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The Yungas Biosphere Reserve of Argentina: a hot spot of South American wild cats

We conducted three camera-trap surveys in a productive conservation landscape within the Yungas Biosphere Reserve of NW Argentina. The surveyed area contains portions of Premontane Forest and sugar cane and citrus plantations and is intersected by riparian forest corridors. We recorded six of the seven wild cat species present in the area. These species make different use of the different environments present in the landscape: Geoffroy's cat *Oncifelis geoffroyi* was the only species recorded in the plantations, pumas *Puma concolor* and margays *Leopardus wiedi* were restricted to the forests, jaguarundis *Herpailurus yaguarondi* were only recorded in the corridors, while ocelots *Leopardus pardalis* and oncillas *Leopardus tigrinus* were recorded in both corridors and forests. Jaguars *Panthera onca* were not photographed during the surveys but are present in the study site. The Yungas Biosphere Reserve contains not only these seven species, but two other felids that inhabit the highlands of the reserve: the Pampas cat *Oncifelis colocolo* and the Andean cat *Oreailurus jacobitus*. We draw the attention to the Yungas, a small region of the Planet, shared by Argentina and Bolivia, which harbors ¼ of the World's cat species.

Wild felids occupy most of the terrestrial ecosystems of the world with the exception of Australasia and Antarctica (Sunquist & Sunquist 2002). There are important differences among regions of the World in terms of species richness. In the lower end of the spectrum, the entire European continent is currently home to only three wild-cat species (the Eurasian lynx *Lynx lynx*, the Iberian lynx *Lynx pardinus*, and the European wild cat *Felis silvestris*). At the higher end of the spectrum, single Asian countries can more than triple those numbers (Macdonald et al. 2010). However, even within tropical forest sites there seem to be a limit to the number of felid species found together at a single location (the alpha diversity of a felid assemblage), which rarely exceeds six species. This limitation probably arises from the strong competitive interactions exerted among carnivore species (Donadio & Buskirk 2006, Davies et al. 2007). Argentina harbors 10 species of felids and is one of the countries with the highest species richness in the world. This is partially the result of its long latitudinal extension and extreme altitudinal gradient, which produce a wide variety of climates and biomes, including subtropical rainforests, dry forests, temperate forests, subtropical savannas, grasslands, and deserts. All the South American cats are present in Argentina, with species that usually inhabit tropical rain forests (the ocelot, the margay, the oncilla, and the jaguarundi, with the latter also using other drier and more open habitats), temperate forests (the guiña *Oncifelis guigna*), grasslands, savannas and dry forests (Geoffroy's cat), grasslands (the Pampas cat), and high altitude deserts (the Andean cat) plus the two larger and more generalists species: the jaguar and the puma.

A hot spot usually refers to a rather small area of the world that contains relatively high species richness. This concept was popularized by Conservation International, which delimited small areas of the world that contain a high proportion of the global biodiversity (Myers et al. 2000). Although Argentina is highly diverse in terms of cat species, this does not necessarily imply that in any particular area of this country many cat species can be found together (i.e., syntopically). Thus, the diversity of habitats results in a high total richness of cat species across Argentina, but how many of these species can be found together in a small region?

In this article we present the results of camera-trap surveys conducted in a relatively small portion of the Yungas ecoregion, the subtropical montane forests of southern Bolivia and north-western (NW) Argentina. During these surveys, we recorded six of the seven cat species present in the area. The study site is located within the Yungas Biosphere Reserve in NW Argentina (Brown et al. 2007, Fig. 1). We draw attention to and discuss the importance of this area as a felid hot spot. We also introduce the concept of Protected Productive Landscapes, a conservation scheme that may aid in wild cat conservation.

Table 1. Number of stations in each treatment during the three camera-trap surveys conducted at Ledesma S.A., Jujuy, Argentina.

