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Short Communication

Food habits and impact of rooting behaviour of the invasive wild boar, *Sus scrofa*, in a protected area of the Monte Desert, Argentina

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ABSTRACT

The wild boar, *Sus scrofa*, was introduced in the central region of Argentina in the early 20th century. A small feral population invaded the western area of the Man and Biosphere Reserve of Ñacuñán, Argentina in the early 1980's. The purpose of our study was to provide information about the diet of wild boars in the semiarid region of Argentina and to assess their potential effect on vegetation through soil rooting. We analyzed 41 faecal samples and compared cover plant composition between rooted and non-rooted soil. Ninety-five percent of the wild boar diet consisted of different parts (leaves, stems, glumes, fruits, seeds, and bulbs) of 36 plant species, while arthropods and animal tissue represented only 5% of the diet. Two plant species (*Sphaeralcea miniata* and *Pitraea cuneato-ovata*) composed the bulk of the diet, representing almost 50% of the total items found in the faeces. Plant cover was significantly different between rooted and non-rooted areas. Rooted areas were dominated by *Pitraea cuneato-ovata,* whereas the cover of *Lycium* sp was higher in non-rooted areas. This is the first study addressing the ecology of the wild boar in a protected area of the Monte Desert biome of Argentina.

Invasive species are an important source of disturbance that can dramatically affect ecosystem structure and functioning (Didham et al., 2005). Eighteen species of exotic mammals have been documented as naturalized populations in Argentina (Novillo and Ojeda, 2008). Among these, the wild boar, *Sus scrofa*, was introduced in the 20th century for hunting purposes (Navas, 1987). Since then, the wild boar has expanded its geographic range across the country. In northern Patagonia, for example, populations of wild boar have increased nearly 30% during the past 20 years (Pescador et al., 2009). In the early 1980's, this species arrived to the western portion of the central Monte Desert, and a small feral population invaded and established in the Man and Biosphere (MaB) Reserve of Ñacuñán, Mendoza province, Argentina (Ojeda and Campos, pers. obs.).

The wild boar is one of the largest invasive mammals in the world and is considered an ecosystem engineer because it modifies the structure and composition of soil and plant communities through soil rooting and nest building behaviour (Crooks, 2002; Singer et al., 1984; Welander, 2000). Due to its impact on ecosystems and human activities it has been nominated as one of the 100 worst invasive species (Lowe et al., 2000). Among the possible causes of its success as an invader are: its large body mass, wide geographic range, adaptation to diverse ecoregions, high reproductive rate, and omnivorous diet (Novillo and Ojeda, 2008; Read and Harvey, 1989).

Despite being the largest mammal in the Reserve, there are no studies addressing its ecology. The aim of our study was to assess two aspects of the ecology of an invasive species, as is the wild boar *Sus scrofa*, in a protected area of the Monte Desert, Argentina, within the framework of the ALARM project (Settele et al., 2005). In particular, we characterized and quantified its food habits and assessed the impact of its rooting behaviour on vegetation.

The study was conducted in the MaB Reserve of Ñacuñán (34° 02′ S, 67° 58′ W; 13 200 ha), located within the Monte Desert phytogeographic province (Fig. 1). The landscape is characterized by a heterogeneous mosaic of vegetation patches. Dominant habitats are known as "algarrobal" or *Prosopis* woodland (*Prosopis flexuosa*), "jarillal" or *Larrea* shrubland (*Larrea cuneifolia*) and "medanal" or sand dunes. Climate is semiarid and strongly seasonal, with hot, humid summers (November–April) and cold, dry winters (May–October). Average annual precipitation is 326 mm. Mean annual temperature is 15.6 °C, with a maximum annual mean of 23.8 °C and a minimum annual mean of 7.6 °C (Claver and Roig-Juñent, 2001).

