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Population density of Geoffroy's cat in scrublands of central Argentina

J. A. Pereira[1,2], M. S. Di Bitetti[3,4], N. G. Fracassi[2], A. Paviolo[3,4], C. D. De Angelo[3,4], Y. E. Di Blanco[3,4,5] & A. J. Novaro[1,6]

1 Centro de Ecología Aplicada del Neuquén – CONICET, Junín de los Andes, Neuquén, Argentina
2 Asociación para la Conservación y el Estudio de la Naturaleza, Buenos Aires, Argentina
3 Instituto de Biología Subtropical, Facultad de Ciencias Forestales, Universidad Nacional de Misiones – CONICET, Misiones, Argentina
4 Asociación Civil Centro de Investigaciones del Bosque Atlántico, Misiones, Argentina
5 The Conservation Land Trust, Corrientes, Argentina
6 Wildlife Conservation Society, Junín de los Andes, Neuquén, Argentina

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Correspondence
Javier A. Pereira, Barrio Cardales Village (UF 90), Ruta 4 km 5,5 – Los Cardales (2814), Provincia de Buenos Aires, Argentina.
Tel: +054 11 1567466483
Email: javipereira@yahoo.com

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Abstract

We studied the density of a Geoffroy's cat *Leopardus geoffroyi* population in a semiarid scrubland of Argentina, by comparing density estimates obtained during camera-trapping surveys in a national park and in nearby cattle ranches in 2006 and 2007–2008. Overall, we obtained 247 pictures of Geoffroy's cats. The density (mean $\pm$ SE) of the species at the park ranged from 1.2 ± 0.3 to 2.9 ± 1.4 individuals km^{-2}, depending on the buffer applied, whereas density estimates at ranches were on average 32% lower. Only 11% of the Geoffroy's cats identified in 2006 could still be detected in the area 2 years later, indicating that there was a high turnover of individuals in this population. The sex ratio (M:F) estimated during both surveys at the park was 1:1.4, whereas at the ranches it was 1:0.8. The capture success of sympatric pampas cats *Leopardus colocolo* and jaguarundis *Puma yagouaroundi* was <0.3 records per 100 trap-days, and no evidence of these species was found in the ranches. Geoffroy's cats seem to be tolerant to some degree of habitat alteration produced by livestock management, and the numerical response of this species in ranches could be largely the result of human persecution and the effects of livestock management on the habitat structure and prey base.

Introduction

The population density of carnivores is affected by several factors, including prey availability (Carbone & Gittleman, 2002), interspecific competition (Creel & Creel, 1996) and hunting by humans (Inskip & Zimmermann, 2009). About 20% of the world's pastures and rangelands have been degraded to some extent due to livestock management (Steinfeld *et al*., 2006) and a decline in food resources for small- and medium-sized carnivores is usually recorded in areas devoted to this activity (e.g. Jones & Longland, 1999; Eccard, Walther & Milton, 2000; Pia, López & Novaro, 2003). In savannah rangelands of Africa, for example, the density and diversity of carnivores are negatively associated with livestock grazing intensity due to the habitat transformation and the consequent decrease in food availability (Blaum *et al*., 2007; Blaum, Tietjen & Rossmanith 2009). On the other hand, pressures to carnivores in livestock areas are also likely to be due to hunting (Novaro, Funes & Walker, 2005), which may or may not be related to the prevailing cattle land use. Data on the numerical response of different species to habitat degradation by livestock and hunting by humans are scarce, particularly for small- and medium-sized felids.

The Geoffroy's cat *Leopardus geoffroyi* is a small Neotropical felid that inhabits a wide variety of habitats, mostly arid and semiarid scrublands and grasslands, including areas under livestock management and crops (Perovic & Pereira, 2006; Castillo *et al*., 2008). This felid is usually a target of hunting by local people either to use its skin, for meat consumption or to prevent predation on poultry (Pereira, Varela & Raffo, 2005; Vilela *et al*., 2009). The only study that reported Geoffroy's cat densities was carried out in the Bolivian Chaco (Cuéllar *et al*., 2006), where this felid appeared to be most abundant at the driest site where numerous cattle ranches occur, suggesting that Geoffroy's cat can tolerate some degree of habitat alteration as a result of livestock management. This study, however, was performed at the northern limit of the species range, and no information is available on the effect of different land uses on its abundance in other parts of its range.

We studied the effect of livestock management and associated impacts (e.g. hunting by ranchers) on the density of a Geoffroy's cat population in a semiarid scrubland of central Argentina by comparing the density estimates obtained with camera-trapping surveys in a national park and in nearby cattle ranches. We also reported for the first time the sex ratio and the turnover rate of a population of this species and described its daily activity pattern. Finally, we present the first estimates of the relative abundance of two other Neotropical small cats that inhabit the area: the pampas cat *Leopardus colocolo* and the jaguarundi *Puma yagouaroundi*.