Survey	Forest	Plantations	Riparian forest corridors	Total
First	30	16	0	46
Second	42	0	0	42
Third	6	12	20	38
Total	78	28	20	126

Study area

The study area is located within the Yungas ecoregion of southern Bolivia and NW Argentina (Grau & Brown 2000). This ecoregion is characterized by subtropical montane forests that expand north to south and in an altitudinal gradient, along the eastern slopes of the Andes. Four types of forests can be differentiated along the altitudinal gradient according to the vegetation physiognomy and species composition (Brown et al. 2001, Fig. 1). The Premontane Forest (Selva Pedemontana), with high diversity of tree species, characterizes the lowest altitudinal level (between 400 and 700 m) of the Yungas. On the east side of this formation transitional forests are in contact with and give way to another ecoregion, the dry Chaco. To the west and up the mountains, the Premontane Forest gives rise to the Montane Humid Forest (Selva Montana), rich in tree species, which expands between 700 and 1500 m a.s.l. Above the Montane Humid Forest start the Upper Montane Forests and Open Woodlands (Bosque Montano), which expand up to 2500-3000 m. Above this altitude the high altitude Foggy Montane Grasslands (Pastizales de Neblina) arise. To the west of the Yungas, the high Andes are characterized by arid mountain tops and plateaus with bare ground and scarce vegetation (the High Andean Grasslands and rocky outcrops).

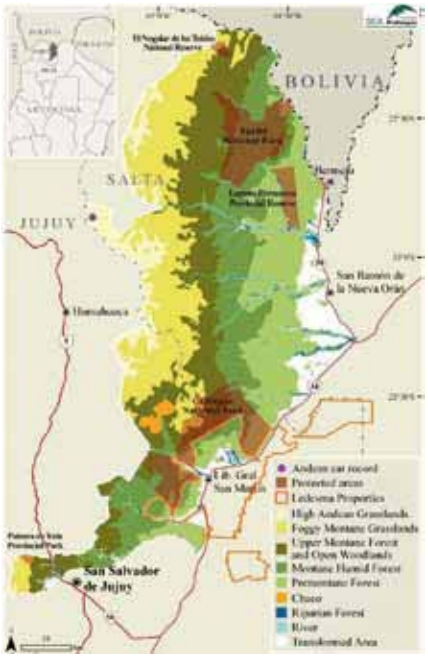

Fig. 1. Location of the Yungas Biosphere Reserve (YBR), in Northwestern Argentina. With different colors are depicted the different ecological formations and the main strictly protected areas within the YBR. The blue dot depicts the location of the only known record of the elusive Andean cat within the YBR.

We conducted this study in a large property (1,500 km^2) that belongs to Ledesma S.A., a company dedicated to sugar cane and citrus production. The study area is located within or next to the Yungas Biosphere Reserve (13,000 km^2), in the department of Ledesma, Jujuy province, Argentina (Fig. 1). The area contains extensive portions (approximately 1000 km^2) of Premontane Forest surrounding and intersecting mostly sugar cane plantations but also citrus plantations (totalizing approximately 500 km^2 of plantations). The area is intersected by rivers with riparian forest on both margins that constitute natural corridors (Fig. 2). The study area limits to the west with Calilegua National Park (763 km^2, Fig. 1, 3). Most of the native forests that were surveyed are primary forests subjected to different levels of extractive activities (hunting and firewood extraction). Hunting pressure in these forests range from very low to moderately high, but tapirs, indicator species of healthy ecosystems, are present in most forest areas.

Fig. 2. Small rivers provide water for irrigation of sugar cane plantations in the study area. Vegetation along these rivers may serve as biological corridors for forest dependent species to move between forested areas (Photo M. Di Bitetti).

Methods

The camera-trap surveys were designed to survey the medium-large size mammal assemblages in three different habitats: 1) continuous forest, 2) sugar cane and citrus plantations and 3) riparian forest corridors. We used a set of 43 digital camera-traps (Moultrie M-40). Camera-trap stations were not located along trails, roads or river banks but in the forest interior and within the sugar cane and citrus plantations. Thus, our surveys were not optimized to obtain records of the larger felids (jaguars, pumas and ocelots), which prefer to walk along roads (Harmsen et al. 2010). A station consisted of a camera-trap baited with a perforated tuna fish can, which was located 2-3 m in front of the camera. With few exceptions, the distance between stations under the same treatment (i.e., forest, plantation, corridor) was greater than 1.5 km (usually, 2-3 km). Camera-traps were programmed to obtain pictures on a 24 h basis with a 5 min delay between successive photos.