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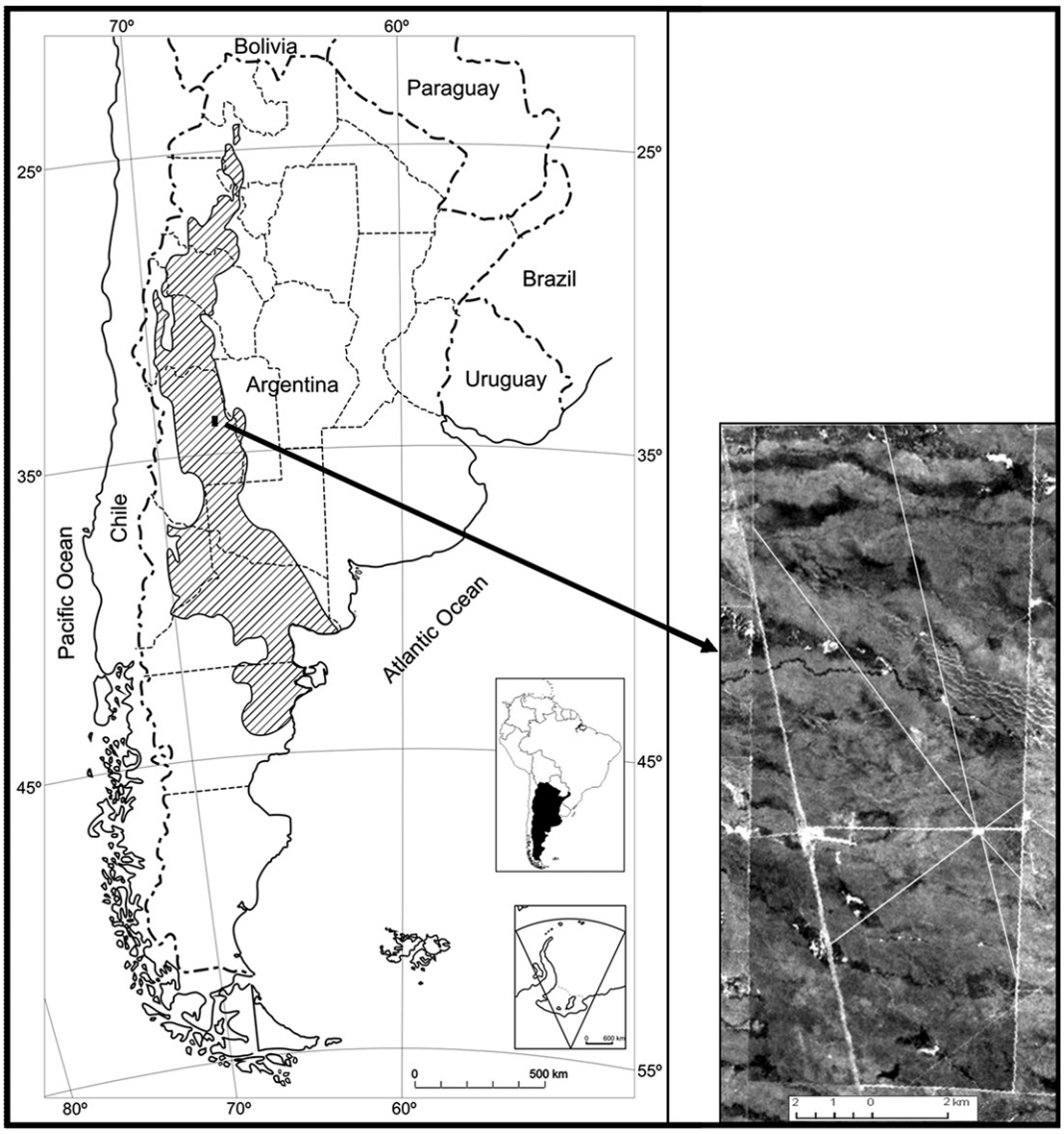

Fig. 1. The Monte Desert phytogeographic province and location of the Man and Biosphere Reserve of Ñacuñán. The aerial picture of the reserve shows the inner and perimeter trails where we established the sampling transects.

The sampling was conducted between the dry seasons 2004 and 2005 and the wet season 2006. We set up transects along the inner and perimeter trails of the reserve in search of faeces and signs of rooting by wild boars (Fig. 1).

