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How rare is the rare Andean cat?

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Abstract

Although rareness is the main criterion used to list the Andean cat *Leopardus jacobita* as endangered, information on its population abundance is lacking. During 14 expeditions to north-western Argentina, we recorded the culpeo *Lycalopex culpaeus* at all sites where we interviewed local people, the Pampas cat *Leopardus colocolo* at 85.2% of sites and *Leopardus jacobita* at 66.7% of sites. Encounter rates for indirect signs of small cats and foxes were similar. DNA genotyping showed that only 4.9% of faecal samples from small cats were from *L. jacobita*. Camera trapping recorded culpeos in 85.7%, Pampas cats in 71.4%, and Andean cats in 42.9% of the areas. The mean capture rate for culpeos was more than twice that for Pampas cats and five-fold that for Andean cats. Direct signs of *L. culpaeus* were the most abundant, whereas those for *L. colocolo* and *L. jacobita* were similar. Culpeos are more widespread and abundant than small cats in the High Andes. Populations of *L. jacobita* are less homogeneously distributed than those of *L. colocolo*, but clear differences in abundance of sympatric populations were not detected. Our results support the need for conservation measures for *L. jacobita*, an endemic of the High Andes.

Keywords: Argentina; camera trapping; *Leopardus jacobita*; population abundance; sign counts.

Introduction

The Andean cat *Leopardus jacobita* (Cornalia 1865) is considered one of the most endangered and least-known felids in the world (Nowell and Jackson 1996, Nowell 2002a,b). Although its presence has recently been reported at an elevation of 1900 m in central Argentina (Sorli et al. 2006), the Andean cat is typically endemic to the high-altitude (3000–5500 m) Andes of Peru, Bolivia, Chile and Argentina (Oliveira 1994, Yensen and Seymour 2000).

In spite of the fact that rareness was one of the main criteria used to assign *L. jacobita* to its conservation status category (Nowell and Jackson 1996), little information is currently available on Andean cat abundance and much that is available is anecdotal (Perovic et al. 2003). The recent conservation action plan for the Andean cat reported that, based on the paucity of data, it has not been possible to establish the size of the species population (Villalba et al. 2004).

Until now, the carnivore guild of the High Andes has received little attention (Walker et al. 2007). Carnivore species occurring in this area include one large cat, the puma *Puma concolor* (Linnaeus 1771), two small-sized mustelids, the hog-nosed skunk *Conepatus* (Grey 1837) sp. and the lesser grison *Galictis cuja* (Molina 1782), and three medium-sized species, *L. jacobita*, the Pampas cat *Leopardus colocolo* (J. Molina 1782), and the culpeo or Patagonian fox *Lycalopex culpaeus* (Molina 1782). The chilla, or grey fox *Lycalopex griseus* (Gray 1837), has also been reported for the region, but its distribution is limited to open areas at lower altitudes (Lucherini et al. 1999). Whereas *P. concolor* is the top-order predator of the High Andes and can kill all other guild members, the body sizes of *L. colocolo*, *L. culpaeus*, and *L. griseus* make them potential competitors of the Andean cat. Of these species, the Andean cat is the only one that is endemic to this ecoregion, as the others are widely distributed throughout a much greater variety of habitats in South America (Redford and Eisenberg 1992).

The distribution range of the Andean cat appears to overlap widely in geography and altitude with the Pampas cat (Perovic et al. 2003). Fine-scale sympatry has also been reported between these two felids (Lucherini and Luengos Vidal 2003, Perovic et al. 2003, Villalba and Delgado 2005).

Intraguild competition has been shown to be a widespread cause of mortality in carnivores (Palomares and Caro 1999), which affects their abundance (Linnell and Strand 2000). More specifically, it has been suggested that intraguild competition with Pampas cats and culpeos may be affecting the present status of *L. jacobita* (Lucherini and Luengos Vidal 2003), whereas habitat segregation from chillas would reduce the chances of competition. Recently, this hypothesis has received support by first studies on the diet of sympatric *L. jacobita*, *L. colocolo* and *L. culpaeus*, which showed extensive food niche overlap, especially between the two small cats (Walker et al. 2007, Napolitano et al. 2008).