We conducted three surveys. The first was performed between March 16 and May 14 2009, the second between November 15 and December 21 2009 and the third between June 10 and July 26 2010. Due to the paucity of camera-traps, the first survey was split into two halves, and each station was active for about one month. During the second and third surveys, stations were active for periods of 30-45 days each. Due to camera failure (e.g., unsynchronized flash) not all camera-traps attained the best performance and some days were lost in several stations but without showing any clear bias in terms of species or habitat that could affect the main results reported here. During the first survey 30 stations were located in the forest, 12 stations were located in sugar cane plantations and four stations in citrus plantations. During the second survey we used the same 30 forest stations of the first survey (all located near the edge of a road or plantation) plus 12 new forest stations located at distances of > 500 m from the edge of plantations or roads. During the third survey we investigated the sugar cane plantations (N=12 stations), the forest (N=6) and the riparian forest corridors (N=20, four stations were separated < 500 m from each other). Some of the forest and sugar cane plantation stations were at the same location during the first and second surveys and during the first and third surveys, respectively. However, for the purposes of this contribution the same station that was active during two different surveys was considered as two different stations (Table 1) since we did not find evidence that stations where a species was recorded during one survey had a higher probability of recording that same species during the subsequent survey.

To assess whether there are differences among species in their associations with different habitats we used program EcoSim (Gotelli & Entsminger 2001). For this analysis we tabulated the frequency of stations in each of the three habitat types where we photographed the three species that were recorded in ≥ 10 stations (i.e., margay, ocelot,

and Geoffroy's cat). A χ^2 value is estimated from the observed frequencies and those expected under the null hypothesis of no association between species and habitats. With this 3 x 3 contingency table EcoSim iterates 10.000 simulations by randomizing the matrix and estimates a χ^2 value for each simulated matrix. The observed χ^2 value is compared to the χ^2 values obtained from these simulations to estimate a probability (P) value of getting the former by chance alone.

Fig. 3. The study site contains large areas of sugar cane plantations (front) and large tracks of native forests (middle) that serve as buffer zones to Calilegua National Park (back; Photo M. Di Bitetti).

Results

During the surveys we recorded six of the seven cat species present in the area (see below); i.e., puma, ocelot, jaguarundi, margay, oncilla, and Geoffroy's cat (Fig. 4). We did not obtain many records for most of the species, probably as a result of our surveys not being aimed at increasing the photographic rates of cats (e.g., by placing stations along trails or roads). The most frequently recorded cat was the ocelot, with 24 photographic records at 17 stations. The least recorded one was the jaguarundi, with only two records at two stations (Table 2). Four bad quality photographs of small spotted cats (probably of ocelots or oncillas) could not be assigned with confidence to a species and were left out of the analysis.

The three species recorded in ≥ 10 stations (margay, ocelot and Geoffroy's cat) showed different associations with habitat types (P = 0.001). Geoffroy's cat was the only cat species recorded in plantations, with a positive association with this habitat. The puma and the margay were restricted to the forest, with no records in the riparian forest corridors. Ocelots and oncillas were recorded in stations located in forests and corridors, making ample use of the latter habitat. The jaguarundi was only recorded in the riparian forest corridors (Table 2, Fig. 5).

No station recorded more than two cat species, probably as a result of the low frequency of records for most species, precluding any analysis of species co-occurrences. Pairs of species recorded together were ocelot-Geoffroy's cat, ocelot-margay, margay-oncilla and puma-margay.

Discussion

We recorded six species of wild cats during the camera trap surveys. There is at least another species, the jaguar, present in the study site, which even though rare and has not been recorded in our surveys, has been previously reported in the area (Grilli 2005). Furthermore, jaguars have been also reported in nearby Calilegua National Park, which has ample continuity with our study area (Perovic & Herrán 1998). The possibility of recording seven cat species living syntopically in a relatively small area is an infrequent situation that has been previously reported only once, in northeastern India (J. Hance 2010; http://news.mongabay.com). We recorded the whole assemblage of Neotropical rainforest cats and a species typical of the dry forests, savannas and grasslands of South America; i.e., Geoffroy's cat. The high species richness found in the area could be due to the relatively good conditions of the native forests and its continuity with large expanses of forest through Calilegua National Park. The relatively high frequency of records of Geoffroy's cat is probably the result of the transformation of some areas of the study site into plantations.

Ledesma S.A. private property where we conducted the surveys is considered a Protected Productive Landscape (PPL), a large terrain with areas dedicated to intensive agriculture but still containing large tracts of well protected and connected natural habitat. PPLs are being promoted as a conservation tool by Fundación ProYungas (http://www.

Table 2. Frequency of photographic records (Freq.) and number of stations where they were recorded (# stations) in relation to the different environments for the six cat species detected in the camera-trap surveys.