To determine the diet of wild boar, we collected 41 fresh faecal samples during the dry seasons 2004 and 2005. We used samples of faeces because animal trapping and killing are not allowed in the protected area. Ten grams from each faecal sample were analyzed by using the modified microhistological technique (Dacar and Giannonni, 2001) that permits identification of leaf epidermis, stems, seed teguments, fruits, arthropod body parts, rhizome tissues, and hairs of mammals. For each sample we prepared one microscope slide and systematically examined 50 fields under microscope at 40×. Food items in the faecal samples were identified by comparison to reference material. Presence of a food item was recorded, and its relative frequency of occurrence per slide was determined by dividing the number of microscope fields in which this item occurred by the total number of microscope fields observed × 100 (Holechek and Gross, 1982). The mean and standard error for each food item was calculated for all 41 samples.

To evaluate the impact of wild boars on vegetation, we recorded their rooting activity within 10 m on either side of each transect during the dry season 2005 and the wet season 2006. At each rooting site (consisting of a rooted and a non-rooted area), we randomly distributed 10 (0.6 × 0.6 m) plots over each type of area. Non-rooted areas were set up adjacent to the rooted ones to guarantee that non-rooted areas represented a similar habitat as rooted areas before being disturbed by wild boars. Percentage of plant cover was quantified on each plot by visual estimation. Data on percentage of plant cover were arcsine square-root transformed prior to analysis. The Wilcoxon matched pairs test was employed to detect differences in plant cover between rooted and non-rooted areas.

Ninety-five percent of the wild boar diet in the central Monte Desert was composed of different parts (leaves, stems, glumes, fruits, seeds, and bulbs) of 36 plant species, while arthropods and animal tissue represented only 5% of the diet (Table 1). Seventy five percent (75%) of the diet was composed of leaves (mostly *Sphaeralcea miniata,* Malvaceae) and bulbs (*Pitraea cuneato-ovata,* Verbenaceae). *S. miniata* is a component of the herb layer in both *Prosopis* woodland and *Larrea* shrubland habitats. This species is a highly

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Table 1
Mean and standard error of percent frequency of occurrence for items present in wild boar's diet in Ñacuñán Reserve, Argentina, from 41 faecal samples during the dry seasons 2004 and 2005.

Leaves	Food item	Frequency (%)	
		Mean	SE
Asteraceae	*Conyza* sp.	0.48	0.68
	Senecio sp.	1.28	0.49
	Hyalis argentea	0.38	1.23
Brassicaceae	*Descurainia* sp.	3.52	1.73
Capparidaceae	*Capparis atamisquea*	0.71	0.12
Chenopodiaceae	*Chenopodium* sp.	2.81	0.82
Ephedraceae	*Ephedra*	0.19	0.14
Fabaceae	*Prosopis flexuosa*	2.14	0.44
	Adesmia sp.	0.09	0.15
	Geoffroea decorticans	0.05	0.05
Hydrophyllaceae	*Phacelia artemisioides*	0.05	0.07
Malvaceae	*Sphaeralcea miniata*	25.05	2.78
	Lecanophora sp.	1.67	0.38
Plantaginaceae	*Plantago patagonica*	0.14	0.10
Poaceae	*Pappophorum philippianum*	2.67	1.20
	Stipa sp.	0.38	0.15
	Chloris castilloniana	0.71	0.19
	Poa lanuginosa	0.57	0.42
	Sporobolus cryptandrus	0.19	0.12
	Digitaria californica	0.14	0.20
	Hordeum stenostachis	0.23	0.22
	Setaria sp.	0.43	0.27
	Bromus brevis	1.00	0.72
	Cottea pappophoroides	0.05	0.05
	Panicum urvilleanum	0.05	0.05
Rhamnaceae	*Condalia microphylla*	0.09	0.07
Solanaceae	*Lycium* sp.	3.57	0.66
	Solanum sp.	0.33	0.22
	Fabiana peckii	0.71	0.15
Verbenaceae	*Pitraea cuneato-ovata*	0.67	0.25
	Glandularia mendocina	1.28	0.83
	Acantholippia seriphioides	0.43	0.36
	Junellia seriphioides	0.05	0.07
Zygophyllaceae	*Larrea* sp.	2.62	1.36
	Bulnesia retama	0.14	0.20
	Total	**54.87**	
Stems	*Larrea* sp.	1.62	1.13
	Prosopis flexuosa	0.19	0.20
	Capparis atamisquea	0.57	0.26
	Total	**2.38**	
Glumes of grasses		**2.67**	1.35
Fruits	*Prosopis flexuosa*	**7.62**	2.49
Seeds	*Prosopis flexuosa*	0.24	0.20
	Capparis atamisquea	0.05	0.05
	Lycium sp.	0.57	0.05
	Hoffmanseggia sp.	5.67	1.39
	Total	**6.63**	
Bulbs	*Pitraea cuneato-ovata*	**20.80**	3.24
Arthropods		**3.67**	1.21
Animal tissue		**1.47**	1.11

