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Artículo

ASSOCIATION BETWEEN LIVESTOCK AND NATIVE MAMMALS IN A CONSERVATION PRIORITY AREA IN THE CHACO OF ARGENTINA

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ABSTRACT. The Chaco has high richness of medium- and large-sized mammal species and is one of the most endangered ecoregions in the world. Our goal was to assess associations between livestock and medium and large mammals in Bañados del Quirquincho of the Chaco of Northwestern Argentina. In five habitat types, we set 15 to 20 camera traps during at least 30 consecutive days to determine native mammal species and livestock camera trapping rate. We used generalized linear mixed models to compare the camera trapping rate of native mammals and livestock among habitat types. We recorded 15 mammal species in all habitat types and found a significantly higher camera trapping rate of native mammal species—with the exception of foxes—in habitats with lower livestock camera trapping rate. Our results provide evidence that unplanned, intensive livestock production have negative effects on most native mammals in remnants forest of the Bañados del Quirquincho. We highlight the need to implement sustainable livestock management plans in the forests of the Chaco ecoregion to ensure the conservation of native mammal species.

RESUMEN. **Asociación entre el ganado y los mamíferos nativos en un área prioritaria de conservación del Chaco de Argentina.** El Chaco tiene una alta riqueza de mamíferos medianos y grandes y es una de las ecorregiones más amenazadas del mundo. Nuestro objetivo fue evaluar la asociación entre el ganado y los mamíferos medianos y grandes en los Bañados del Quirquincho del Chaco del Noroeste Argentino. En cinco tipos de ambientes, colocamos entre 15 y 20 cámaras trampa durante al menos 30 días para determinar la tasa de captura en cámara de mamíferos nativos y del ganado. Utilizamos modelos lineales generalizados para comparar entre tipos de ambientes la tasa de captura en cámara de mamíferos nativos y del ganado. Registramos 15 especies de mamíferos en todos los tipos de ambientes y encontramos una tasa de captura en cámara de mamíferos nativos —sin incluir zorros— significativamente mayor en ambientes con una tasa de captura en cámara de ganado menor. Nuestros resultados proveen evidencia de que la producción intensiva de ganado no planificada tiene un efecto negativo sobre la mayoría de los mamíferos nativos en los bosques remanentes de

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los Bañados del Quirquincho. Resaltamos la necesidad de implementar planes de manejo ganadero sustentable en los bosques de la ecorregión del Chaco que aseguren la conservación de los mamíferos nativos.

Key words: camera trap, forest, management, threatened species, wetland.

Palabras clave: bosque, cámara trampa, especies amenazadas, humedal, manejo.

INTRODUCTION

The Chaco is the second largest forest region in South America—with a size of more than 1 000 000 km^2 (Morello et al. 2006)—and one of the most endangered ecoregions in the world (Zak et al. 2004). In the 20th century, timber harvest and charcoal and tannin production depleted the valuable hardwood tree stock, thereby degrading these forests (The Nature Conservancy et al. 2005). Livestock entered following roads opened by foresters and in many cases affected the regeneration of valuable timber species, thereby further degrading these forests (Zak et al. 2004; The Nature Conservancy et al. 2005; Trigo et al. 2017). Another threat to the Chaco region is the recent land conversion from forest to agriculture made possible by technological advancements and a rainy season suitable for soybean production (Carreño et al. 2009; Caldas et al. 2015). This change in land use is currently the primary factor responsible for wildlife habitat loss in the Chaco (Altrichter 2005).

The Chaco ecoregion has high levels of endemism and species diversity (Torrella & Adámoli 2006). Species richness of medium-sized and large mammals in the Chaco is almost as high as in Amazonia (30 and 34 species, respectively; Redford et al. 1990). The Chacoan peccary (*Parachoerus wagneri*) is an endemic species from the Chaco listed as Endangered by the International Union for Conservation of Nature (IUCN 2016). Other large mammals that are present in the Chaco have important roles as ecosystem engineers or top predators, and are in the Red List of the IUCN (2016): giant anteater (*Myrmecophaga tridactyla*, Vulnerable), lowland tapir (*Tapirus terrestris*, Vulnerable), giant armadillo (*Priodontes maximus*, Vulnerable), white-lipped peccary (*Pecari tajacu*, Vulnerable), and jaguar (*Panthera onca*, Near-threatened). Given the number of threatened species in this ecoregion, it is particularly important to focus studies on these species with higher extinction risk than non-threatened species to address conservation actions (Lee & Jetz 2011; Hoffmann et al. 2015).

