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# Spatial segregation among pampas deer and exotic ungulates: a comparative analysis at site and landscape scales

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The pampas deer (*Ozotoceros bezoarticus*) is native to South America and is endangered in Argentina. In Buenos Aires province, Argentina, the last population of pampas deer is harbored in the Bahía Samborombón Wildlife Refuge (BSWR), which includes protected areas and numerous cattle ranches. This population has been declining and changing progressively in its distribution since 1985, and negative interactions between pampas deer and introduced ungulates (livestock and feral pigs) have been proposed among the main causes of its decline. We examined the abundance, distribution, and interactions among pampas deer, cattle, and feral pigs at site and landscape scales in the BSWR. At the site scale, coexistence between pampas deer and cattle at the same paddock was only possible at moderate stocking rates (0.2–0.4 AU/ha), and no deer were recorded at paddocks when stocking rates were above 0.6 AU/ha. Pampas deer and feral pigs co-occurred more frequently, but deer switched their behavior and increased levels of surveillance in response to proximity of feral pigs. At the landscape scale, a clear spatial segregation and differential distribution was detected among pampas deer, cattle, and feral pigs along the BSWR. Our results suggest that the current distribution of pampas deer at the study area is a consequence of avoiding contact with both livestock and feral pigs at the site scale. Thus, negative interactions recorded between pampas deer and introduced ungulates at the site scale were expressed at the landscape scale. Both in situ and ex situ conservation efforts are urgently needed to conserve pampas deer.

El venado de las pampas (*Ozotoceros bezoarticus*) es un cérvido nativo de Sudamérica que se encuentra seriamente amenazado en Argentina. En la provincia de Buenos Aires, Argentina, el último núcleo poblacional de la especie se encuentra en el Refugio de Vida Silvestre Bahía Samborombón (RVSBS), que alberga áreas protegidas y, mayormente, campos ganaderos. Dicha población ha estado declinando y cambiando progresivamente su distribución desde 1985 y, al respecto, se ha propuesto a las interacciones negativas entre el venado y especies introducidas como el ganado vacuno y los chanchos cimarrones entre las principales causas de su declinación. El objetivo de este estudio fue analizar la abundancia, la distribución y las interacciones del venado de las pampas con el ganado vacuno y los chanchos cimarrones, simultáneamente, a escala de sitio y de paisaje en el RVSBS. A escala de sitio, la coexistencia entre venados de las pampas y ganado vacuno en el mismo potrero sólo fue posible a cargas ganaderas moderadas (0.2–0.4 E.V./ha), y no se registraron venados cuando la carga fue mayor a 0.6 E.V./ha. Por otro lado, los venados y los chanchos cimarrones ocurrieron simultáneamente más frecuentemente, pero ante la proximidad de éste, el venado manifestó alteraciones en su conducta e incrementó sus niveles de vigilancia. A escala de paisaje, los relevamientos aéreos permitieron detectar una segregación espacial y una distribución diferencial de vacunos, chanchos y venados a lo largo del

RVSBS. Nuestros resultados sugieren que la distribución actual del venado de las pampas en el área de estudio es consecuencia de evitar el contacto tanto con el ganado vacuno como con los chanchos cimarrones a escala de sitio. Por lo tanto, las interacciones negativas registradas entre venados de las pampas y ungulados introducidos a escala de sitio se vieron expresadas a escala de paisaje. Nuestros resultados tienen implicancias directas para el manejo y la conservación del venado de las pampas, cuya población viene declinando desde 1985. Ante esta situación, es necesario implementar de manera urgente estrategias de conservación in situ y ex situ para conservar al venado de las pampas.

Key words: conservation, introduced ungulates, livestock, *Ozotoceros bezoarticus*

Livestock husbandry and sport hunting have caused the introduction of numerous ungulate species outside their native ranges across different ecosystems all over the world (Spear and Chown 2009). Introduced ungulates have been found to alter habitat and ecosystem functioning, and to compete with, infect, and hybridize with native ungulates (Mack et al. 2000; Steinfeld et al. 2006; Spear and Chown 2009).

Major effects of cattle (*Bos taurus*) grazing on native ungulates include competition for forage and changes in the behavior of native ungulates resulting from the presence of livestock, such as avoidance of the areas grazed by cattle or increased vigilance when cattle are in the vicinity, affecting flight behavior (i.e., the distance at which an animal becomes alert to a stimulus), and altering activity budgets that make foraging less productive (Mattiello et al. 2002; Chaikina and Ruckstuhl 2006; Brown et al. 2010).

The effect of feral pigs (*Sus scrofa*) as an invasive species also is well documented around the world, not only from the damage inflicted to agricultural crops and livestock (Seward et al. 2004), but also from the damage caused to the native biota and the environment in several places where naturalized populations occur (Barrios-García and Ballari 2012). Impacts of feral pigs on native biota include its role as an ecosystem engineer that modifies the structure and composition of soil and plant communities through soil rooting and nest-building behavior, along with its role as a predator and competitor for food (Seward et al. 2004; Barrios-García and Ballari 2012).