nourishing food resource (16.9% protein, 1.95% Ca, 0.26% P, nutritional relationship 1:3.8) and reaches high abundance on disturbed soils. The nutritional relationship is the ratio between protein and fat, fibre and compounds without nitrogen. This ratio determines how good a plant is as forage for livestock (Candia, 1980). *P. cuneato-ovata* is an annual herb, typical of the *Larrea* shrubland habitat. Its nutritional analysis indicates it as a good forage plant because of its nutritional relationship (1:4.6), suitable palatability and high carbohydrate content in the bulbs (Stasi and Medero, 1983). *P. cuneato-ovata* becomes established from seeds, but plant growth is driven by its gemmiferous roots. This species is a highly water-demanding plant, occurring primarily in low swampy areas where it forms colonies on flooded sites with clay soils (Roig, 1971; Stasi and Medero, 1983).

A high content of plant matter and a low percentage of animal tissue in the diet of the wild boar have been reported for Mediterranean biomes (Baubet et al., 2004; Massey et al., 1996; Pinna et al., 2007; Rudge, 1976; Schley and Roper, 2003; Skewes et al., 2007). These previous studies reported a diet of grasses as the most frequent food item, whereas in the warm Monte Desert grasses (leaves and glumes) only constituted 9% of the diet and dicotyledonous herbs (leaves and bulbs) were the most frequent food item. Adkins and Harveson (2006) found 38.6% of herbs and 34.3% of roots and tubers in the diet of wild boars in semiarid regions in Texas, while animal material represented only 2% of the diet. In our study, we also found that the percentage of animal tissue was very low. Even though the wild boar is considered an omnivorous species, the present results and previous studies indicate that wild boars feed mainly on plant species. Although faeces had been subjected to a higher digestive activity than stomach contents, they still contributed pertinent qualitative information on diet (Barreto et al., 1997; Rudge, 1976).

We recorded 15 rooting sites and 45 plant species at the sites. Only the cover of two plant species showed significant differences between rooted and non-rooted areas: *Lycium* sp. (Solanaceae) and *P. cuneato ovata*. Cover of *Lycium* sp. was higher in non-rooted areas during the dry season. *P. cuneato-ovata* showed a significantly higher cover in rooted areas during the wet season (Table 2).

Disturbance produced by soil rooting of wild boars significantly reduced the cover of perennial species such as *Lycium* sp. On the other hand, the wild boar exhibited a close relationship with the annual plant *P. cuneato-ovata*, whose bulbs constituted 21% of the animal diet. *P. cuneato-ovata* dominated the rooted areas where soil moisture lasts much longer than in areas where the soil remains intact (Cuevas et al., unpublished data). In this sense, the wild boar is behaving as an ecological engineer, creating conditions (e.g. higher water retention in rooted soil) for the establishment of

Table 2
Mean and standard error of percentages of plant cover in rooted and non-rooted areas during the dry season 2005 and the wet season 2006 at Ñacuñán Reserve, Argentina. An asterisk indicates that significant differences existed between rooted and non-rooted plots (Wilcoxon matched paired test). Only plants with over 1% cover in plots were included.

