereas. *D. hybridus* showed the opposite trend, being more frequently found at rangeland plots (46.5% vs. 26.5% for crop field plots; see also Table 1). Additionally, we found 74 signs of *C. vellerosus* in 6 plots of the Inland Pampas.

The best model explaining variation in recorded burrowing signs of *C. villosus* (mean = 15.2; variance = 713.4) included year, unit, and use as explanatory variables (wi = 1, Table 2A). *C. villosus* showed fewer signs during the wet year than in the year with normal rainfall. *C. villosus* also had fewer signs in livestock than cropland plots. Finally, variation according to biogeography (unit) revealed significantly more burrowing signs of *C. villosus* in the Inland Pampas (Flat and West) than in the other ecological units (Table 2B and Fig. 2a).

Two models explained the variation in recorded burrowing signs of *D. hybridus* (mean = 4.8; variance = 225.9) and included unit, year, and use as explanatory variables (wi = 0.504, and wi = 0.336; Table 3A). *D. hybridus* showed more signs in the Flooding Pampas (FP) than in the Inland Pampas (Flat and West) and Rolling Pampas (RP), but no differences with the Southern Pampas (Table 3B and Fig. 2b). As observed for *C. villosus*, *D. hybridus* also showed fewer signs during the wet year than the year with normal rainfall (year 1; Table 3B and Fig. 1C). Livestock plots showed more *D. hybridus* signs than cropland plots (Table 3B).

Table 2
(A) Model selection, based on ΔAICc comparison, of generalized linear mixed model (GLMM) describing *Chaetophractus villosus* activity; *k* is the number of estimated parameters. Models are listed in decreasing order of importance. (B) Parameter likelihoods, coefficients estimates SE, and 95% confidence interval limits (CL) for explanatory variables describing variation in the number of *C. villosus* activity. Explanatory variables with CL excluding zero are in bold. Ecological unit (=unit): SP = Southern Pampas, FP = Flooding Pampas, FIP = Flat Inland Pampas, WIP = West Inland Pampas, RP = Rolling Pampas. See Section 2 for details.

A Response variable	Candidate models	*k*	AICc	ΔAICc	wi
Burrowing activity of *C. villosus*	Year unit use	8	2756.8	0.00	1.000
	Unit use	7	2780.3	23.50	0.000
	Year use	4	2787.9	31.19	0.000
	Year unit	7	2789.5	32.78	0.000
	Use	3	2804.1	47.37	0.000
	Year	3	2811.0	54.27	0.000
	Unit	6	2813.1	56.32	0.000
	Null model	2	2826.1	69.31	0.000

B Response variable	Explanatory variable	Parameter likelihood	Coefficients estimate ± SE	CL Lower	CL Upper
	Intercept		3.94 ± 0.19	3.55	4.32
Burrowing activity of *C. villosus*	**Year$_{(2)}$**[a]	**1**	**−0.71 ± 0.14**	**−0.98**	**−0.44**
	Unit$_{(SP)}$[b]	**1**	**−0.89 ± 0.22**	**−1.32**	**−0.45**
	Unit$_{(FP)}$[b]	**1**	**−0.66 ± 0.22**	**−1.09**	**−0.23**
	Unit$_{(FIP)}$[b]	1	−0.27 ± 0.22	−0.70	0.16
	Unit$_{(RP)}$[b]	**1**	**−1.29 ± 0.22**	**−1.73**	**−0.85**
	Use$_{(livestock)}$[c]	**1**	**−0.85 ± 0.14**	**−1.12**	**−0.58**

[a] Relative to year 1.
[b] Relative to unit WIP.
[c] Relative to cropland.