Examples of interactions between native and introduced ungulates related to conservation issues and wildlife management include several cases from South America, particularly Argentina (Baldi et al. 2001; Novillo and Ojeda 2008; Reus et al. 2014). One such example involves the pampas deer, *Ozotoceros bezoarticus* (Linnaeus, 1758), an ungulate native to the open grassland habitats of South America (Cabrera and Yepes 1960). Currently, the pampas deer is classified as Near Threatened in light of an ongoing decline (González et al. 2016). In turn, it is considered endangered in Argentina (Ojeda et al. 2012). In Buenos Aires province, Argentina, the last population of pampas deer is harbored in the Bahía Samborombón Wildlife Refuge (BSWR). This population has been declining and its distribution has been changing progressively during the last 2–3 decades: in the mid-1980s, pampas deer were distributed along all the BSWR but currently they are almost entirely confined to the south (Perez Carusi et al. 2009). Negative interactions between pampas deer and introduced ungulates such as livestock and feral pigs have been proposed among the main causes of its decline (Carpinetti 1998; Vila et al. 2008; Perez Carusi et al. 2009). In this regard, livestock have been considered one of the negative factors for pampas deer due to competition for food and habitat, and risk of disease transmission (Uhart et al. 2003; Vila et al. 2008; Cosse et al. 2009). In addition, some studies provide evidence of the potential existence of negative interactions between pampas deer and feral pigs, including inverse spatial relationships and possible predation of neonates or poorly attended fawns (Carpinetti 1998; Fernández et al. 2004; Perez Carusi et al. 2009).

Despite this body of knowledge and its relevance to conservation of pampas deer, the interaction among pampas deer, cattle, and feral pigs at different spatial scales and how these interactions affect the spatial distribution of ungulates has not been evaluated. In particular, there is a pressing need to understand how ecological patterns and dynamics vary with scale and how patterns at one scale may be related to processes operating at other scales (Bowyer and Kie 2006). Studies at fine scales may reveal greater detail about the biological mechanisms underlying patterns (Wiens 1989). In this context, we examined the abundance, distribution, and interactions among pampas deer, cattle, and feral pigs simultaneously at 2 spatial scales (site and landscape) in the area that harbors the last population of pampas deer in Buenos Aires Province, central Argentina.

## Materials and Methods

*Study area.*—The study took place in the BSWR, Buenos Aires Province, Argentina. BSWR is located in the western coast of the Rio de la Plata estuary, extending along the coast of Bahía Samborombón and delimited by the Provincial Road Nº11 to the West (Fig. 1). BSWR covers about 244,000 ha of grasslands and wetlands. Its vegetation forms a mosaic of communities determined primarily by edaphic factors (Vervoorst 1967; Cagnoni and Faggi 1993). Except for small forest patches of *Celtis ehrenbergiana*, all other vegetation is mainly herbaceous. The area is crossed by numerous rivers and canals for draining that flow into the bay (Tosi et al. 2013), dividing the study area into 6 main zones (Fig. 1).

The climate in the region is temperate with hot summers (December–March) and cold, wet winters (June–August), with a mean annual temperature of 15°C. The annual rainfall is around 1,000 mm; the mean monthly rainfall varies between 50 and 150 mm (Vila et al. 2008), and in hot, dry summers drinking water for cattle may be lacking at some ranches (Nemoz et al. 2013).