Most of the Chaco forest remnants remain in northern Argentina, southeastern Bolivia, and western Paraguay. Both rural and indigenous communities have a subsistence economy that depends on remnant forests for livestock raising, fuel wood production, and wildlife hunting (Gasparri & Grau 2009). These subsistence activities exert pressure on wildlife through habitat degradation and overhunting in remnant forests (Torrella & Adámoli 2006). Medium-sized and large native mammals with large area requirements are the most affected by these human pressures (Altrichter & Boaglio 2004; Núñez-Regueiro et al. 2015; Quiroga et al. 2016). Subsistence hunting in other regions (i. e., the Atlantic and Amazon forests) has been observed to depress densities of large mammals, particularly those with large geographical ranges and sensitivity to hunting (Cullen et al. 2000; Peres 2000).

Few studies have been conducted in the Chaco to assess if free-ranging livestock production compete or affect wildlife animal species. A negative association between livestock presence and abundance of the collared peccary (*Pecari tajacu*) and the grey-brocket deer (*Mazama gouazoubira*) has been suggested (Noss & Cuéllar 1999; Altrichter & Boaglio 2004) and large carnivores suffer retaliation effects of livestock owners (Loveridge et al. 2010; Quiroga et al. 2013). When livestock is raised in forest areas without any management

or regulation, it results in overgrazing which decreases the productivity of these forests (Saravia Toledo 1995). Forest degradation creates a loop wherein human communities place greater pressure on wildlife to compensate for their decreasing income from livestock production (Saravia Toledo 1995; Barbarán 2003). Forecasts predict an intensification of livestock production in the Chaco in the near future (Mastrangelo & Gavin 2012). However, Argentina's Native Forest Law requires implementing economic activities under sustainable management guidelines, and the compatibility of livestock intensification and expansion with wildlife conservation still needs to be explored (Martinuzzi et al. 2018; Semper-Pascual et al. 2018).

The objectives of this study were to (1) determine if habitat types defined a priori differ in forest characteristics; (2) compare camera trapping rate of native mammal species and livestock among habitat types; and (3) assess the influence of livestock, forest characteristics and distance to villages on the camera trapping rate of native mammals in the Bañados del Quirquincho wetland in the Chaco of Northwestern Argentina. The information gathered in this study is essential to understand threats mammals face in the Chaco in order to take effective conservation actions.

MATERIALS AND METHODS

Study area

We carried out this study in the semi-arid Chaco located in the western part of the Chaco of Argentina. The climate is markedly seasonal with rainfall between 450 and 700 mm (Barbarán 2003). The vegetation is a medium-tall xerophilous forest with a canopy layer of about 12 m tall surpassed by a few species of taller trees reaching 16-18 m (Bucher 1982). We conducted fieldwork from August 2012 to May 2013, at the wetland Bañados del Quirquincho (500 000 ha), in the east of Salta province (**Fig. 1**). The Chaco is a mosaic of different habitat types