A number of direct and indirect methods to study population numbers have been described (e.g., Macdonald et al. 1998, Gese 2001), but none are flawless. Deciding which methodology to use should be based on the natural history and spatial distribution of the species to be studied, the topography and vegetation of the study area, observer experience, logistics, funding, and research objectives (Gese 2001, Pollock 2006). Whenever possible, direct counts should be favoured. For many species, however, direct observation is impractical, forcing researchers to rely on estimates of relative abundance based on the detection and identification of indirect signs (Wilson and Delahay 2001, Jackson et al. 2006). Furthermore, many ecological problems can be addressed with the help of indices of density (Caughley 1977) and many conservation priorities cannot afford the time or funding necessary to obtain absolute calculations of density or abundance.

We present here results of the first long-term effort to estimate the relative abundance of carnivore populations in the High Andes. We concentrated on the carnivore species that are likely competitors (Walker et al. 2007): the Andean cat, the Pampas cat and the culpeo. We focused on two of the main components of species rareness: low density and restricted distribution, and tested the following hypotheses: (1) in the high-altitude Andes of Argentina, *L. jacobita* has a more restricted distribution than its two main potential competitors, *L. colocolo* and *L. culpaeus*; and (2) populations of *L. jacobita* are less abundant than those of *L. colocolo* and *L. culpaeus*. We also compare different survey methods to estimate abundance indices for the populations of carnivores occurring in these areas.

Materials and methods

Study region

We recorded data during 14 expeditions from March 1998 to June 2006. The expeditions covered an area of approximately 89 500 km^2 in the high-altitude (elevation of 2000–5000 m) portions of four provinces (Catamarca, Jujuy, Salta and Tucumán) in north-western Argentina and south-western Bolivia (one expedition; Figure 1). The climate within the survey area is cool and dry. The High Andes receive less than 400 mm of annual rainfall, which is concentrated in summer. The temperature fluctuates greatly from night to day. Productivity is low, and tropical alpine herbs and grasses with dwarf shrubs characterise the vegetation. At altitudes above 4500–5000 m, no vegetation occurs (Cabrera 1976).

During our expeditions, we simultaneously used a variety of standard survey techniques to maximise information obtained in the field and evaluate their comparative effectiveness. A combination of interviews, field surveys and DNA analysis of faecal samples has been recommended as survey methodology to determine the status of this felid covering large geographical areas (Perovic et al. 2003). We incorporated camera trapping as an additional survey tool because of its success for other rare and secretive felids (e.g., Carbone et al. 2001, Karanth et al. 2004, Jackson et al. 2006) and its first successful tests to verify the presence of *L. jacobita* and *L. colocolo* in the Andes (Villalba 2002, Lucherini et al. 2004a, Barbry and Gallardo 2006).

Interviews

Interviews are widely used to assist researchers in determining the presence or absence of mammals, especially carnivores (e.g., Rabinowitz 1993, Dietrich 1995, Brooks et al. 1999, Marino 2003), and have been previously used to study the distribution of High Andes cats (Cossíos et al. 2007). We visited settlements located at altitudes of 2000–4500 m, and chose adults who lived in or frequently visited the high-altitude areas. Interviews followed a semi-structured procedure (Kapila and Lyon 1994) and were based on a standard questionnaire that was not shown to the interviewees. Here we report results obtained from answers to the question "Which carnivores live in the area?". Since *L. jacobita* and *L. colocolo* are morphologically similar (García-Perea 2002), we first asked the interviewees to describe the small cats they sighted and the characteristics they used to identify each. We verified their identification skills by showing a series of pictures of small-sized, spotted Neotropical cats and asking them to identify the species they had reported (Gros et al. 1996, Chapron 1999, Lucherini and Merino 2008). We discarded interviews that were considered unreliable. Interviews were also used to confirm that chillas live in different habitats to *L. jacobita*.

Sign counts

Sign counts are a very effective method for carrying out surveys over vast geographic areas (Smallwood and Schonewald 1998). We conducted sign counts in areas containing a suitable habitat (e.g., rocky outcrops) and where the presence of the Andean cat was reported by local people or previous reports. We defined a sign a "latrine" if more than two faecal samples were found that could be positively determined to have been deposited at different times. To avoid overestimating the abundance of the species that tend to defecate at latrines, each latrine was recorded as a single sign of presence.