Study area

The study was conducted in Lihué Calel National Park (37°57′S 65°33′W, 9,900 ha, hereafter 'park') and two adjacent cattle ranches (each > 5000 ha, hereafter 'ranches') located in the Monte eco-region of central Argentina (Burkart *et al*., 1999). Vegetation at both sites is characterized by creosote bush *Larrea* sp. scrublands, small xeric forests and patches of mixed scrubland. In ranches, although this vegetation pattern remains, the structure of the vegetation has been altered due to livestock management (Pereira, 2009). Several species of small rodents, birds and reptiles are potential prey for carnivores. However, the abundance of these prey resources is significantly lower in ranches with respect to the park (Pereira, 2009). Besides the three feline species studied, the pampas fox *Pseudalopex gymnocercus* and the puma *Puma concolor* also occurred in the region.

The mean daily temperatures are below 8 °C in winter and above 25 °C in summer, and the annual rainfall is 498 mm ($\pm$141 SD). However, a prolonged drought occurred in the area during the 2006–2008 period as a result of annual rainfall levels of < 370 mm.

Materials and methods

To estimate the density of Geoffroy's cat, we used the method described in Karanth & Nichols (1998), which makes use of standard camera-trapping and capture–mark–recapture population models (Otis *et al*., 1978; Silver *et al*., 2004). We performed two surveys using the same general methodology. The first survey was carried out only in the park from 18 January to 2 April 2006. The second survey was carried out simultaneously in the park and in the ranches, from 23 November 2007 to 26 February 2008. We set sampling stations on trails and dirt roads. Individuals were identified in photographs by their distinctive spotted coat, body shape or sex (Fig. 1). The pictures that failed to present diagnostic details to identify individuals ($n = 28$, 11.3% of the total pictures obtained) were excluded from the analysis. Stations were active 24 h day^{-1}, and when an individual was captured more than once in a sampling station within a period of 24 h, we only considered the first capture of that animal as a record (Di Bitetti, Paviolo & De Angelo, 2006).

During the first survey, the distance among adjacent stations (993 ± 79 m; range = 748–1193 m) was selected based on the movements of radio-collared Geoffroy's cats in the area (Pereira, Fracassi & Uhart, 2006). However, this distance among adjacent stations produced a low recapture rate of individuals in different stations (only 11% of the individuals were recorded in greater than one station). To increase the capture rate, in the 2007–2008 survey, we decreased the distance among adjacent stations to 721 ± 63 m (range = 568–948 m), which increased to 25% the percentage of individuals recorded in more than one station.

The first and second surveys lasted 74 and 94 days, respectively. Because of the limited number of camera traps, we subdivided each study area into two time periods following the protocol described in Di Bitetti *et al*. (2006) and Paviolo *et al*. (2008). We set up camera traps in half of the sampling stations for the first half of the surveys (days 1–37 in 2006 and 1–47 in 2007–2008), after which we moved the stations to the remaining sampling stations for the rest of the survey (days 38–74 in 2006 and 48–94 in 2007–2008). Sampling effort was 1002 trap-days at the park in 2006, 920 trap-days at the park in 2007–2008 and 880 trap-days at the ranches in 2007–2008.

We overlapped both study periods of each survey (e.g. day 1 of both study periods was considered as day 1 of the survey) following Di Bitetti *et al*. (2006). Thus, we treated each sample as coming from a 37-day-long survey with 26 sampling stations in 2006 and a 47-day-long survey with 18 sampling stations at the ranches and 19 sampling stations at the park in 2007–2008. In order to improve the estimation of population abundance, Otis *et al*. (1978) and White *et al*. (1982) recommended an individual probability of capture of > 0.1 per trapping occasion. This value was reached for the three surveys after pooling 8 successive days as one trapping occasion (e.g. days 1–8 = first trapping occasion, days 9–16 = second trapping occasion, etc.). Thus, the trapping history of each individual consisted of a string of five trapping occasions in 2006 and of six trapping occasions in both sites in 2007–2008. We estimated the population size using the software CAPTURE (Rexstad & Burnham, 1991), considering the results of model M_h, which assumes heterogeneity among individuals in their capture probabilities (White *et al*., 1982) and is the most appropriate model for felids because of the unequal access to sampling stations by different individuals (Karanth & Nichols, 2002).

We applied three different buffers to estimate the area effectively sampled by our surveys: (1) the radius (905 m) of the mean adult home-range size of the studied population ($n = 22$ individuals) from Pereira (2009); (2) the mean maximum distance moved (MMDM) for the individuals recorded at more than one station (Silver *et al*., 2004); (3) half of the MMDM. Because of the overall small number of individuals recorded at more than one station in our study, we calculated the MMDM by pooling the data from the three surveys ($n = 12$). We used the geographical information system ArcView v. 3.2 (ESRI, Redlands, CA, USA) to estimate the MMDM values and surveyed areas (Fig. 2). Finally, the absolute density (and SE) was estimated following Silver *et al*. (2004) and Maffei *et al*. (2005), using each of the three buffer types mentioned above. The areas surveyed according to these three methods were large enough (see