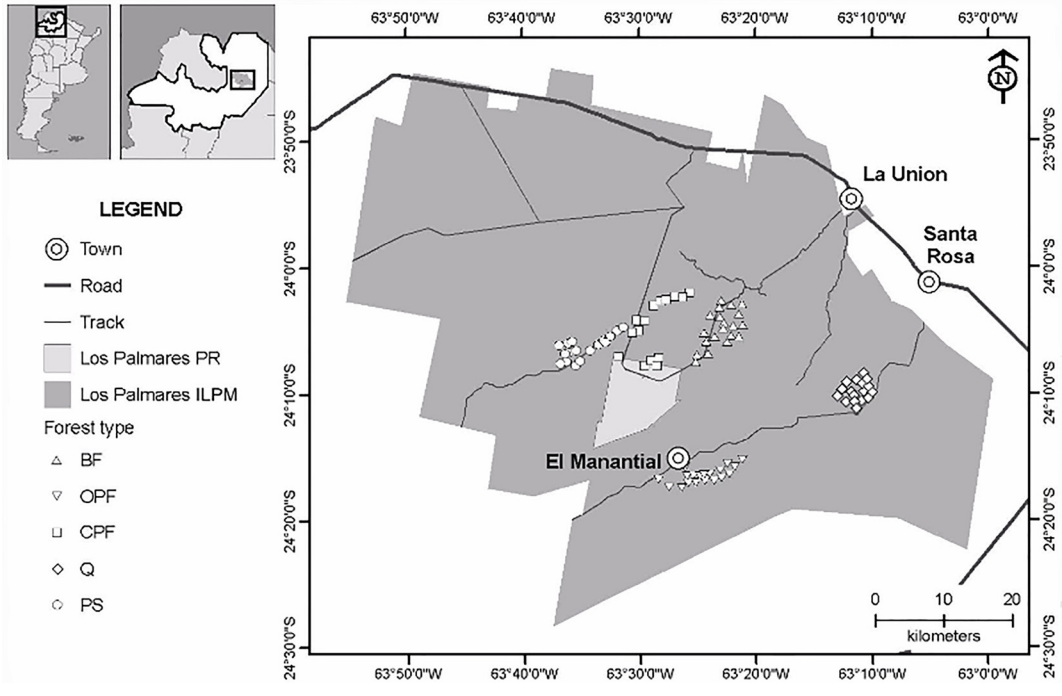

Fig. 1. Location of camera traps in five habitat types at the Bañados del Quirquincho, Salta Province, Argentina. Light Gray: Los Palmares Provincial Reserve (PR). Dark grey: Los Palmares Integrated Land Planning Management (ILPM). BF = Bañadero Forest (n = 20 cameras), PS = Palo-santal (n=17), Q = Quebrachal (n=17), OPF = Open Palm Forest (n=19), and CPF = Closed Palm Forest (n=15).

(Puechagut et al. 2013; Caldas et al. 2015). We defined five habitat types at Bañados del Quirquincho (**Fig. 1**, **Table 1**): (1) bañadero forest (BF) or short forest/scrub dominated by *Prosopis* spp., located in land depressions that flood in the summer; (2) quebrachal (Q) or high forest dominated by *Prosopis* spp., located in highlands; (3) palo-santal (PS), a high forest dominated by *Bulnesia sarmientoi*; (4) closed palm forest (CPF) or low forest dominated by *Copernicia alba*, located inside and in the area of influence of Los Palmares Provincial Reserve; and (5) open palm forest (OPF) or Palm savannah, dominated by grasslands with scarce palm trees or other woody species.

In the study area there are a few small human settlements spread throughout the wetland, where the rural residents have a subsistence economy based on small-scale and unplanned livestock ranching and forest exploitation for charcoal and fence posts (Altrichter 2006). Livestock graze freely, without rotation or fences (Puechagut pers. obs.).

Camera traps survey

Through the dry season, we set between 15-20 camera traps (Bushnell Trophy Cam Trail) in each of the five different habitat types (**Table 1**). We chose to focus our study on the dry season because accessing the study area in the wet season is logistically unfeasible. Therefore, our study only characterizes native mammal species distribution during this 'dry season window' (Mendes Pontes 2004; Keuroghlian & Eaton 2008). We rotated camera traps after being active for at least 30 consecutive days in each habitat type, so we surveyed each habitat types in different months.

Camera traps are the most appropriate technique to detect native mammals of varying body size (1-70 kg) (Silveira et al. 2003; Tobler et al. 2008; O'Connell et al. 2011). Camera traps are commonly used to describe mammal patterns of co-occurrence in multi-species studies in wide ranging habitat types (Kays et al. 2011; O' Connell et al. 2011; Lesmeister

Table 1

Location, vegetation characteristics, number of camera traps, and sampling effort in five habitat types at the Bañados del Quirquincho, Salta Province, Argentina. # = number

	Habitat types				
	Bañadero forest (BF)	**Palo-santal (PS)**	**Quebrachal (Q)**	**Closed Palm forest (CPF)**	**Open Palm Forest (OPF)**
Number of camera traps	20	17	17	15	19
Sampling effort (# camera traps x # days active)	640	510	527	465	570
Location	24° 5'31.56"S, 63°23'28.38"W	24° 7'31.02"S, 63°36'20.64"W	24°10'41.64"S, 63°12'19.44"W	24° 7'50.94"S, 63°29'32.88"W	24°16'57.06"S, 63°24'23.52"W
Dominant vegetation characteristics	Dense, thorny vegetation, dominated by carob tree species (*Prosopis* spp, Leguminosae)	Tall palo-santo trees (*Bulnesia sarmientoi*, Zygophyllaceae)	White quebracho (*Aspidosperma quebracho-blanco*, Apocynaceae) and red quebracho (*Schinopsis balansae*, Anacardiaceae)	*Copernicia alba* palms (Arecaceae), intermixed with xerophilous vegetation of thorny bushes and trees	*C. alba* palms (Arecaceae) in a matrix of grass with a less dense woody vegetation cover and scattered structure