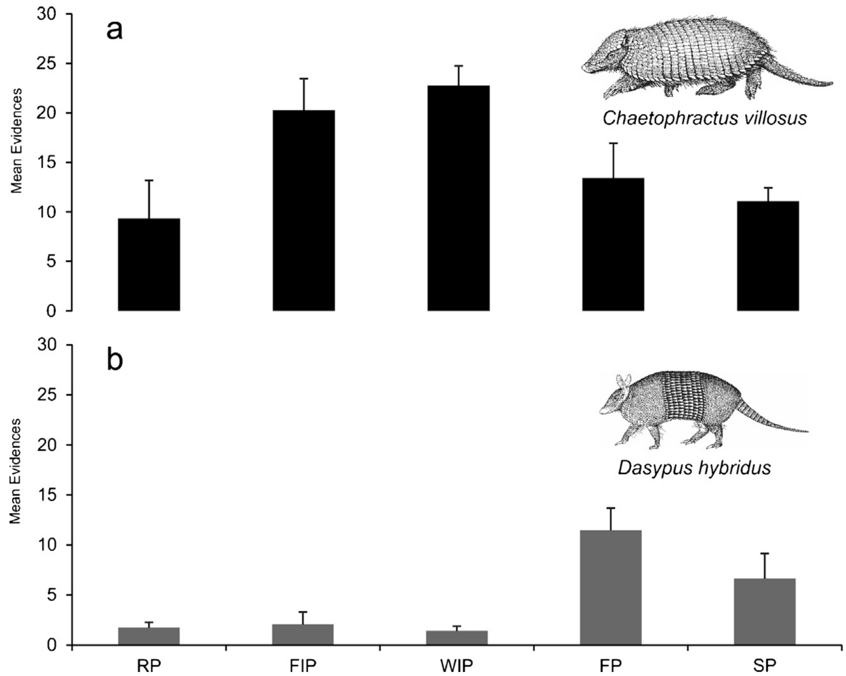

Fig. 2. Mean and standard error of armadillo burrowing signs in the Pampas of Buenos Aires province, classified by ecological unit (RP = Rolling Pampas, FIP = Flat Inland Pampas, WIP = West Inland Pampas, FP = Flooding Pampas, and SP = Southern Pampas) and species (a *Chaetophractus villosus*; b *Dasypus hybridus*). Illustration modified from Díaz and Barquez (2002).

Table 3
(A) Model selection, based on ΔAICc comparison, of generalized linear mixed model (GLMM) describing *Dasypus hybridus* activity; k is the number of estimated parameters. Models are listed in decreasing order of importance. (B) Parameter likelihoods, coefficients estimates SE, and 95% confidence interval limits (CL) for explanatory variables describing variation in amount of *D. hybridus* activity. Explanatory variables with CL excluding zero are in bold. Ecological unit (= Unit): SP = Southern Pampas, FP = Flooding Pampas, FIP = Flat Inland Pampas, WIP = West Inland Pampas, RP = Rolling Pampas. See Section 2 for details.

A Response variable	Candidate models	*k*	AICc	ΔAICc	wi
Burrowing activity of *D. hybridus*	Unit year	7	1464.1	0.00	0.504
	Unit year use	8	1464.9	0.81	0.336
	Unit use	7	1467.6	3.48	0.089
	Unit	6	1468.0	3.91	0.071
	Year	3	1483.3	19.16	0.000
	Year use	4	1483.4	19.24	0.000
	Use	3	1491.7	27.56	0.000
	Null model	2	1495.1	30.98	0.000

B Response variable	Explanatory variable	Parameter likelihood	Coefficients estimate ± SE	CL	
				Lower	Upper
Burrowing activity of *D. hybridus*	Intercept		2.46 ± 0.35	1.77	3.16
	Unit $_{(SP)}$[a]	1.00	−0.47 ± 0.41	−1.27	0.33
	Unit$_{(WIP)}$[a]	**1.00**	**−1.97 ± 0.43**	**−2.82**	**−1.12**
	Unit$_{(FIP)}$[a]	**1.00**	**−1.28 ± 0.47**	**−2.20**	**−0.36**
	Unit$_{(RP)}$[a]	**1.00**	**−1.72 ± 0.42**	**−2.55**	**−0.89**
	Year$_{(2)}$[b]	**0.84**	**−0.69 ± 0.29**	**−1.26**	**−0.12**
	Use $_{(livestock)}$[c]	0.42	0.35 ± 0.29	−0.22	0.92

[a] Relative to unit FP.
[b] Relative to year 1.
[c] Relative cropland.

Summarizing, our results, showed that the burrowing activity of the two most abundant and widely distributed armadillo species inhabiting the Pampas of Buenos Aires province are influenced by biogeographic, land use, and rainfall. *C. villosus* was more active mainly in the Inland Pampas and in cropland plots, whereas, *D. hybridus* was more active in the Flooding Pampas at plots with livestock use. Both species showed less burrowing activity during the second year of surveys, in association with a period of exceptionally high annual rainfalls which surpassed 1200 mm regionally.

4. Discussion

To the best of our knowledge, this is the first attempt to estimate activity of armadillo species in the Pampas of Buenos Aires province, central Argentina, at both regional and local scales. Our results show that activity of armadillo species is influenced by the three factors originally considered in our analyses: biogeography, land use, and annual rainfalls.

Our results suggest that the introduction of crop fields may have favored to *C. villosus* in the Pampas. The higher activity of *C. villosus* at crop fields may be related to increased food availability for this omnivorous armadillo (Abba and Cassini, 2008; Redford, 1985). Agricultural practices enhance availability of food items to *C. villosus* by directly increasing the grain food supply left as stubble. Furthermore, the absence of soil tillage allows that the burrows dug by *C. villosus* are not destroyed by agricultural labors and remain to be used for much longer periods. These observations are in agreement with a preliminary study at one site in the Inland Pampa showing fewer *C. villosus* at crop fields under soil tillage vs. non-tillage (Merino Tosoni and Pennisi, 2010). In addition, some studies indicate that the supply of soil invertebrates (e.g., earworms, beetles, crickets, etc.) may have increased with non-tillage systems (Brown et al., 2003; House, 1989; Lienhard et al., 2013) even though other studies have shown opposite trends (Domínguez et al., 2010).