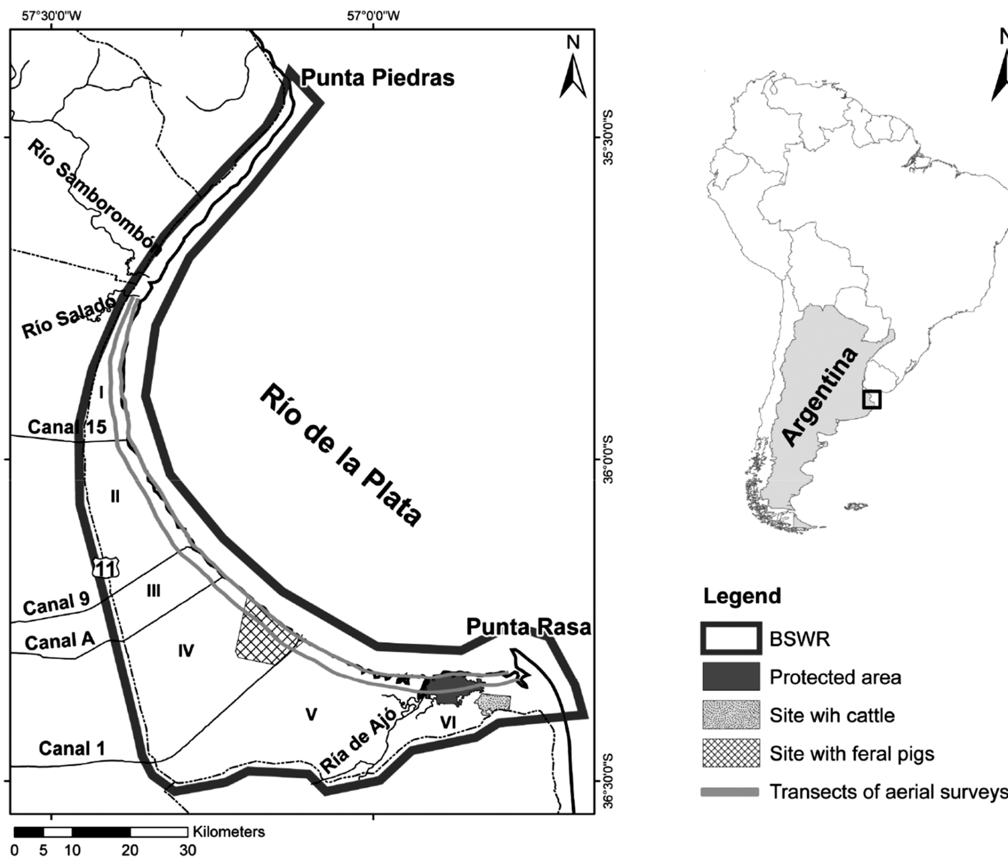


**Fig. 1.**—Location of the Bahía Samborombón Wildlife Refuge (BSWR), Argentina. The map shows the entire study area, including the protected area Campos del Tuyú National Park, the sampling site with cattle, and the sampling site with feral pigs. Approximate location of the inner and coastal transects lines of aerial surveys and the 6 zones of the BSWR, indicated with roman numbers, are also shown.

In the BSWR, hunting of native and nonnative species is forbidden all year round, which may have promoted the increase in feral pigs in the area (Perez Carusi et al. 2009). The study area includes protected areas, such as Campos del Tuyú National Park (CDTNP; 3,040 ha) devoted to protect grassland and the last population of pampas deer in Buenos Aires Province, and several ranches, with the main activity being extensive cattle ranching (stocking rates of 0.5–1 animal units (AU)/ha—Vila et al. 2008).

*Sampling of pampas deer and introduced ungulates at the site scale.*—Fine-scale analysis consisted of behavioral observations made from vantage-point structures located in 3 different sites: a protected area and 2 cattle ranches (Fig. 1). Sampling sites located 5–25 km apart were selected to analyze and compare the interaction of deer with cattle and feral pigs. Sampling sites were homogeneous from a geomorphological standpoint with the same habitat types and plant coverage, and they have been under the same land use for at least 3 decades (Merino 2003; Isacch et al. 2006), so that differences in abundance and behavior of pampas deer among sites are mostly due to the abundance of introduced ungulates. Characteristics of sampling sites are: 1) The protected area (CDTNP) is characterized by the presence of pampas deer, the absence of cattle, and a very low density of feral pigs (Perez Carusi et al. 2009). CDTNP is separated from its neighboring ranches by natural barriers such as streams and lagoons, which restrict cattle movement but allow pampas deer to move freely in and out of the national park (Vila et al. 2008). 2) The site with cattle corresponds to a ranch with seasonal grazing and stocking rates typically ranging between 0.5 and 1 AU/ha. Cattle usually graze in this ranch from April to November, while throughout December–March they are moved to other areas to graze (Vila et al. 2008). During this study, stocking rates at this ranch ranged from 0.2 to 1 AU/ha during the observation period, depending on prevailing weather conditions and water availability. 3) The site with feral pigs corresponds to a ranch located in an area which is known for having feral pigs (Perez Carusi et al. 2009). During the entire study period, cattle were moved to another ranch, so there was no record of cattle in this site.

Behavioral data were gathered over 8 seasonal surveys from 2008 to 2011: 2 during winter (2008, 2009), 2 during spring (2008, 2009), 2 during summer (2009, 2010; 1 summer survey for the site with feral pigs was conducted later due to logistical problems, so that it was carried out during summer 2011), and 2 during autumn (2009, 2010). Thus, each sampling site was surveyed 8 times during the entire study period. Observations were made by the same observer (LCPC) at distances of 0.1–2 km using a tripod-mounted 20–60 × 70 mm Bushnell Elite spotting scope (Liley and Creel 2008) from vantage-point structures, ranging between 4 and 12 m high depending on the site. These structures were hidden inside small patches of forest surrounded by open areas to avoid interference with ungulate behavior.