et al. 2015). We placed camera traps in animal trails to increase the chances of capturing images of native mammals (Kays et al. 2011), and we set camera traps 1000 ± 250 m apart to avoid sampling the same individual during the same day for most species (TEAM Network 2011). We placed camera traps at the base of a tree trunk, 50-70 cm above the ground, and we programmed camera traps to take three pictures for each trigger, with a 10-sec delay between successive shots, during a 24-h cycle. To consider two records as independent, we used the criterion of an interval of >12 h between successive photographs of the same species at each camera (Di Bitetti et al. 2013). According to the Bushnell Trophy Cam Trail manual, heat and motion trigger the cameras.

Forest characteristics and human influence

Forest characteristics can influence richness of mammals (O'Connell et al. 2011), therefore, we used Enhanced Vegetation Index (EVI) and percentage of woody vegetation to differentiate each habitat type (i. e., BF, Q, PS, CPF, and OPF). EVI minimizes canopy background variations and maintains sensitivity over dense vegetation conditions (Solano et al. 2010). EVI is calculated through the near infrared, red, and blue bands, and uses the blue band to remove residual atmosphere contamination caused by smoke and sub-pixel thin clouds (Solano et al. 2010; LP DAAC 2014). We obtained EVI and the percentage of woody vegetation from the Moderate Resolution Imaging Spectrometer (MODIS) (Matsushita et al. 2007). The average EVI value for each camera trap location was obtained from 23 scenes (product MOD13Q, spatial resolution: 250 m) built with filtered data according to their quality in the month the camera traps were set in each habitat type. The percentage of woody vegetation was obtained from images of the years 2012 to 2013 from the Vegetation Continuous Fields collection derived from all seven bands of the MODIS sensor onboard NASA's Terra satellite (Di Miceli et al. 2011).

To evaluate the impact of livestock raising on native mammals we determined livestock camera trapping rate as the number of livestock records (considering goats, pigs, horses, donkeys, sheep, and cattle altogether) in each camera trap during the sampling period (30-32 days) in each habitat type (Rovero & Zimmermann 2016).

We determined the distance from each camera trap to the nearest of the three villages (**Fig. 1**); i. e., La Unión, El Manantial, and Santa Rosa (Secretaría de Ambiente de Salta 2013). Hunting is carried out mainly by locals near villages (Altrichter & Boaglio 2004; Altrichter 2005, 2006). Therefore, we considered distance to villages as a proxy to hunting influence (Di Bitetti et al. 2013).

Data analysis

We determined the camera trapping rate of native mammal species (O'Connell et al. 2011) as: 1) total camera trapping rate: number of records of mammals in each camera trap during the sampling period (30-32 days) in each habitat type (**Table 1**), 2) species camera trapping rate: number of records of each mammal species in each camera trap during the sampling period, 3) threatened species camera trapping rate: number of record of species categorized as threatened by the International Union for Conservation of Nature (IUCN 2016) in each camera trap during the sampling period (Rovero & Zimmermann 2016). Camera trapping rate should not be considered as equivalent to the abundance of a species given that this index does not account for imperfect detectability (MacKenzie et al. 2003).

We used generalized linear mixed models (GLMM) with a Poisson error distribution, log link function and a posteriori LSD Fisher tests (Quinn & Keough 2002; Di Rienzo et al. 2012) to compare the camera trapping rate of native mammals (total, individual species and threatened species) among habitat types. We used the same analysis to compare camera trapping rate of livestock among habitat types. Given that fox species are reported to be associated with human settlements and benefit from livestock (Pia et al. 2003; Acosta-Jamett & Simonetti 2004; Lemos 2007; Farias & Kittlein 2008) we performed the same analyses excluding the crab-eating fox (*Cerdocyon thous*) and the grey fox (*Lycalopex gymnocercus*) and we called this variable camera trapping rate excluding foxes.