Species	Dry Season 2005			Wet Season 2006		
	Plant cover (%)			Plant cover (%)		
	Rooted soil	Non rooted soil	*p*	Rooted soil	Non rooted soil	*p*
	Mean (SE)	Mean (SE)		Mean (SE)	Mean (SE)	
Baccharis darwinii	0.48 (0.4)	1.66 (1.1)	0.07	2.01 (0.8)	2.49 (1.5)	0.99
Digitaria californica	0.15 (0.1)	0.17 (0.1)	0.99	1.28 (0.7)	0.95 (0.8)	0.99
Lycium sp.	0.16 (0.1)	2.5 (0.9)	0.002*	0.45 (0.2)	0.92 (0.5)	0.08
Pappophorum sp.	1.87 (0.7)	4.99 (1.8)	0.4	5.54 (1.6)	9.09 (2.0)	0.09
Pitraea cuneato-ovata	0.13 (0.1)	–	0.99	12.06 (3.1)	0.88 (0.4)	0.002*
Setaria leucopila	0.2 (0.1)	0.74 (0.4)	0.48	1.37 (0.6)	0.63 (0.3)	0.44
Sphaeralcea miniata	1.07 (0.4)	1.87 (0.6)	0.12	0.05 (0.04)	0.13 (0.1)	0.07
Sporobolus cryptandrus	0.07 (0.07)	–	0.99	1.01 (0.5)	0.07 (0.05)	0.99
Stipa sp.	2.54 (0.7)	6.91 (3.0)	0.22	3.59 (1.2)	3.75 (1.3)	0.99

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certain plant species. On the other hand, it has been shown that wild boars reduce seed survival and seedling regeneration of *Araucaria araucana* in the northern portion of the Patagonian region (Sanguinetti and Kitzberger, 2010).

Despite being the largest mammal in the Ñacuñán Reserve, this is the first study to assess the diet of the wild boar and its effect on plant cover in the drylands of South America. Arid and semiarid ecoregions of Argentina, particularly the Chacoan thornscrub and Monte shrublands, are undergoing rapid habitat conversion (i.e. grazing, logging, agriculture) (Ojeda et al., 2002) and disturbance caused by invasive species now becomes of great importance. Potential effects of wild boar disturbance in the Monte Desert biome may include changes in soil properties, plant structure and composition (our ongoing research), and seed predation (Campos and Ojeda, 1997). Ongoing research on the ecology of the wild boar in the Monte Desert will help to clarify the role of one of the largest invasive species in the dynamics of temperate dryland ecosystems.

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References

Adkins, R.N., Harveson, L.A., 2006. Summer diets of Feral Hogs in the Davis Mountains, Texas. The Southern Naturalist 50, 578–580.

Barreto, G.R., Hernandez, O.E., Ojasti, J., 1997. Diet of peccaries (*Tayassu tajacu* and *T. pecari*) in a dry forest of Venezuela. Journal of Zoology 241, 279–284.

Baubet, E., Bonenfant, C., Brandt, S., 2004. Diet of the wild boar in the French Alps. Galemys 16 (número especial), 101–113.

Campos, C.M., Ojeda, R.A., 1997. Dispersal and germination of *Prosopis flexuosa* (Fabaceae) seeds by desert mammals in Argentina. Journal of Arid Environments 35, 707–714.

Candia, R.J., 1980. Aspectos ecológicos de *Sphaeralcea miniata* (Cav.) Spach. Deserta 6, 101–111.

Claver, S., Roig-Juñent, S., 2001. El desierto del Monte: La Reserva de Biosfera de Ñacuñán. IADIZA, MAB, UNESCO. Ed. Triunfar. Argentina.

Crooks, J.A., 2002. Characterizing ecosystem-level consequences of biological invasions: the role of ecosystem engineers. Oikos 97, 153–166.

Dacar, M.A., Giannonni, S.M., 2001. A simple method for preparing reference slides of seed. Journal of Range Management 54, 191–193.