Behavioral data were collected by instantaneous scan sampling (Altmann 1974) during 2-day surveys in each sampling site. Each day in a survey, data were collected in 24 random scans from sunrise to sunset. Each site received approximately equal observational effort. In each scan, we recorded total number of individuals sighted, sex, age (fawn, juvenile, adult), behavior, and distance and angle from the observer to the individual (measured with a laser rangefinder and compass, respectively). Behaviors were characterized as maintenance (conduct related to the survival of the individual such as foraging, resting, displacement), surveillance (the animal lifts its head above the body axis, intently looking around and orienting the ears toward the source of disturbance), and social (intraspecific interactions such as maternal or agonistic behavior between deer—Jackson 1985). We also recorded the number of sightings of each introduced ungulate. The closest distance between pampas deer and introduced ungulates was measured and the behavioral response of the deer to the cow or feral pig was recorded as vigilant or non-vigilant (Brown et al. 2010; see Jackson 1985).

*Sampling of pampas deer and introduced ungulates at the landscape scale.*—Aerial surveys were conducted to assess occurrence of pampas deer and introduced ungulate species in the study area, following the methodology of Gimenez Dixon (1991), which has been systematically applied in the study area since 1985 (Carpinetti 1998; Merino and Carpinetti 1998; Vila 2006; Perez Carusi et al. 2009), allowing us to estimate and to compare abundance of pampas deer through time (Caughley 1977a). Eight surveys were conducted from a Cessna 152 aircraft between 2008 and 2011: 2 during winter (2008, 2009), 2 during spring (2008, 2010), 2 during summer (2010, 2011), and 2 during autumn (2009, 2010). Aerial surveys were based on the strip-transect technique that involved counting the number of pampas deer, cattle, and feral pigs detected within a fixed distance of transect lines (Caughley 1977a, 1977b). The distribution of pampas deer is restricted to a narrow strip of the BSWR, no more than 2 km wide, which includes almost the entire population (Merino and Carpinetti 1998). A total of 12 fixed transects of variable length (between 7 and 25 km) were systematically arranged along the BSWR to cover the area where pampas deer occur, resulting in a combination of 6 zones and 2 strata (Gimenez Dixon 1991; Vila 2006). All transect lines were placed parallel to the coast of Rio de la Plata; 6 transects were placed 350 m inland from the coast (coastal stratum) and the other 6 were placed 1,500 m inland (inner stratum—Vila 2006; Perez Carusi et al. 2009; Fig. 1). Surveys were flown at an altitude of 110 m and an average speed of 110 km/h. Two tandem observers (LCPC, MSB) on either side of the aircraft counted deer, cattle, and feral pigs within 320 m wide transects marked by the struts of the aircraft (Caughley 1977a) in an estimated area of 128 km$^2$ (Perez Carusi et al. 2009). Counts were made during the first 3 h of daylight under conditions of little or no clouds or wind.

The distribution of ungulates in the area was expressed as the mean density of pampas deer, cattle, and feral pigs per zone and stratum. Densities of ungulates and their associated *SE*s were estimated for each transect in each aerial survey, using an unequal-size units ratio method (Jolly 1969; Caughley 1977b). The area surveyed within each transect was calculated by multiplying the transect width estimates by the transect length, discounting the "dead-zone" (i.e., an area below the aircraft that cannot be observed from windows on the side of the plane—Dohl 1987). Data are presented as the estimated mean density (ind/ km$^2$) ± *SE*.

*Statistical analyses.*—At the site scale, responses of pampas deer to introduced ungulates in BSWR were evaluated using sighting frequency analyses (Loft et al. 1993; Brown et al. 2010). Chi-squared tests were used to assess whether the presence of pampas deer depends on the presence of cattle and feral pigs (Zar 2010). The frequency of scans (percentage) with sightings of pampas deer (effective scans) was used as indicator of the presence of pampas deer in each sampling site. The frequency of scans with sightings of cattle and feral pigs also were calculated (effective scans), whereas data on the stocking rate for each sampling period were provided by the cattle ranch manager.

We calculated the average and minimum distances between each pair of pampas deer and cows, and between each pair of pampas deer and feral pigs. For pairs of pampas deer and feral pigs, we also compared the simultaneous distances between nearest neighbors (pampas deer–feral pig pairs with the shortest average distance) when the pampas deer was vigilant and when it was non-vigilant, using *t*-tests (Zar 2010). Data were log-transformed to obtain normality and homoscedasticity (Zar 2010).