To determine if habitat types (i. e., BF, Q, PS, CPF, and OPF) differ in vegetation characteristics and distance to villages, we compared EVI, percentage of woody vegetation, and the distance to villages among habitat types using an Analysis of Variance (ANOVA) and a posteriori LSD Fisher tests (Quinn & Keough 2002; Di Rienzo et al. 2012). Prior to testing with Shapiro Wilks tests the normal distribution of EVI, percentage of woody vegetation, and distance to villages.

We used a model selection based on the Akaike Information Criterion (AIC; Di Rienzo et al. 2012) to decide the order of the variables to include in the model. Prior to the model analysis, we calculated Spearman's rank correlation coefficients to assess multicollinearity among independent variables and given that correlation between variables was low

(< 0.40) we retained all of the variables. Then we developed a Poisson regression model with a log link function using GLMM (Di Rienzo et al. 2012, 2014) to analyze if livestock camera trapping rate, distance to village, EVI, and percentage of woody vegetation have a relation with camera trapping rate of native mammals (total, each species, and threatened species). To obtain the best model, we first selected the relevant variables with a manual backward stepwise procedure, removing insignificant ($P > 0.05$) variables at each step (Quinn & Keough 2002). We tested the influential variables of each model (i. e., livestock camera trapping rate, distance to villages, EVI, and percentage of woody vegetation) as the covariables of the model (fixed effects). We included habitat types and the number of active days of each camera trap as random effects to consider possible influences of these variables in the model (Burnham & Anderson 2002). We conducted data analyses in Infostat (Di Rienzo et al. 2012). Values are shown as mean ± standard error (S.E.).

RESULTS

We recorded 15 mammal species in all habitat types (**Table 2**). *Pecari tajacu* was the species with the highest camera trapping rate (2.84 ± 0.57 records per camera trap), followed by *L. gymnocercus* (1.47 ± 0.32 records per camera trap) and *C. thous* (1.11 ± 0.35 records per camera trap). We recorded two species listed in the IUCN Red List of Threatened Species i. e., the Chacoan peccary (*Parachoerus wagneri*) and the giant anteater (*M. tridactyla*). The camera trapping rate of all mammal species was lowest in CPF, and 11 out of the 15 native mammals showed significantly different camera trapping rates among habitat types (**Table 2**). *Cerdocyon thous* and *L. gymnocercus* were the only native mammals with significantly high camera trapping rate in OPF. We found that the camera trapping rate excluding foxes was significantly higher in Q (10.26 ± 2.03 records per camera trap), BF (10.03 ± 1.97 records per camera trap), and PS (9.13 ± 1.83 records per camera trap) than in CPF (2.47 ± 0.87 records per camera trap), which was higher than in OPF (0.39 ± 0.15 records per camera trap; $z = 11.72$; $P < 0.05$).

OPF had a significantly higher livestock camera trapping rate, was significantly closer to villages, showed an intermediate EVI, and had a significantly lower percentage of woody vegetation than the other habitat types (**Table 3**). We found that the most influential and significant related variable with camera trapping rate of native mammals, of threatened species, and of all the species excluding fox species was livestock camera trapping rate (**Table 4**). There was a negative association of livestock camera trapping rate with native mammals excluding fox species camera trapping rate (**Fig. 2**).

DISCUSSION

Native mammals and human influence

Our results suggest that the camera trapping rate of native mammal species excluding foxes is negatively influenced by the camera trapping rate of livestock in the wetland Bañados del Quirquincho in the Chaco. In other forest areas, a decline or local extinction of mammal populations has been observed due to competition of resources with livestock (Hibert et al. 2010). Furthermore, the lower camera trapping rate of native mammal species excluding foxes in the palm forests (CPF and particularly in OPF) could be due to the changes that livestock grazing can have on woody vegetation (Altrichter & Boaglio 2004).

In OPF, only fox species (*C. thous* and *L. gymnocercus*) had higher camera trapping rate per camera trap than in other habitat types. This could be because foxes feed on domestic cubs and carrion (Pia et al. 2003; Farias & Kittlein 2008), are associated with human settlements (Acosta-Jamett & Simonetti 2004; Lemos 2007), and benefit from changes on the environment by livestock (Farias & Kittlein 2008). The vegetation characteristics of OPF—i. e., with lowest percentage of woody vegetation—are expected of an overgrazed *C. alba* palm forest (Puechagut et al. 2013).