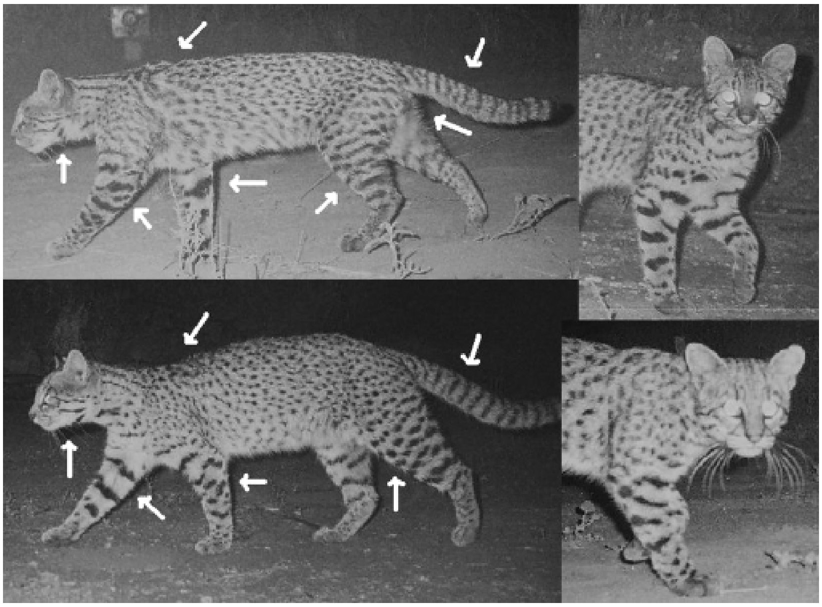

Figure 1 Diagnostic characteristics used to distinguish individual Geoffroy's cats *Leopardus geoffroyi* from pictures. Left: Example of identification of two different Geoffroy's cat individuals based on the coloration pattern of the legs (outer and inner faces), tail, back and head. In addition, testicles can be observed in the upper male. Right: Example of identification of a female (above) and a male (below) Geoffroy's cats. See the relative size and robustness of the head, the distance between the ears and the robustness of the jaw.

Table 2) to encompass greater than three to four times the estimated home-range size of individual Geoffroy's cats in the area (260 ha; Pereira, 2009). Thus, our estimations fulfil the requisite to obtain an unbiased and robust population density estimate proposed in Maffei & Noss (2008). Although by using half of the MMDM the effective survey area was not continuous (see Fig. 2), Maffei & Noss (2008) found this not to be a problem for density estimation.

Because of the sampling design we used (subdividing the study area into two time periods and then clumping these periods into one survey), our data structure was not valid for testing the closed population assumption using the closure test provided by CAPTURE. As our surveys were performed during relatively short periods, we assumed no change in the population due to the births and deaths during these periods. However, dispersal may have occurred in the study subpopulations. Thus, the assumption of a demographically closed population should be considered cautiously.

An estimation of the sex ratio of the two subpopulations studied (park and ranches) was performed by identifying the sex of the individuals by observation of the genital area when pictures made it possible. In the remaining cases, we attempted to identify sex using other characteristics (Fig. 1) such as body robustness, the relative size of the head, and the robustness of the jaw and of the forehead (Pereira, 2009). To test the accuracy of this identification method, we performed a 'blind test' based on pictures of specimens of known sex ($n = 28$ recorded individuals), conducted independently by two observers. The overall success in sex identification was 86% (Binomial test, $P = 0.0002$); hence, this method was considered suitable for assigning sex.

We studied the activity pattern of Geoffroy's cat based on the date and time recorded in each picture. If an individual was captured more than once within a 2-h period, we only considered the first capture as an activity record. Ninety and 64 activity records were obtained in the park during the 2006 and 2007–2008 surveys, respectively, whereas 16 records were obtained in the ranches. Because no clear differences were apparent in the daily activity pattern among surveys, and given the small sample size obtained in the ranches, we described the activity of Geoffroy's cat by pooling the data of the three surveys.

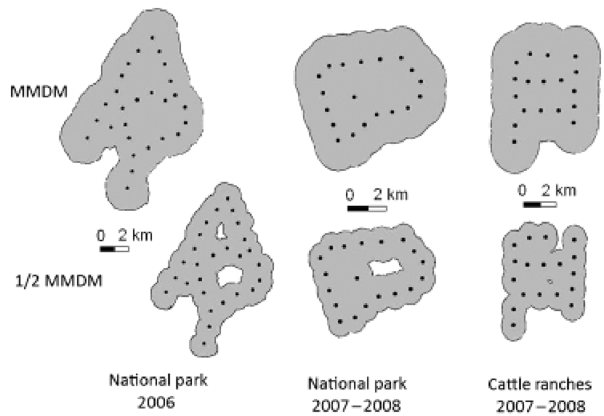

Figure 2 Effectively surveyed areas determined using the mean maximum distance moved (MMDM) and half of the MMDM (1/2 MMDM) at Lihué Calel National Park and adjacent cattle ranches, Argentina. Effectively surveyed areas using the home-range radius were similar to those obtained with 1/2 MMDM. Each black dot represents a camera-trapping station.