At the landscape scale, distribution patterns of ungulates were analyzed by general linear mixed models (Di Rienzo et al. 2011). The general linear mixed model provides a useful approach for analyzing repeated measures data by allowing one to incorporate lack of independence between observations repeated over time and to model more than one error term (Zuur et al. 2007). In this regard, each aerial survey was considered a repeated measure. The model was fitted with residual maximum likelihood estimation and varIdent as variance structures. The response variable was species abundance (pampas deer, cattle, feral pig), and the explanatory variables were zone (I–VI; Fig. 1) and stratum (coastal or inner) plus the interaction between both factors. Zone and stratum were fitted as fixed effects and aerial survey as a random term. Plots of residuals and normal probability were examined to evaluate assumptions of normality and homogeneity of variance (Di Rienzo et al. 2011). Differences between means were tested using Fisher's least significant difference (LSD) test at the 0.05 level (Zar 2010). All these analyses were conducted using statistic software InfoStat (Di Rienzo et al. 2012).

## Results

*Sampling of pampas deer and introduced ungulates at the site scale.*—The sighting frequency of pampas deer varied among sites ($X^2 = 428.9$, *d.f.* = 2, $P < 0.0001$; Fig. 2). The number of pampas deer sightings per survey ranged between 3 and 15 for the protected area, 0 and 6 individuals for the site with

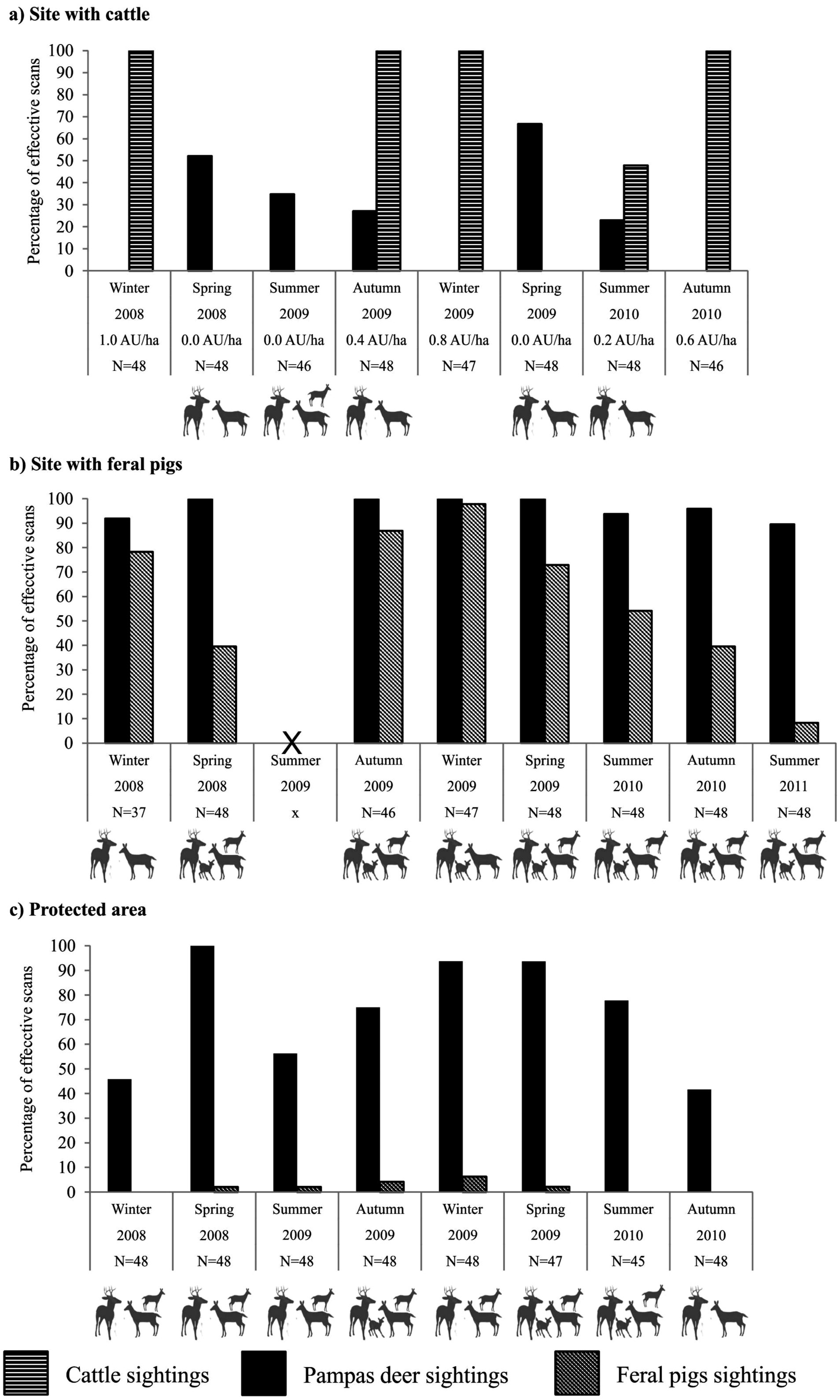


**Fig. 2.**—Total sightings of pampas deer (*Ozotoceros bezoarticus*), cattle (*Bos taurus*), and feral pigs (*Sus scrofa*) as a percentage of total scans for a) site with cattle, b) site with feral pigs, and c) protected area in Bahía Samborombón Wildlife Refuge, Argentina, 2008–2011. Total number of scans is shown for each survey and site (*N*), and stocking rates with cattle (AU/ha) for each survey for each site is also shown. Sex and age of pampas deer sighted in each site per survey are indicated below each figure by deer silhouettes: adult male, adult female, juvenile, fawn.