Intensive surveys ($\geq$5 days of sign searching) were completed in 11 areas (Figure 1). Since geographical variations in population abundance of High Andes carnivores have been reported (Lucherini et al. 1999), we treated each area in which intensive surveys were carried out as a single sampling unit and averaged across areas. In these sampling units, the search effort was calculated as the number of hours searched per person. The encounter rate, or the number of signs counted during the survey per search effort, was used as an index of relative abundance to account for variations in sampling effort between areas.

Faeces of culpeo, puma, mustelids and small cats were differentiated based on form, size and smell (Litvaitis 2000, Walker et al. 2007). The freshest faecal samples from small cats were genotyped using a Qiagen Stool Kit (Valencia, CA, USA), amplifying the 16S rRNA mitochondrial gene and comparing the resulting sequences to those of known species and reference samples (Johnson and O'Brien 1997, Cossíos and Angers 2006). Some culpeo samples were also genotyped to confirm the validity of our morphological identification and test for the presence of chillas. This analysis was performed by Wildlife Genetics International, Nelson, BC, Canada and subsequently by D. Cossíos, Universitè de Montreal, Canada. Owing to the high cost of this analysis, only a sub-sample of fresh scats deposited by small cats was analysed.

Tracks were identified based on shape, number of toes, size and presence of claws, whereas fresh scent marks were identified by their smell. These signs were used to identify carnivore families and, in the case of felids, to separate puma from small cats. We used a key to identify small cat skulls (García-Perea 2002).

Samples that could not be unambiguously identified were discarded from the subsequent data analysis.