We estimated the relative abundance of two sympatric small felids (pampas cat and jaguarundi) using pictures obtained during the camera trap surveys. The absolute density of these species could not be estimated using capture–recapture models due to the small number of records obtained. Thus, we report the minimum number of individuals recorded and the relative abundance of each species as the number of records per 100 trap-days.

Results

We obtained 247 pictures of Geoffroy's cats, representing 162 records (Table 1). Capture success in the park was 9.1 records per 100 trap-days in 2006 and 6.1 records per 100 trap-days in 2007–2008, whereas in ranches, it was 1.7 records per 100 trap-days. The mean maximum distances moved (MMDM) by individual Geoffroy's cats detected in more than one sampling station in 2006 ($n = 5$) and 2007–2008 ($n = 7$) were 1735 m (range = 1017–2004 m) and 1810 m (range = 608–3978 m), respectively. Effectively sampled areas ranged from 15.5 to 81.6 km^2 (Table 2). Geoffroy's cat densities (mean ± SE) at the park ranged from 1.2 ± 0.3 to 2.9 ± 1.4 individuals km^{-2}, depending on the buffer applied (Table 2). Density estimates at ranches were on average 32% lower than those estimated at the park at the same time (Table 2).

During the 2006 survey, 23 sampling stations (85% of the total number of stations installed) recorded at least one Geoffroy's cat, and the average number of individuals recorded per sampling station was 1.9 (range = 0–5). During the 2007–2008 survey, 14 stations (74%) in the park but only 6 (33%) in the ranches recorded at least one Geoffroy's cat, and the average number of individuals recorded per sampling station was 1.4 (range = 0–4) in the park and 0.8 (range = 0–4) in the ranches. The total number of individuals recorded per sampling station was similar between the two samples in the park ($H = 2.02$, $P = 0.155$) and between sites during the 2007–2008 survey ($H = 3.62$, $P = 0.057$). Reducing the area sampled at the national park during the 2006 survey to the same area sampled in the 2007–2008 survey (the first was 2.5 times larger than the second), only three out of the 28 individuals identified in 2006 could still be detected in the area 2 years later. None of the animals recorded in the park was detected in the ranches or vice versa.

The sex ratio (M:F) estimated during both surveys at the park was 1:1.4, whereas it was 1:0.8 at the ranches (Table 1). This relationship was also observed at the different sampling stations. During both surveys conducted in the park, in those stations where more than one individual was detected ($n = 21$), the sex ratio was balanced (1 M–1 F or 2 M–2 F) or female biased (0 M–2 F, 0 M–3 F, 1 M–2 F, or 1 M–3 F), except in two stations (2 M–1 F and 3 M–0 F). In the ranches, in all sampling stations in which more than one individual was recorded ($n = 4$), the sex ratio was always male biased (2 M–0 F or 2 M–1 F).

Geoffroy's cats were mainly nocturnal (Fig. 3). Combining the three surveys, 93% of the activity records were included within the 20:00–06:00 h period, with the bulk of the activity concentrated from 00:00 to 04:00 h (Fig. 3).

We obtained only five pictures of pampas cat, all of them at the park (Table 1). For the 2006 survey, two of the

Table 1 Total number of records of Geoffroy's cats *Leopardus geoffroyi*, pampas cats *Leopardus colocolo* and jaguarundis *Puma yagouaroundi*, and number of individuals captured according to their sex in Lihué Calel National Park (NP) and adjacent cattle ranches (CR), Argentina, during 2006 and 2007–2008 surveys

					Sex		
Species	Survey	Pictures	Records	Individuals	M	F	Unknown
Geoffroy's cat	2006 NP	143	91	47	17	24	6
	2007–2008 NP	82	56	20	7	10	3
	2007–2008 CR	22	15	9	4	3	2
Pampas cat	2006 NP	3	3	1	0	1	0
	2007–2008 NP	2	1	1	0	1	0
	2007–2008 CR	0	0	0	0	0	0
Jaguarundi	2006 NP	2	2	1	0	0	1
	2007–2008 NP	0	0	0	0	0	0
	2007–2008 CR	0	0	0	0	0	0

Table 2 Population size estimates of Geoffroy's cat *Leopardus geoffroyi* provided by CAPTURE (using Model M_h) for 2006 and 2007–2008 surveys and density estimates using the three different buffers to calculate the effectively sampled area

Survey	Population (± SE)	95% CI	Buffer used	Surveyed area (km^2)	Density ± SE (individuals km^{-2})
NP 2006	101 ± 14.1	80–136	HR radius	42.3	2.4 ± 0.3
			MMDM	81.6	1.2 ± 0.3
			1/2 MMDM	46.9	2.2 ± 0.7
NP 2007–2008	54 ± 12.8	37–89	HR radius	23.8	2.3 ± 1.0
			MMDM	34.0	1.6 ± 0.6
			1/2 MMDM	18.8	2.9 ± 1.4
CR 2007–2008	29 ± 8.8	19–55	HR radius	20.1	1.4 ± 0.7
			MMDM	28.8	1.0 ± 0.4
			1/2 MMDM	15.5	1.9 ± 1.1