cattle, and 11 and 18 individuals for the site with feral pigs. The occurrence of pampas deer and cattle in the same paddock was recorded in a few situations (19 scans; Figs. 2a and 3) and when this happened they were separated by a minimum average distance of 978 ± 68 m. In most cases, pampas deer were recorded at paddocks without livestock or with moderately low stocking rates (0.2–0.4 AU/ha); no deer were recorded when stocking rates were above 0.6 AU/ha (Fig. 3). In contrast, the co-occurrence of pampas deer and feral pigs was recorded in 212 scans (Fig. 2b). Pampas deer displayed vigilance behaviors when feral pigs were closer (125 ± 43 m, $n$ = 11), whereas maintenance behaviors such as feeding or rest prevailed when feral pigs were far away (468 ± 27 m, $n$ = 201, $t$ = 4.39, $P$ < 0.0001). As expected, in the protected area, pampas deer were recorded during the entire study period (Fig. 2c). In particular, adult pampas deer (females and males) and juveniles were registered both in the protected area and in the site with feral pigs during the whole observation period, whereas fawns were recorded during autumn, spring, and summer. In contrast, in the site with cattle, no fawns were recorded and juveniles were recorded occasionally (Fig. 2). Social behaviors were not recorded in the site with cattle, whereas maternal care and agonistic behaviors between deer were recorded both in the protected area and in the site with feral pigs (Table 1). The frequency of surveillance behaviors was low in all sampling sites (Table 1). In the site with feral pigs, in 6% (13/212) of cases when feral pigs and pampas deer were observed at the same time, pampas deer displayed alarm reactions toward feral pigs; 54% of those corresponded to females with their nursing fawns. In particular, a mother actively defended her fawn against a feral pig on one occasion. In other sampling sites, alarm reactions were performed by pampas deer toward humans or cattle.

**Table 1.**—Cumulative effective scans in which at least 1 pampas deer (*Ozotoceros bezoarticus*) was recorded performing maintenance, surveillance, or social behaviors per sampling site. The frequency of effective scans corresponds to the number of scans with deer sightings. A scan may include more than 1 category of behavior if different deer were recorded performing behaviors in different categories during the scan.

| Sampling sites | Maintenance | Surveillance | Social | Effective scans |
|---|---|---|---|---|
| Protected area | 273 | 3 | 13 | 277 |
| Site with cattle | 96 | 3 | 0 | 97 |
| Site with feral pigs | 356 | 13 | 8 | 357 |

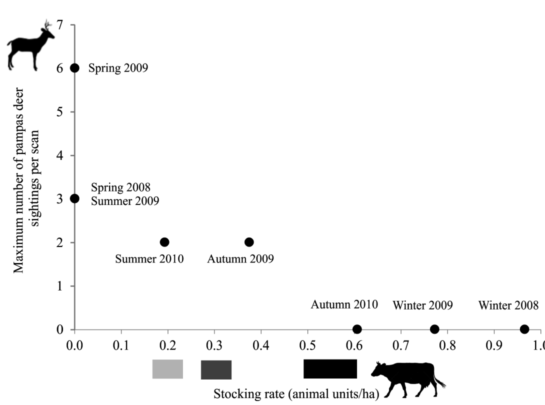


**Fig. 3.**—Relationship between stocking rate of cattle (*Bos taurus*) and abundance of pampas deer (*Ozotoceros bezoarticus*) registered during 2008–2011 ($n$ = 8 surveys) in Bahía Samborombón Wildlife Refuge, Argentina, 2008–2011. Bottom bars show cattle stocking rates for others grazing systems, where pampas deer share the range with cattle: light gray for San Luis (Merino et al. 2011), dark gray for Brazil (Desbiez et al. 2011), and black for Uruguay (Moore 2001).

*Sampling of pampas deer and introduced ungulates at the landscape scale.*—The number of pampas deer sightings per aerial survey was 58 ± 6 (range: 30–73). For cattle, the average number of individuals counted was 1,402 ± 201 (range: 405–2189), whereas the mean number of feral pigs was 237 ± 54 (range: 45–489).

A significant spatial segregation and a differential distribution of cattle, feral pigs, and deer were detected along the BSWR (Fig. 4).The greatest density of cattle was found in the north of the BSWR (zone: $F_{5,77}$ = 16.90, $P$ < 0.0001; Fig. 4a), whereas feral pigs were more widespread in the central zones and especially in the inner stratum (zone * stratum: $F_{5,77}$ = 2.28, $P$ = 0.05; Fig. 4b). Pampas deer were more abundant at the south-central zones of the study area, and particularly in the coastal stratum (zone * stratum: $F_{5,77}$ = 17.61, $P$ < 0.0001; Fig. 4c).