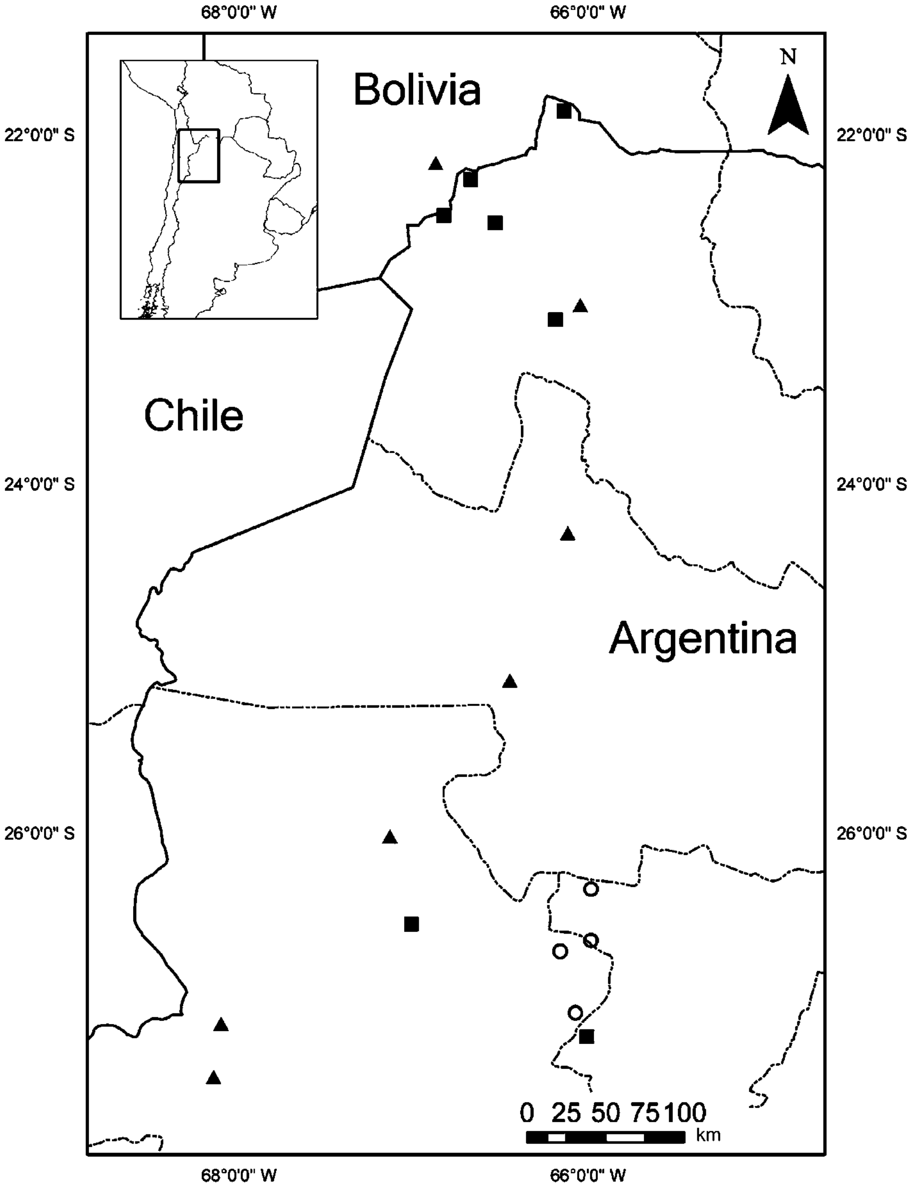

Figure 1 Map showing areas of the High Andes where field data collection on carnivore abundance was carried out during this study. ▲, areas where only sign counts were carried out. ○, areas where intensive sign counts were carried out and encounter rates were estimated. ■, areas where both intensive sign counts and camera trapping were carried out. Filled symbols indicate areas where faecal samples were identified through molecular genetic analysis. Solid lines show national borders, and broken lines the borders between national administrative regions.

Camera trapping

We incorporated the standardised use of camera traps in February 2004 and completed camera trapping surveys in seven survey areas (Figure 1). All camera traps (n=15) used passive infra-red detection systems that were programmed to operate continuously without a camera delay. Camera traps were set at a height of approximately 30 cm. The cameras were set to record the date and hour on each photograph. To maximise the chances of capturing a carnivore, traps were placed in close proximity to sites where carnivore signs were observed and a lure was placed on the ground in front of the trap. Stations were checked every three days, and lures were replaced.

The capture rate (i.e., the number of events during the survey/total number of days the camera trap was operational×100, to normalise) was calculated to account for variations in trapping effort and was used as an index of relative abundance (Carbone et al. 2001, Jackson et al. 2006, Cuéllar et al. 2006). To avoid pseudoreplication, when the same camera trap took more than one photograph of a species within a short period of time (<30 min), we counted these as one event. This index is simple, and may be more reliable for rare species and small sample sizes where capture/recapture methods have decreased power (Carbone et al. 2001, Wilson and Anderson 1985).

Results

We interviewed 51 adults belonging to different families from 34 settlements. Ten of the interviewees were considered unreliable and their data were excluded from the analysis. Culpeos and pumas were recorded for the great majority of the 27 sites (100% and 96.3%, respectively), whereas chillas were far more rare (33.3%) and were reported to occur in open flatlands. The presence of

L. colocolo was recorded in a marginally greater number of sites than *L. jacobita* (85.2% vs. 66.7%, respectively). The occurrence of Pampas cats, Andean cats and, more notably, chillas decreased with altitude (Figure 2). In 21.6% of the cases, reports of small cats were confirmed by recent skins shown by interviewees. Eight of these 11 skins (72.7%) belonged to *L. colocolo* and three (27.3%) to *L. jacobita*.

A total of 1560 signs of wild carnivores were recorded, 97.6% of which were characterised as secondary or indirect signs (faeces, tracks, dens containing faeces, scent marks), whereas 2.4% were direct signs of presence (sightings and skulls or skeletons). We were unable to unambiguously identify a total of 88 signs, which were thus discarded (Table 1). The percentage of the different types of sign (direct vs. indirect) varied between carnivores (χ^2=653.2, df=3, p=0.0001): 75.1% of all cat signs were from latrine sites, whereas this proportion was 31.8% for mustelids, 6.6% for foxes and 4.6% for pumas.

Small cat signs made up more than half of the indirect evidence recorded. Signs of foxes were found less frequently and those attributed to mustelids and pumas were much less common (Table 1). Fourteen (87.5%) of the 16 skulls/skeletons were identified as *L. culpaeus*, one was *L. colocolo* and one was *L. jacobita* (Table 1). We observed 11 culpeos, three chillas (all in open plains), two Andean cats and one Pampas cat (Table 1).