The absence or lower camera trapping rate of medium and large mammal species and of those preferred by hunters (e. g., *P. tajacu*, *M. gouazoubira*) near villages could be the result of the direct impact of hunting on these species. Similar results have been found in a previous study in the Chaco region (Altrichter

Table 2

Camera trapping rate of native mammal species (mean ± S.E.) in five habitat types at the Bañados del Quirquincho, Salta Province, Argentina. BF = Bañadero Forest, PS = Palo-santal, Q = Quebrachal, OPF = Open Palm Forest, and CPF = Closed Palm Forest. Asterisk after mammal species indicates threatened species according to IUCN (2016). Different letters indicate significant differences ($P<0.05$) among habitat types.

Camera trapping rate	Habitat types					z	P
	BF	Q	PS	CPF	OPF		
Total mammal species	13.54 ± 1.87[a]	13.12 ± 1.83[a]	10.57 ± 1.56[a]	4.21 ± 0.78[b]	3.02 ± 0.75[b]	3.24	**<0.05**
Threatened species	1.21 ± 0.56[a]	2.41 ± 1.00[a]	0.40 ± 0.24[b]	0.25 ± 0.19[b]	0.00 ± 0.00[c]	2.76	**<0.01**
Pecari tajacu	5.30 ± 0.51[a]	3.41 ± 0.45[b]	3.76 ± 0.47[b]	1.47 ± 0.31[b]	0.00 ± 0.00[b]	17.17	**<0.01**
Lycalopex gymnocercus	0.53 ± 0.24[b]	0.13 ± 0.10[b]	0.53 ± 0.25[b]	0.18 ± 0.14[b]	2.39 ± 0.85[a]	-1.39	**0.02**
Cerdocyon thous	0.20 ± 0.10[b]	0.35 ± 0.14[b]	0.24 ± 0.12[b]	0.40 ± 0.16[b]	4.11 ± 0.46[a]	-3.22	**0.01**
*Parachoerus wagneri**	0.50 ± 0.16[b]	2.76 ± 0.40[a]	0.06 ± 0.06[b]	0.27 ± 0.13[b]	0.00 ± 0.00[b]	-2.19	**0.02**
Mazama gouazoubira	1.20 ± 0.24[b]	2.35 ± 0.37[a]	2.47 ± 0.38[a]	0.80 ± 0.23[b]	0.00 ± 0.00[c]	1.02	**0.03**
Tolypeutes matacus	0.65 ± 0.18[a]	0.59 ± 0.19[a]	1.00 ± 0.24[a]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	-2.13	**0.05**
Conepatus chinga	0.75 ± 0.19	0.65 ± 0.20	0.47 ± 0.17	0.40 ± 0.16	0.11 ± 0.07	-1.11	0.26
Leopardus geoffroyi	0.65 ± 0.18[a]	0.88 ± 0.23[a]	0.24 ± 0.12[b]	0.07 ± 0.07[b]	0.26 ± 0.12[b]	-1.55	**0.02**
*Myrmecophaga tridactyla**	0.45 ± 0.15[a]	0.24 ± 0.12[a]	0.24 ± 0.12[a]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	-2.40	**0.02**
Dasypus novemcinctus	0.00 ± 0.00	0.00 ± 0.00	0.18 ± 0.10	0.00 ± 0.00	0.00 ± 0.00	0.00	0.16
Chaetophractus villosus	0.25 ± 0.11[a]	0.18 ± 0.10[a]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	-3.10	**<0.01**
Puma concolor	0.20 ± 0.10[a]	0.00 ± 0.00[b]	0.18 ± 0.10[a]	0.00 ± 0.00[b]	0.00 ± 0.00[b]	-3.22	**<0.01**
Tamandua tetradactyla	0.00 ± 0.00	0.18 ± 0.10	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.02	0.16
Procyon cancrivorus	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.05 ± 0.05	0.00	0.55
Dolichotis salinicola	0.20 ± 0.10[a]	0.06 ± 0.06[a]	0.00 ± 0.00[b]	0.07 ± 0.07[a]	0.00 ± 0.00[b]	-3.22	0.05

& Boaglio 2004). Other factors could also be influencing the absence of medium and large mammal species, such as interactions between native mammal species. For example, the trophic cascade can have effects on the structure and composition of communities of native mammals (Jorge et al. 2013).