## Discussion

These results show that domestic livestock and feral pigs have a negative impact on pampas deer in the BSWR. In particular, pampas deer exhibited a strong spatial segregation from cows in cattle ranches at both site and landscape scales. On the other hand, pampas deer showed more interactions with feral pigs at site scale, but changed their behavior and increased levels of surveillance in response to proximity of feral pigs. At the landscape scale, a clear spatial segregation and differential distribution was detected among pampas deer, cattle, and feral pigs along the BSWR.

The concentration of cattle in the north of the BSWR is in agreement with the fact that permanent water troughs have been available for cattle in the northern zones of the study area for the last 2–3 decades, allowing permanent presence and grazing of livestock in these northern zones. In contrast, the scarcity of adequate water supplies for livestock in the southernmost zones (Nemoz et al. 2013) forces livestock managers to remove cattle from those ranches during drier periods. Feral pigs were mainly concentrated in the inner strata of the central zones of the BSWR, which are characterized by the presence of water courses and permanently flooded lowlands (Tosi et al. 2013), providing suitable habitat conditions for feral pigs (Jackson 1989). Pampas deer were concentrated in the coast of the south-central zones of the BSWR, where the lowest densities of cattle and feral pigs were recorded. Thus, our results suggest that pampas deer might have been restricted to their current location in the study area by avoiding contact with both livestock and feral pigs. This observation is reinforced by a progressive change in the distribution of the pampas deer population that has been detected during the last 2–3 decades in the BSWR (Perez Carusi et al. 2009), following livestock intensification activities (i.e., high grazing pressure and provision of

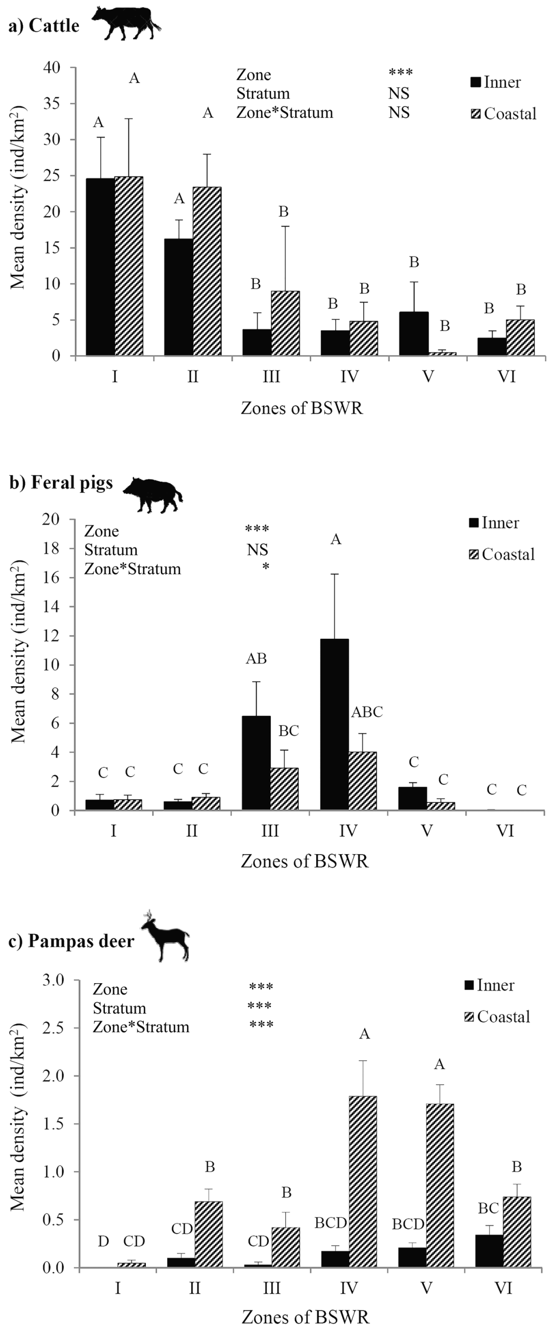


**Fig. 4.**—Distribution of a) cattle (*Bos taurus*), b) feral pigs (*Sus scrofa*), and c) pampas deer (*Ozotoceros bezoarticus*) in Bahía Samborombón Wildlife Refuge (BSWR), Argentina, 2008–2011 ($n$ = 8 surveys), expressed as mean density (ind/km$^2$) ± $SE$ by zones and strata. Filled and hatched bars indicate sightings in the inner and coastal strata, respectively. Asterisks indicate statistically significant differences resulting from Fisher's least significant difference (LSD) tests: *$P < 0.05$, ***$P < 0.001$; NS no significant difference. Different letters indicate significant differences between means ($P < 0.05$).

permanent water supply for cattle—Bilenca et al. 2012), and the introduction and subsequent increase of the feral pig population in the BSWR as well (Perez Carusi et al. 2009).