CI, confidence interval; SE, standard error.

pictures could be attributed to the same individual based on the fur pattern, but the third picture could not be unambiguously identified. Because this third record was obtained on the same date as the two pictures of the same cat and in a nearby sampling station, these three records probably belonged to the same individual. The straight-line distance between the two stations at which this individual was recorded was 3061 m. The two pictures obtained during the 2007–2008 survey at the park constituted a single capture occasion of another individual. The capture success of pampas cats in each survey was 0.3 and 0.1 records per 100 trap-days.

Only two pictures of jaguarundis were obtained, and both of them during the 2006 survey at the park (Table 1). Although it was not possible to determine whether both pictures belonged to the same individual, they were obtained in the same sampling station and within a period of 3 days. Thus, these records probably belong to the same individual. The capture success of jaguarundis was 0.2 records per 100 trap-days.

Discussion

Geoffroy's cats were present both in the park and in the ranches, and the estimated population density for this species in the park was one-third higher than that estimated for the ranches. The numerical response of this predator in ranches could be largely the result of the effects of livestock management on the habitat structure and on the prey base. The densities of main food resources for these small felids such as small rodents and passerine birds were 90 and 20% lower, respectively, in the ranches studied with respect to the park (Pereira, 2009). Because a relationship between prey abundance and predator density is frequently observed (e.g. Avenant & Nel, 1998; Blaum *et al.*, 2009), this lower food density could be limiting the abundance of Geoffroy's cats in the ranches. Also, human persecution usually reduces the abundance of carnivores (e.g. Novaro *et al.*, 2005; Paviolo *et al.*, 2008). Accordingly, sources of mortality of Geoffroy's cats in studied ranches include illegal harvesting, predation by domestic dogs and incidental mortality in traps used to catch foxes (Pereira, 2009). These factors may contribute to a population decline of this species in ranches.

The high density of a carnivore at a particular site could be indicative of the existence of good habitat conditions or could also mean that this area with good habitat conditions is acting as a refuge for individuals persecuted in adjacent areas (Slough & Mowat, 1996). Both mechanisms may be involved in the high Geoffroy's cat density estimated in the park. First, Lihué Calel National Park is a relatively large area with undisturbed natural vegetation and high prey density surrounded by cattle ranches where felids are persecuted and prey is less abundant (Pereira, 2009). Second, most of the individuals were recorded only once or twice during the three surveys (81% in 2006 and 60% in 2007–2008), and although the existence of behavioural responses to capture (*trap-shyness*) should not be discarded, this pattern suggests the possible existence of transient animals. Transients are usually juveniles or subadults dispersing from their natal ranges (Kamler & Gipson, 2000), but adults can also behave as transients if severe environmental disturbances take place (e.g. Ward & Krebs, 1985; Norbury, Norbury & Heyward, 1998). Evidence on behalf of the presence of transient Geoffroy's cats in the area was collected during a radiotelemetry study (Pereira, 2009). During a camera trapping study focused on coyotes *Canis latrans*, Larrucea *et al.* (2007) reported an increase in the capture rate of individuals due to the entry of dispersing juveniles into the study area. These authors demonstrated that an increase in the recording rate accompanied by a decline in the recapture rate could lead to an overestimation of the population size. This fact would suggest caution regarding the accuracy of our Geoffroy's cat density estimates, because they might be inflated due to the presence of transient individuals.

A bias toward females is expected in undisturbed populations of solitary felids, due to their spatial organization pattern (Sandell, 1989). However, different studies showed that the sex ratio in mammal populations could be affected by other factors, such as the population density (Kruuk *et al.*, 1999), hunting by humans (Barnhurst, 1986) or climatic conditions (Mysterud *et al.*, 2000). Although crude

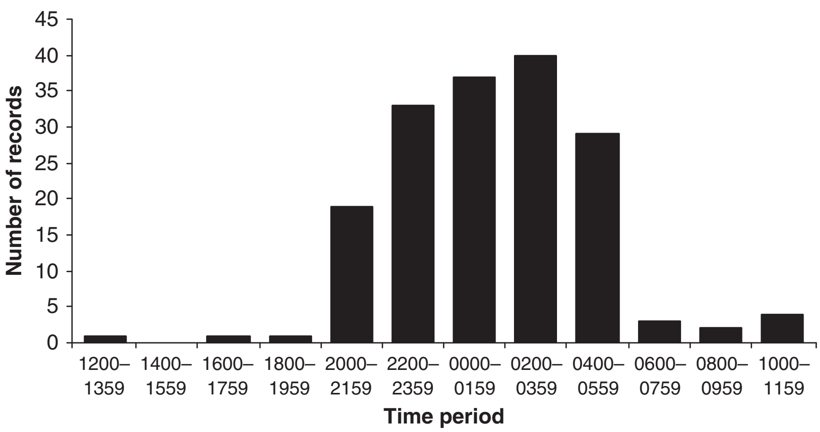

Figure 3 Daily activity patterns ($n=170$ records) of Geoffroy's cat *Leopardus geoffroyi* as determined from camera trapping in Lihué Calel National Park and adjacent cattle ranches, Argentina.