Threatened species

When we limited our analysis to threatened IUCN species (i. e., *P. wagneri* and *M. tridactyla*), we found that these species were absent in the habitat type with highest livestock camera trapping rate and closer to villages. *Parachoerus wagneri* has a more restricted distribution than other peccary species, is susceptible to hunting, and absent in many areas of the Chaco where it was previously common (Altrichter & Boaglio 2004). *Parachoerus wagneri* is able to thrive in degraded forests of the Chaco as long as its habitat is not totally transformed (Altrichter & Boaglio 2004). Bañados del Quirquincho harbors the endangered *P. wagneri* highlighting the importance of the area as a conservation priority area. *Myrmecophaga tridactyla* is less represented in the area probably due to its dietary specificity, low reproductive rates, and large area require-

Table 3

Livestock camera trapping rate, distance to villages, enhanced vegetation index (EVI), and percentage of woody vegetation (values are shown as mean ± S.E.) in five habitat types at the Bañados del Quirquincho, Salta Province, Argentina. BF = Bañadero Forest, PS = Palo-santal, Q = Quebrachal, CPF = Closed Palm Forest, and OPF = Open Palm Forest. Different letters indicate significant differences among habitat types.

	Habitat type					*Parameter*	P
	BF	PS	Q	CPF	OPF		
Livestock camera trapping rate	11.40 ± 0.75[a]	3.76 ± 0.47[a]	9.94 ± 0.76[a]	55.20 ± 1.92[b]	206.26 ± 3.29[c]	11.75 (*z*)	**<0.01**
Distance to villages (m)	19985.00 ± 535.15[a]	21362.11 ± 580.45[a]	19291.89 ± 580.45[a]	19711.52 ± 617.93[a]	5286.80 ± 549.05[b]	44.35 (*F*)	<0.01
EVI	0.21 ± 0.01[a]	0.30 ± 0.01[b]	0.34 ± 0.01[c]	0.23 ± 0.01[a]	0.30 ± 0.01[b]	28.62 (*F*)	<0.01
Woody vegetation (%)	17.10 ± 1.29[a]	17.59 ± 1.40[a]	17.94 ± 1.40[a]	12.60 ± 1.49[b]	9.58 ± 1.33[c]	7.43 (*F*)	<0.01

Table 4

Relation among livestock camera trapping rate, distance to villages, enhanced vegetation index (EVI), and percentage of woody vegetation on the total camera trapping rate of native mammals, on the threatened species camera trapping rate, and on the camera trapping rate of native mammals excluding foxes (i. e., *Lycalopex gymnocercus* and *Cerdocyon thous*) using a Poisson regression model with log link function in five habitat types at the Bañados del Quirquincho, Salta Province, Argentina. Significant relationships ($P < 0.05$) are shown in bold. n = 88 camera traps.

	Total species camera trapping rate		Threatened species camera trapping rate		Camera trapping rate excluding foxes	
Variables	**z**	**P**	**z**	**P**	**z**	**P**
Livestock camera trapping rate	3.96	**<0.01**	-2.89	**<0.01**	-2.75	**<0.01**
Distance to villages	0.37	0.71	2.57	**0.01**	-1.61	0.10
EVI	3.01	**<0.01**	-2.35	**0.01**	-1.49	0.13
Percentage of woody vegetation	-0.96	0.33	-2.43	**0.01**	-1.86	0.06

ments (Braga 2010). *Myrmecophaga tridactyla* vulnerability may be due to the high livestock load and hunting (Puechagut et al. 2013; Miranda et al. 2014).

Non-threatened species

The Molina's hog-nosed skunk (*Conepatus chinga*) and the Geoffroy's cat (*Leopardus geoffroyi*) were recorded in all the habitat types, showing a relative high camera trapping rate in most of them. This could be explained by their higher tolerance to a degree of habitat alteration due to human activities (Donadio et al. 2004; Cuéllar et al. 2006). Five non-threatened species: the large hairy armadillo (*Chaetophractus villosus*), *M. gouazoubira*, *P. tajacu*, the puma (*Puma concolor*), and *T. matacus*, showed a lower camera trapping rate in at least one of the palm forests than in the other habitat types. These species could be negatively affected by human activities, mainly due to the habitat modifications of livestock raising (Noss & Cuéllar 1999; Altrichter 2005), to hunting for medicinal purposes (fat of pumas and peccaries for preparing curatives), and by ranchers (Barbarán 2003; Polisar et al. 2003; Altrichter 2006). Similarly, to an assumed competition of wildlife with livestock reported in the Bolivian