At the site scale, our results indicate that coexistence between pampas deer and cattle in the same paddock is only possible below a threshold stocking rate of ~0.6 AU/ha, which usually corresponds with the minimum stocking rate for the study area (Vila et al. 2008). This means that the conservation of pampas deer in cattle ranches requires grazing systems that allow pastures to rest (paddocks without cattle) or have moderately low stocking rates, so these paddocks could be used by pampas deer. Similar findings have been documented for others populations of pampas deer, which can share the range with cattle in grazing systems with low stocking rates ranging from 0.2 to 0.5 AU/ha (Moore 2001; Cosse et al. 2009; Desbiez et al. 2011; Merino et al. 2011). When stocking rates are above the threshold, pampas deer avoid concentrations of cattle, probably because it is difficult to maintain a distance from cattle that minimizes interference and, therefore, they move to suboptimal areas that are free of livestock, although it may carry nutritional costs (Bianchini and Luna Pérez 1972). The mechanism involved in the segregation is probably the avoidance of cattle by pampas deer and may be related to the behavioral intolerance of pampas deer to cattle accompanied by dogs and people on horseback (Vila et al. 2008). The mere physical presence of cattle also can impact native ungulates by creating disturbance and introducing alarming visual and audible stimuli because of their larger size (Mattiello et al. 2002; Brown et al. 2010).

The presence of feral pigs seemed to affect some aspects of the behavior of pampas deer, especially if pigs were in close proximity. Alert behavior has been observed in response to different stimuli and has been used as an indicator of the presence of some source of disturbance both in farmed deer and in wild deer (Mattiello et al. 2002; Liley and Creel 2008). Changes in feeding behavior of pampas deer to adopt vigilance postures when feral pigs are close to them also may be considered a response to a source of disturbance. Feral pigs can be considered a threat to pampas deer for several reasons including land perturbation due to its rooting behavior, as a reservoir for many diseases that can be shared with wildlife, as an attractor for poachers in the area, and as a potential competitor and predator. These interactions can induce psychological stress that extends to affecting reproduction, survival, and nutritional status (Carpinetti 1998; Moberg and Mench 2000; Carpinetti et al. 2014).

Our results also show that interactions recorded between pampas deer and introduced ungulates at the site scale were then expressed at a broader scale, as they were reflected in the pattern of distribution of pampas deer in the study area.

*Conservation implications.*—The population of pampas deer in the BSWR has shown a progressive change in its distribution since 1985 (Perez Carusi et al. 2009). In addition, the index of abundance of pampas deer estimated over time for the study area shows a clear decline from ~400 individuals in the mid-1980s to ~150 individuals in 2013, decreasing at an annual rate of 4.3% (Gimenez Dixon 1991; Vila 2006; Fig. 5). Thus, both in situ and ex situ conservation efforts are urgently needed to safeguard against local extinction of pampas deer in the study area (Vila 2006; Raimondi 2013; this study). In this regard, a captive breeding program or translocations of genetically compatible individuals from other populations should be implemented in BSWR to reinforce this pampas deer population (Raimondi 2013; this study).

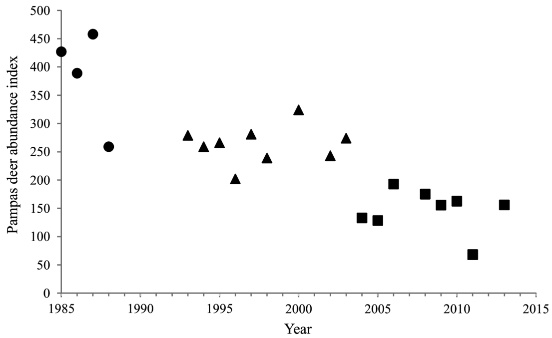


**Fig. 5.**—Abundance index for pampas deer (*Ozotoceros bezoarticus*) estimated over time (1985–2013). Different symbols represent data collected by different researchers using the same methodology. Circles, triangles, and squares represent data reported by Gimenez Dixon (1991), Vila (2006), and Perez Carusi (2015; this study), respectively.

In summary, pampas deer in BSWR occur in a productive region that includes protected areas and several ranches. Some management recommendations emerging from this study include: 1) to integrate pampas deer in grazing systems that allow some pastures to have a resting period or in systems with moderate stocking rates (lower than 0.6 AU/ha); 2) to implement feral pig control programs mainly in the central zone of the BSWR; and 3) to implement ex situ conservation efforts (captive breeding or translocations) to reinforce this pampas deer population and to prevent its extinction in the wild.

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