numbers in our study indicate a high proportion of Geoffroy's cat males in ranches, the low number of individuals recorded and the fact that unambiguous sex assignment was not possible for all of the individuals preclude the possibility of assessing whether differences in the sex ratio between areas were statistically significant. Hunting of Geoffroy's cats practiced by rural people in ranches or predation by domestic dogs appeared not to be biased toward a particular sex (J. Pereira, pers. obs.). However, the removal of individuals through hunting, emigration and mortality would reduce the density of the population, allowing other individuals to re-colonize the area. As usually occurs in mammals (Greenwood, 1980), Geoffroy's cat has a polygynous breeding system involving female phylopatry. As a result, immigration into the ranches would be dominated by males, contributing to an increase in the relative proportion of this sex.

Several authors (e.g. Johnson & Franklin, 1991; Cuéllar *et al.*, 2006) noted that Geoffroy's cats used small parts of their territory for a relatively short period of time (up to 3 months) and then moved to other areas or even abandoned their home ranges. This behaviour was also evident for radio-collared Geoffroy's cats in Lihué Calel (Pereira *et al.*, 2006; Pereira, 2009), and suggests the existence of an unstable home-range behaviour and little site fidelity by this felid, at least under severe environmental conditions (drought). Accordingly, only 11% of the individuals identified in 2006 could still be detected in the area 2 years later, indicating that there was a high turnover of individuals in this Geoffroy's cat population. High turnover rates of individuals in a population may be related to different factors. For example, while populations of feral domestic cats *Felis catus* and leopards *Panthera pardus* showed high turnover rates due to poaching (Genovesi, Besa & Toso, 1995; Balme & Hunter, 2004), similarly high turnover rates occurred in populations of pumas and tigers *Panthera tigris* due to high emigration and immigration rates (Seidensticker *et al.*, 1973; Harihar, Pandav & Goyal, 2008). The apparent existence of transient Geoffroy's cats and the fact that none of the 24 individuals of this species radiocollared in the area in 2007–2008 remained there for >1.5 years (Pereira, 2009) suggest that the high turnover rate in this population was associated with high rates of emigration and immigration.

Very few records of pampas cats and jaguarundis were obtained during this study, and no evidence of these species was collected in the ranches. Some authors (e.g. Maffei, Cuéllar & Noss, 2002; Cuéllar *et al.*, 2006; Arispe, Rumiz & Noss, 2007) have reported capture rates for jaguarundis ranging from 0.3 to 0.9 individuals per 100 trap-days at dry forests in Bolivia, whereas Lucherini, Luengos Vidal & Merino (2008) have reported a capture rate for pampas cat of <1 individual per 100 trap-days at the high Andes in Argentina. These figures, although higher than those obtained in our study, are relatively low and may indicate the rarity of these species in various habitat types.

Our estimations of Geoffroy's cat density are considerably higher than those obtained by Cuéllar *et al.* (2006) using the same method in areas of dry forest in the Bolivian Chaco. These authors estimated densities ranging from 0.1 to 0.4 individuals km^{-2} (considering half of the MMDM), and they even suggested that such values could be overestimated because of the small area surveyed. Interestingly, Cuéllar *et al.* (2006) found a greater abundance of Geoffroy's cat in livestock ranches than in areas without hunting and no cattle. However, other causal factors of this opposite pattern could be the different environmental conditions among sites (the species was most abundant at the driest site, dominated by grassland/shrub formations) and the different abundances of the species that composed the regional carnivore assembly. In contrast to that observed in Lihué Calel, where Geoffroy's cat is the most abundant felid, the ocelot *Leopardus pardalis* is the most abundant felid in the Bolivian Chaco, and Geoffroy's cats were most abundant where ocelots were absent (Cuéllar *et al.*, 2006). Interspecific competition may limit the Geoffroy's cat abundance in the Bolivian Chaco, either by competition for food or by intraguild predation (Donadio & Buskirk, 2006). Differences between Lihué Calel and the Bolivian Chaco may also represent regional (biogeographical) differences; Cuéllar *et al.* (2006) estimated the density of Geoffroy's cats in an area near the north end of its distribution, and species generally tend to have lower population abundances in their range limits (Brown, Mehlman & Stevens, 1995).

Geoffroy's cats seem to be tolerant to some degree of habitat alteration produced by livestock management, although a possible effect of this activity on the sex ratio of the population remains to be studied. The apparent ability of the species to coexist with livestock management reflects its behavioural plasticity and indicates that cattle ranches could be potentially important for the conservation of this predator in the Monte eco-region.