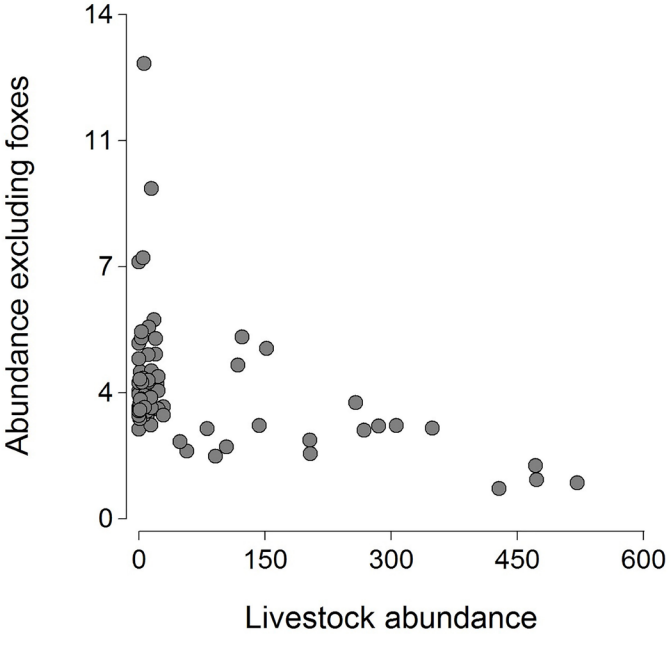

Fig. 2. Adjusted values for native mammals camera trapping rate excluding foxes in relation to livestock camera trapping rate in five habitat types at the Bañados del Quirquincho, Salta Province, Argentina. n = 88 camera traps.

Chaco (Noss & Cuéllar 1999), we found the lowest camera trapping rate of *M. gouazoubira* and *P. tajacu* where livestock camera trapping rate is higher. The low camera trapping rate of some native species (*Dasypus novemcinctus*, *Dolichotis salinicola*, *Procyon cancrivorus*, and *Tamandua tetradactyla*) does not allow us to draw conclusions of them.

Absent species

The presence of the *P. tajacu* and *T. terrestris* was reported recently for the Bañados del Quirquincho (Secretaría de Ambiente de Salta 2013), but we were not able to capture images of them in our study. *Pecari tajacu* has been reported to be sensitive to human disturbances, requires high vegetation cover (Altrichter & Boaglio 2004), and forms large groups being prone to be hunted (Reyna-Hurtado et al. 2009) resulting in local extirpations and distributional range declines (Altrichter et al. 2011; Di Bitetti et al. 2013). However, we cannot discard lack of capture in images due to *P. tajacu* seasonal movements (Reyna-Hurtado et al. 2009). *Tapirus terrestris* is even more sensitive than *P. tajacu*, requires larger areas of continuous forest cover as habitat (Jorge et al. 2013) and is highly vulnerable to hunting (Noss & Cuéllar 2008). Therefore, the absence of *T. terrestris* might be the result of changes in forest characteristics or hunting pressure in the study area. *Panthera onca* was not detected in our study but the last record in the wetland was from the 90's, as referred by the local ranger. *Panthera onca* seems to be extirpated in the Bañados del Quirquincho wetland, confirming the critical status of this species in the Chaco region (Jorge et al. 2013; Quiroga et al. 2013).

CONCLUSIONS

Our results suggest that in the Chaco it is necessary to design a land-use landscape that balances livestock production system with the conservation of biodiversity (Mastrangelo & Gavin 2012). The National Forest Law mandates a sustainable production systems (Seghezzo et al., 2011; Piquer-Rodriguez et al., 2015), therefore, guidelines—i. e., that specify livestock loads and identify forest areas excluded from production—need to rapidly be developed and implemented or the opportunity to assure the conservation of biodiversity, particularly of threatened mammal species will be lost (Nori et al. 2013). The recently approved management plan of Los Palmares lntegrated Land Planning Management (ILPM) that promotes sustainable uses of the forest in the wetland Bañados del Quirquincho and the surrounding area might provide an opportunity to raise local awareness and to include local communities to decrease hunting pressure,

develop sustainable livestock production, and promote alternative economic activities such as, ecotourism or non-timber harvesting.

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