Didham, R.K., Tylianakis, J.M., Hutchison, M.A., Ewers, R.M., Gemmell, N.J., 2005. Are invasive species the drivers of ecological change? Trends in Ecology and Evolution 20, 470–474.

Holechek, J.L., Gross, B.D., 1982. Evaluation of different calculation procedures for microhistological analysis. Journal of Range Management 35, 721–723.

Lowe, S., Browne, M., Boudjelas, S., De Poorter, M., 2000. 100 of the World's worst invasive Alien species. A selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), 12 pp. First published as special lift-out in Aliens 12, December 2000. Updated and reprinted version: November 2004.

Massey, G., Genov, P.V., Staines, B.W., 1996. Diet, food availability and reproduction of wild boar in a Mediterranean coastal area. Acta Theriologica 41, 307–320.

Navas, J.A., 1987. Los vertebrados exóticos introducidos en la Argentina. Revista del Museo Argentino de Ciencias Naturales, Serie Zoología 14, 7–38.

Novillo, A., Ojeda, R.A., 2008. The exotic mammals of Argentina. Biological Invasions 10, 1333–1344.

Ojeda, R.A., Borghi, C.E., Roig, V.G., 2002. Mamíferos de Argentina. In: Ceballos, G., Simonetti, J. (Eds.), Diversidad y Conservación de los Mamíferos Neotropicales. CONABIO-UNAM, México, D.F, pp. 23–63.

Pescador, M., Sanguinetti, J., Pastore, H., Peris, S., 2009. Expansion of the introduced wild boar (*Sus scrofa*) in the Andean region, Argentinean Patagonia. Galemys 21, 121–132.

Pinna, W., Nieddu, G., Moniello, G., Cappai, G., 2007. Vegetable and animal food sort found in the gastric content of Sardinian Wild Boar (*Sus scrofa meridionalis*). Journal of Animal Physiology and Animal Nutrition 91, 252–255.

Read, A.F., Harvey, P.H., 1989. Life history differences among eutherian radiations. Journal of Zoology 219, 329–353.

Roig, F.A., 1971. Flora y vegetación de la Reserva Forestal de Ñacuñán. Deserta 1, 25–232.

Rudge, M.R., 1976. A note on the food of feral pigs (*Sus scrofa*) of Auckland Island. Proceedings of the New Zealand Ecological Society 23, 83–84.

Sanguinetti, J., Kitzberger, T., 2010. Factors controlling seed predation by rodents and non-native *Sus scrofa* in *Araucaria araucana* forests: potential effects on seedling establishment. Biological Invasions 12, 689–706.

Schley, L., Roper, T.J., 2003. Diet of wild boar *Sus scrofa* in Western Europe, with particular reference to consumption of agricultural crops. Mammal Review 33, 43–56.

Settele, J., Hammen, V., Hulme, P., Karlson, U., Klotz, S., Kotarac, M., Kunin, W., Marion, G., O'Connor, M., Petanidou, T., Peterson, K., Potts, S., Pritchard, H., Pysek, P., Rounsevell, M., Spangenberg, J., Steffan-Dewenter, I., Sykes, M., Vighi, M., Zobel, M., Kühn, I., 2005. ALARM (Assessing LArge-scale environmental Risks for biodiversity with tested Methods). GAIA 14 (1), 69–72.

Singer, F.J., Swnak, W.T., Clebsch, E.E.C., 1984. Effects of wild pig rooting in a deciduous forest. Journal of Wildlife Management 48, 464–473.

Skewes, O., Rodríguez, R., Jaksic, F., 2007. Ecología trófica del jabalí europeo (*Sus scrofa*) silvestre en Chile. Revista Chilena de Historia Natural 80, 295–307.

Stasi, C.R., Medero, M.N., 1983. Estudio ecológico y bromatológico de *Pitraea cuneato-ovata* (Cav.) Caro, una especie forrajera del "Monte" mendocino y sanjuanino. Deserta 7, 7–11.

Welander, J., 2000. Spatial and temporal dynamics of wild boar (*Sus scrofa*) rooting in a mosaic landscape. Journal of Zoology 252, 263–271.

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