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References

Arispe, R., Rumiz, D. & Noss, A. (2007). Six species of cats registered by camera trap surveys of Tropical dry forest in Bolivia. *Cat News* **46**, 36–38.

Avenant, N. & Nel, J. (1998). Home range use, activity and density of caracal in relation to prey density. *Afr. J. Ecol.* **36**, 347–359.

Balme, G. & Hunter, L. (2004). Mortality in a protected leopard population, Phinda Private Game Reserve, South Africa: a population in decline? *Ecol. J.* **6**, 1–6.

Barnhurst, D. (1986). *Vulnerability of cougars to hunting*. PhD thesis. Utah State University, Logan.

Blaum, N., Rossmanith, E., Popp, A. & Jeltsch, F. (2007). Shrub encroachment affects mammalian carnivore abundance and species richness in semiarid rangelands. *Acta Oecol.* **31**, 86–92.

Blaum, N., Tietjen, B. & Rossmanith, E. (2009). Impact of livestock husbandry on small- and medium-sized carnivores in Kalahari savannah rangelands. *J. Wildl. Mgmt.* **73**, 60–67.

Brown, J., Mehlman, D. & Stevens, G. (1995). Spatial variation in abundance. *Ecology* **76**, 2028–2043.

Burkart, R., Barbaro, N., Sanchez, R.O. & Gómez, D.A. (1999). *Eco-regiones de la Argentina*. Administración de Parques Nacionales, PRODIA, Buenos Aires.

Carbone, C. & Gittleman, J. (2002). A common rule for the scaling of carnivore density. *Science* **295**, 2273–2276.

Castillo, D., Luengos Vidal, E., Lucherini, M. & Casanave, E. (2008). First report on the Geoffroy's cat in a highly modified rural area of the Argentine Pampas. *Cat News* **49**, 27–28.

Creel, S. & Creel, N.M. (1996). Limitation of African wild dogs by competition with larger carnivores. *Conserv. Biol.* **10**, 526–538.

Cuéllar, E., Maffei, L., Arispe, R. & Noss, A. (2006). Geoffroy's cats at the northern limit of their range: activity patterns and density estimates from camera trapping in Bolivian dry forests. *Stud. Neotrop. Fauna Environ.* **41**, 169–177.

Di Bitetti, M., Paviolo, A. & De Angelo, C. (2006). Density, habitat use and activity patterns of ocelots (*Leopardus pardalis*) in the Atlantic forest of Misiones, Argentina. *J. Zool. (Lond.)* **270**, 153–163.

Donadio, E. & Buskirk, S. (2006). Diet, morphology, and interspecific killing in Carnivora. *Am. Nat.* **167**, 524–536.

Eccard, J., Walther, R. & Milton, S. (2000). How livestock grazing affects vegetation structure and small mammal distribution in the semi-arid Karoo. *J. Arid Environ.* **46**, 103–106.

Genovesi, P., Besa, M. & Toso, S. (1995). Ecology of a feral cat *Felis catus* population in an agricultural area of northern Italy. *Wildl. Biol.* **1**, 233–237.

Greenwood, P. (1980). Mating systems, philopatry and dispersal in birds and mammals. *Anim. Behav.* **28**, 1140–1162.

Harihar, A., Pandav, B. & Goyal, S. (2008). Responses of tiger (*Panthera tigris*) and their prey to removal of anthropogenic influences in Rajaji National Park, India. *Eur. J. Wildl. Res.* **55**, 97–105.

Inskip, C. & Zimmermann, A. (2009). Human–felid conflict: a review of patterns and priorities worldwide. *Oryx* **43**, 18–34.

Johnson, W. & Franklin, W. (1991). Feeding and spatial ecology of *Felis geoffroyi* in southern Patagonia. *J. Mammal.* **72**, 815–820.

Jones, A. & Longland, W. (1999). Effects of cattle grazing on salt desert rodent communities. *Am. Midl. Nat.* **141**, 1–11.

Kamler, J. & Gipson, P. (2000). Home range, habitat selection, and survival of bobcats *Lynx rufus* in a prairie ecosystem in Kansas. *Can. Field Nat.* **114**, 388–394.

Karanth, K. & Nichols, J. (1998). Estimation of tiger densities in India using photographic captures and recaptures. *Ecology* **79**, 2852–2862.

Karanth, K. & Nichols, J. (2002). *Monitoring tigers and their prey: a manual for researchers, managers and conservationists in tropical Asia*. Bangalore: Centre for Wildlife Studies.

Kruuk, E., Clutton-Brock, T., Albon, S., Pemberton, J. & Guinness, F. (1999). Population density affects sex ratio variation in red deer. *Nature* **399**, 459–461.

Larrucea, E., Brussard, P., Jaeger, M. & Barrett, R. (2007). Cameras, coyotes, and the assumption of equal detectability. *J. Wildl. Mgmt.* **71**, 1682–1689.