On the other hand, it can be argued that *D. hybridus*, a species with a more specialized diet and with a stronger tendency to myrmecophagy (Abba et al., 2011a; Redford, 1985) may have not be been favored by the expansion and intensification of agriculture as was for *C. villosus*.

The expansion of croplands and the increase in *C. villosus* activity interferes with farming practices and grain storing operations at silo bags, thus, producing many human–armadillos conflicts. The higher activity of *C. villosus* at the Inland Pampas (mostly in the West Inland Pampa) may be related to the fact that this ecological unit have regionally sandy and deeper soils with good permeability, thus, providing an advantage to *C. villosus* to dig more easily (Abba et al., 2007; Abba and Vizcaíno, 2011; Crespo, 1944).

On the other hand, *D. hybridus* showed higher activity in relation with livestock land use, particularly in the Flooding Pampas. These associations are closely related, since more than 85% of the Flooding Pampas remains as grassland (Solbrig, 1997; Viglizzo et al., 2011). Thus, the matrix of scarce cropland and abundant natural or semi-natural grasslands seem to favor *D. hybridus* (Abba et al., 2007; Abba and Vizcaíno, 2011). Similar responses of vertebrates to dominant landscape matrix in the study area have also been reported for small mammals (González-Fischer et al., 2011) and birds (Codesido et al., 2013).

The high rainfall recorded during the second year of our study generated temporal flooding in several areas of the Pampas region, thus affecting the activity of both armadillo species. The extreme rainfalls may have forced displacement of armadillo populations to avoid flooded areas, since water logging affects burrowing activity and interferes with their foraging. These results are concordant with previous studies on other *Dasypus* species such as, *Dasypus novemcintus* and *Dasypus sabanicola* in USA and Venezuela, respectively, where displacements to minimize the impact of floods have been reported (Layne and Waggener, 1984; McBee and Baker, 1982; Pacheco and Naranjo, 1978).

Over the last 25–30 years, Buenos Aires province has witnessed extreme agriculturization growth, as crops increased by more than 30% between 1988 (25%) and 2008 (33%; Baldi and Paruelo, 2008; INDEC, 1988, 2009). The effects of this recent agriculturization on biodiversity has already been detected in both birds (Codesido et al., 2008, 2011, 2013; Filloy and Bellocq, 2007; Weyland et al., 2014) and small mammal assemblages at landscape and regional scales (Bilenca et al., 2012; González-Fischer et al., 2011, 2012). Additionally, effect of land use on armadillos has been observed at a local scale in a livestock area of the Flooding Pampas, where *D. hybridus* was associated with natural grasslands and avoided cultivated pastures (Abba et al., 2007). Other factors like hunting pressure may also affect abundance of armadillos like *C. villosus* at local scales (Abba et al., 2007).

5. Conclusion

Armadillos (*C. villosus*; *D. hybridus*) are an important component of biodiversity in agroecosystems of Buenos Aires province, as observed by the high occupation rate and burrowing activity by both species in fields devoted to crop or livestock use.

Land use change from grasslands to cropland seems to favor *C. villosus*, particularly in the Inland Pampas, where more burrowing signs of this species (and more conflicts) have been observed. If this trend to further increase in the cropland area continues in Buenos Aires province (Vega et al., 2009), it is likely that the population of *C. villosus* will still grow, along with more problems related to these armadillos.

On the other hand, *D. hybridus* showed a tendency to select areas with high proportion of natural or semi-natural grassland in the rural landscape, so this species may be affected by the strong tendency of land use change in Buenos Aires province. This situation may have implications for conservation, since, *D. hybridus* has been recently classified as near threatened (Abba and Superina, 2010; Superina et al., 2012) due to an inferred population decline over the past 10 years throughout its range (see Abba et al., 2007; Abba and Superina, 2010; Abba et al., 2011a). Therefore, if this tendency continues, *D. hybridus* is close to qualify as a threatened species in the near future.

Future studies are needed regarding (1) estimates of crop losses and agricultural impacts by armadillos, (2) ecological management of armadillos in order to reduce human–armadillo conflicts in the Pampas of Central Argentina, as has already initiated for other vertebrate–crop conflicts (e.g., Canavelli et al., 2012, 2013), and (3) food habits of armadillos and their association with the availability of soil invertebrates.

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