Intensive surveys recorded 1131 signs of wild carnivores during 2624.1 researcher hours (mean±SD, 437.3±153.2 researcher h/site, n=11 sites). The proportion of signs recorded for each carnivore was very similar

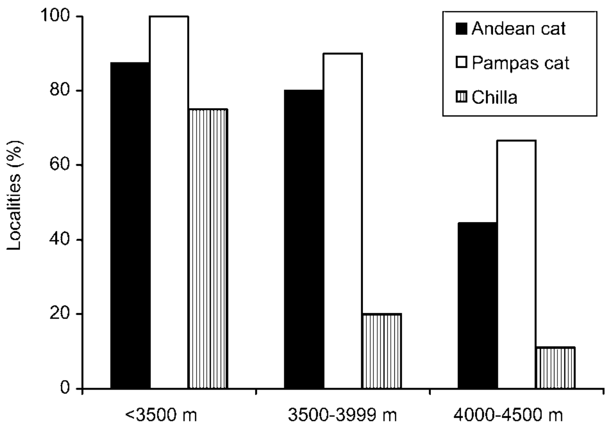

Figure 2 Reported occurrences for *Leopardus jacobita, Leopardus colocolo* and *Lycalopex griseus* in relation to altitude of the sites in north-western Argentina where local people were interviewed. Eight localities were sampled at <3500 m, nine at 3500–3999 m, and ten at >4000 m.

to the global sample results (Table 1). Pooling all carnivores, the overall encounter rate ranged from 0.276 to 0.769 signs/h (mean 0.459 signs/h, n=11 sites). Encounter rates appeared to vary between areas for all carnivores (Figure 3). Pumas were recorded in all but three areas surveyed, but their encounter rates were consistently low (0.028±0.027 signs/h). Small cat signs were found more frequently than those of foxes in 63.7% of the areas. In 26.3% of the surveys, the encounter rate for foxes tended to be higher (Figure 3). The average encounter rate varied between carnivores (ANOVA, $F_{3,10}$=16.51, p=0.0001) and was significantly greater (Tukey post hoc test) for small cats (0.223±0.098 signs/h) than for mustelids and pumas, but not for foxes (0.165±0.104 signs/h).

DNA genotyping was successful in 93.2% of the 294 samples analysed. Out of 246 small cat faecal samples, 95.1% were from *L. colocolo* and only 4.9% from *L. jacobita*. Whereas the presence of the Pampas cat was recorded in all areas, genotyping confirmed the presence of Andean cats in seven of the 14 localities where faecal samples were collected (Figure 1), and 70% of the areas where this cat occurrence was confirmed by at least one of our survey methods.

Camera traps were set at 101 different sites in seven areas (Figure 1), totalling 1385 trap days (mean trapping effort per area, 197.9±179.6 trap days). *L. culpaeus* was recorded in 85.7% of the areas, *L. colocolo* in 71.4%, *L. jacobita* in 42.9%, and *P. concolor* in only one area (14.3%). This method failed to detect the presence of culpeos in only one of the areas where we proved them to occur by faecal genotyping. The same was true for the Andean cat in three areas and the Pampas cat in two areas. Most (65.9%) carnivore photo-captures were of culpeos. The number of Pampas cat captures was twice that of Andean cats (Table 1). Although the mean capture rate for culpeos was more than twice that for Pampas cats and five-fold that for Andean cats, the capture rate did not vary significantly (ANOVA, $F_{2,6}$=3.29, p=0.07) and the only pair-wise difference detected by a post hoc Tukey test occurred between culpeos and Andean cats (Figure 4).

When the data for all direct signs of presence (i.e., skulls/skeletons, direct observations and camera trap photographs, n=74; Table 1) were pooled, foxes were the most abundant (74.3%, 5.3% corresponding to chillas), followed by Pampas cats (14.9%) and Andean cats (9.5%).

The combination of field surveys, genotyping of faecal samples and camera trapping confirmed the presence of the Andean cat in all the seven areas where these techniques were employed simultaneously.

Table 1 Number of carnivore signs recorded in the High Andes of Argentina (see Figure 1).