Species	Continuous forest (N=78 stations)		Riparian Corridors (N=20 stations)		Sugar cane and citrus plantations (N=28 stations)		Total (N=126 stations)	
	Freq.	# stat.	Freq.	# stat.	Freq.	# stat.	Freq.	# stat.
Puma	6	6	0	0	0	0	6	6
Margay	11	10	0	0	0	0	11	10
Oncilla	1	1	2	2	0	0	3	3
Ocelot	10	9	14	8	0	0	24	17
Jaguarundi	0	0	2	2	0	0	2	2
Geoffroy's cat	5	2	1	1	12	7	18	10

Fig. 4. Photographs of the six species of felids recorded at Ledesma, province of Jujuy, Argentina: a) puma, b) ocelot, c) jaguarundi, d) margay, e) oncilla, and f) Geoffroy's cat.

proyungas.org.ar/genesis.html), a NGO involved in the development of land use planning schemes for this property and for the provinces of Jujuy and Salta, where the Yungas Biosphere Reserve is located.

The aim of this study was to assess the conservation value of Ledesma PPL for the terrestrial mammals by evaluating their presence in natural and anthropogenic ecosystems found within this property and tp assess the connectivity of the landscape for these species. Our results suggest that sugar cane plantations are of low permeability for forest wild cats; i.e., a barrier. At the same time, plantations increase the presence of Geoffroy's cat, which was probably rare at our study site before the conversion of forests into plantations. Riparian forests that transverse the plantations constitute corridors that facilitate the movement of at least three wild cat species (the ocelot, the oncilla, and the jaguarundi) between large forest tracks. We do not have evidence of the use of these corridors by margays and pumas; these species may require wider and protected corridors with low anthropogenic impacts. Productive systems like Ledesma PPL, that assure the conservation of large forest areas in good condition and their connectivity through corridors, constitute a complement to strictly protected

areas and contribute to cat and biodiversity conservation.

The Foggy Montane Grasslands in the Yungas Biosphere Reserve (just 30-50 km W of our study site) constitute the natural habitat of another wild cat, the Pampas cat. This species has been reported at different locations in the Yungas Biosphere Reserve within the province of Jujuy (e.g., Alto Calilegua, Valle Morado; Olrog 1979, Heinonen & Bosso 1994). There is also a record of the elusive Andean cat within the Yungas Biosphere Reserve, near the locality of Iruya (Perovic et al. 2003) where the typical habitat (above 3500 m a.s.l.) of this species is found (Marino et al. 2010, Fig. 1). Most records of Andean cats in Argentina are located in the province of Jujuy (Perovic et al. 2003, Marino et al. 2010). We do not know if the Yungas Biosphere Reserve contains a large population of this rare and endangered species, but if well managed, it might contribute to Andean cat conservation.

The Yungas Biosphere Reserve harbors populations of nine wild cat species (i.e., ¼ of the world cats), the highest diversity of cats reported for any single conservation unit in the world. The Yungas Biosphere Reserve contains large areas of natural habitats. If productive areas within this reserve are well managed they can provide the conditions necessary for the survival of the area-demanding wild felids (see Woodroffe & Ginsberg 1998).

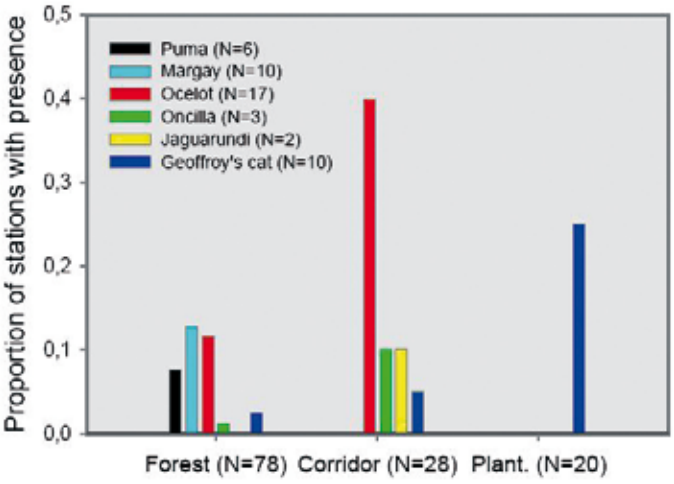

Fig. 5. Proportion of camera-trap stations with records of the six cat species in the Premontane Forest of Yungas in the province of Jujuy, Argentina.

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