Lucherini, M., Luengos Vidal, E. & Merino, M.J. (2008). How rare is the rare Andean cat? *Mammalia* **72**, 95–101.

Maffei, L., Cuéllar, E. & Noss, A.J. (2002). Uso de trampas-cámara para la evaluación de mamíferos en el ecotono Chaco-Chiquitanía. *Rev. Bol. Ecol.* **11**, 55–65.

Maffei, L. & Noss, A. (2008). How small is too small? Camera trap survey areas and density estimates for ocelots in the Bolivian Chaco. *Biotropica* **40**, 71–75.

Maffei, L., Noss, A., Cuéllar, E. & Rumiz, D. (2005). Ocelot (*Felis pardalis*) population densities, activity, and ranging behavior in the dry forests of eastern Bolivia: data from camera trapping. *J. Trop. Ecol.* **21**, 349–353.

Mysterud, A., Yoccoz, N., Stenseth, N. & Langvatn, R. (2000). Relationships between sex ratio, climate and density in red deer: the importance of spatial scale. *J. Anim. Ecol.* **69**, 959–974.

Norbury, G., Norbury, D. & Heyward, R. (1998). Behavioral responses of two predator species to sudden declines in primary prey. *J. Wildl. Mgmt.* **62**, 45–58.

Novaro, A., Funes, M. & Walker, S. (2005). An empirical test of source–sink dynamics induced by hunting. *J. Appl. Ecol.* **42**, 910–920.

Otis, D., Burhnam, K., White, C. & Anderson, D. (1978). Statistical inference from capture data on closed animal population. *Wildl. Monogr.* **62**, 1–135.

Paviolo, A., De Angelo, C., Di Blanco, Y. & Di Bitetti, M. (2008). Jaguar population decline in the Upper Paraná Atlantic Forest of Argentina and Brazil. *Oryx* **42**, 554–561.

Pereira, J.A. (2009). *Efectos del manejo ganadero y disturbios asociados sobre la ecología trófica y espacial y la demografía del gato montés (*Leopardus geoffroyi*) en el desierto del Monte, Argentina*. PhD thesis, Universidad de Buenos Aires.

Pereira, J.A., Fracassi, N.G. & Uhart, M.M. (2006). Numerical and spatial responses of Geoffroy's cat (*Oncifelis *geoffroyi*) to prey decline in Argentina. *J. Mammal*. **87**, 1132–1139.

Pereira, J.A., Varela, D.M. & Raffo, L. (2005). Relevamiento de los felinos silvestres en la región del Parque Nacional Pre-Delta, Entre Ríos. *FACENA* **21**, 69–77.

Perovic, P. & Pereira, J.A. (2006). Felidae. In *Mamíferos de la Argentina. Sistemática y distribución*: 93–100. Barquez, R., Díaz, M. & Ojeda, R. (Eds). Tucumán: Sarem.

Pia, M., López, M. & Novaro, A. (2003). Effects of livestock on the feeding ecology of endemic culpeo foxes (*Pseudalopex culpaeus smithersi*) in central Argentina. *Rev. Chil. Hist. Nat*. **76**, 313–321.

Rexstad, E. & Burnham, K. (1991). User's guide for interactive program CAPTURE: abundance estimation of closed animal populations. Colorado State University, Fort Collins, CO, USA.

Sandell, M. (1989). The mating tactics and spacing patterns of solitary carnivores. In *Carnivore behavior, ecology, and evolution*: 164–182. Gittleman, J. (Ed.). Ithaca: Cornell University Press.

Seidensticker, J., Hornocker, M., Wiles, W. & Messick, J. (1973). Mountain lion social organization in the Idaho primitive area. *Wildl. Monogr*. **35**, 1–60.

Silver, S., Ostro, L., Marsh, L., Maffei, L., Noss, A., Kelly, M., Wallace, R., Gomez, H. & Ayala, G. (2004). The use of camera traps for estimating jaguar *Panthera onca* abundance and density using capture/recapture analysis. *Oryx* **38**, 148–154.

Slough, B. & Mowat, G. (1996). Lynx population dynamics in an untrapped refugium. *J. Wildl. Mgmt*. **60**, 946–961.

Steinfeld, H., Gerber, P., Wassenaar, T., Castel, V., Rosales, M. & de Haan, C. (2006). Livestock's long shadow – environmental issues and options. The Livestock, Environment and Development (LEAD) Initiative & FAO, Rome, Italy.

Vilela, A., Bolkovic, M., Carmanchahi, P., Cony, M., de Lamo, D. & Wassner, D. (2009). Past, present and potential uses of native flora and wildlife of the Monte desert. *J. Arid Environ*. **73**, 238–243.

Ward, R. & Krebs, C. (1985). Behavioural responses of lynx to declining snowshoe hare abundance. *Can. J. Zool*. **63**, 2817–2824.

White, G., Anderson, D., Burnham, K. & Otis, D. (1982). Capture–recapture and removal methods for sampling closed populations. Los Alamos National Laboratory, NM, USA.