Type of evidence	Small cats	Puma	Foxes	Mustelids	Total
Total number of signs	728	87	562	88	1465
Number of signs in intensive surveys	534	81	437	79	1131
Number of skeletons/skulls	2	0	14	0	16
Number of sightings	3	0	14	0	17
Number of camera trap photos	13	0	27	1	41

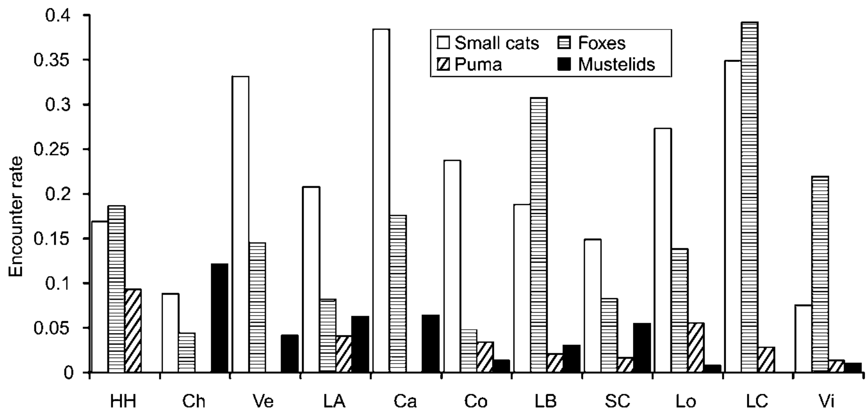

Figure 3 Encounter rates (number of signs counted per sampling effort) for High Andes carnivore signs in 11 areas of north-western Argentina where intensive carnivore sign counts were carried out.

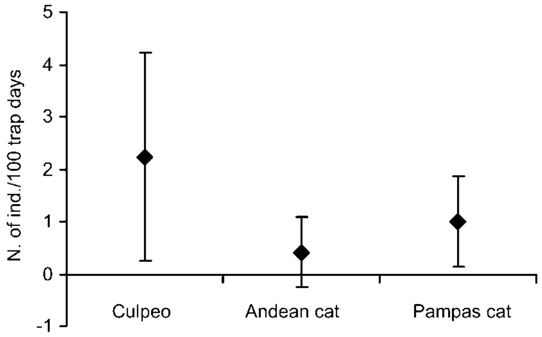

Figure 4 Mean (±SD) camera capture rates for High Andes carnivores in seven areas of north-western Argentina; n=12, 31, and 40 photos for *Leopardus jacobita*, *Leopardus colocolo* and *Lycalopex culpaeus*, respectively.

Discussion

Interviews with local people suggest that *P. concolor* and *L. culpaeus* are the most homogeneously distributed carnivores of the High Andes of north-western Argentina, and Andean cats are less common than Pampas cats. This is also supported by the smaller number of Andean cat skins shown by informants. Nevertheless, according to this method, populations of *L. jacobita* and *L. colocolo* occurring in this region are relatively widespread, and the lack of Andean cat records in some of the areas surveyed may be a result of insufficient sampling effort, since we were successful in recording the presence of this felid in all the areas where we used all surveying methodologies simultaneously.

The proportion of faecal samples genetically identified as belonging to *L. jacobita* was much lower than that for *L. colocolo*. This suggests that the Andean cat is much rarer. Another possible explanation is that the Andean cat has a defecating behaviour that differs from that of the Pampas cat, i.e., it does not usually defecate at large latrine sites. This is supported by a recent study carried out at Surire Natural Monument and Las Vicuñas National Reserve, northern Chile. In this area, Andean cat faeces were found in none of the five latrines from which several samples were genotyped (Napolitano et al. 2008). Napolitano et al. (2008) also reported that the proportion of Andean cat samples of the total of small cat faeces successfully identified was 30.6%. If sampling procedures were consistent in the two studies, this difference could be related to changes in the relative abundance of the two species. Unfortunately, Napolitano et al. (2008) did not explain their procedures for scat collection.

On the other hand, the difference in relative abundance between *L. jacobita* and *L. colocolo* as suggested by genotyped faeces in our study seems far greater than what would be expected on the basis of the proportion of direct signs, which is undoubtedly the most reliable type of evidence. The relative frequency of direct signs strongly indicates that culpeos are the most common carnivores of the High Andes of Argentina, with *L. jacobita* and *L. colocolo* being rare. They also suggest that *L. jacobita* is only slightly less common than *L. colocolo*, although the small sample size prevents us from drawing definitive conclusions on the differences in population abundance between these two species.

Our results also support the hypothesis that the range overlap between chillas and Andean cats is small in the High Andes, since its distribution is limited to large open areas surrounding the salt flats, or *salares*, located at comparatively lower altitude.

The results for pumas show an apparent contradiction between interviews, which indicated that they are widely distributed, and the paucity of signs we collected. We suspect that this is related to a high awareness of local people to its presence because of conflicts with their ranching activities (Lucherini and Merino 2008) and to a very low population density of this top carnivore.

The conservation status of the Andean cat (Nowell and Jackson 1996, Nowell 2002b) and the species-specific conservation actions that it prompted (Villalba et al. 2004) are based on the assumption that *L. jacobita* is rare throughout its range. We conclude that our first hypothesis is supported by the results: in accordance with its comparatively greater adaptability (Jiménez and Novaro 2004), it is probable that *L. culpaeus* is the most widespread and abundant carnivore of the High Andes of Argentina, small cats have a more restricted distribution than culpeos, and Andean cats are less homogeneously distributed compared to Pampas cats. On the other hand, our second hypothesis is only partially supported by the data. Whereas *L. jacobita* and *L. colocolo* are likely less abundant than culpeos, we cannot conclude that *L. jacobita* populations are less abundant than those of *L. colocolo* in the areas where the two felids occur sympatrically.

To summarise, although more data are needed, by combining the two components of population rareness we tested, the Andean cat can probably be regarded as the rarest medium-sized carnivore of the High Andes of Argentina.

Based on a study of food niche overlap, Walker et al. (2007) examined the issue of potential competition between these two felids in the High Andes and concluded that the major prey species of the two cats have a patchy distribution and very large areas may be required to support individual cats and populations. Our results support this expectation, as well as the need for conservation measures, especially for the Andean cat, which, unlike its potential competitors, is exclusively distributed in the High Andes ecoregion. Furthermore, this conclusion is in agreement with those obtained by a survey of local people's perceptions and attitudes (Lucherini et al. 2004b, Lucherini and Merino 2008).

It is notoriously difficult to assess the abundance of solitary and secretive felids (Sunquist and Sunquist 2002, Jackson et al. 2006). In the case of the Andean cat, Perovic et al. (2003) recommended the combined use of interviews, short field surveys and genetic analysis of faeces to determine its status over large geographical areas. Based on our data, the use of this procedure is successful in detecting the presence of the Andean cat, but only if the amount of samples obtained and analysed is sufficiently large to account for rareness and low encounter rates. We suggest incorporation of camera trapping into the survey methodology to increase the efficiency and reliability of detecting the Andean cat.

According to Gese (2001), standardised sign surveys can provide repeatable, efficient, and reasonably accurate indices of carnivore abundance. The use of encounter rates as abundance indices is based on the assumption that the detection probability of signs of different species and in different areas is comparable (Conn et al. 2004). In the open, vegetation-poor, relatively homogeneous environment of the High Andes, this assumption might be acceptable, but it is clear that further studies are necessary to calibrate sign densities with known population densities. This is also necessary before we can determine whether variations in sign encounter rates or photographic capture rates reflect true variations in population numbers. Furthermore, the differences in results between indirect signs of presence and direct methods suggest that the defecating/marking behaviour of the Andean cat may complicate estimations of its abundance using sign counts and DNA genotyping of faeces.

Camera trapping is a non-intrusive method that has been successfully used for studying the presence and estimating population numbers of elusive animals, particularly carnivores (e.g., Kucera and Barrett 1993, Karanth et al. 2004), and was used to estimate densities of rare cat populations in remote mountain regions (Jackson et al. 2006). The photographs obtained from camera trapping indicate that it is probably possible to individually identify Andean and Pampas cats by their unique spot patterns, similar to recent accomplishments for other small cat species (Heilbrun et al. 2003, Trolle and Kéry 2003, Cuéllar et al. 2006). The use of capture-recapture analysis may also be a promising technique for the estimation of Andean cat population densities. However, the sampling effort must be sufficient to obtain an adequate number of pictures of both flanks of the animals during a period of time short enough not to violate the closed-population assumption underlying capture-mark-recapture methodology.

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