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RESEARCH ARTICLE

Mammals of Paso Centurión, an area with relicts of Atlantic Forest in Uruguay

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Abstract

Paso Centurión is one of the most diverse areas of Uruguay. It is legally protected at local and national level, however, there are different interests competing for its land use and management. With the aim to document the biodiversity of the area together with the local people, the NGO JULANA has been conducting a participatory monitoring process with camera traps since 2013. Here, we present a list of 23 medium and large-size mammal species documented in the area and a standardised dataset of occurrence records. Top observations include the last *Chrysocyon brachyurus* seen in Uruguay, the first record of *Herpailurus yagouaroundi* in the country and the second report of *Leopardus munoai* in the area. We also highlight the frequent observation of numerous rare species such as *Tamandua tetradactyla*, *Leopardus wiedii*, *Cabassous tatouay*, *Coendou spinosus* and *Cuniculus paca*. Although the cameras were located within only a few metres of the houses of the local people, some of the rarest and most elusive species in the country were reported. This suggests a possible coexistence between people – their socio-economic practices – and nature in the area. Our work underlines the importance of the recent inclusion of Paso Centurión and Sierra de Ríos to the National System of Protected Areas under the proposed category of 'Protected Landscape'. Collectively, in a context of global change and lack of biodiversity data on species distribution, we emphasise the value of these records for the knowledge of mammals in Uruguay and the need to extend and continue monitoring this area.

Keywords

biodiversity conservation, participatory monitoring, species occurrence records

Introduction

Paso Centurión, located in the department of Cerro Largo by the Yaguarón River (Fig. 1), is one of the richest areas of biodiversity in Uruguay (Soutullo et al. 2013, Brazeiro 2015). The region is characterised by an undulating topography with different types of native forest (Grela and Brussa 2003) and exotic plantations of eucalyptus (*Eucalyptus grandis* W.Hill ex Maiden) (Achkar et al. 2010). Placed in the border with Brazil, its territory is marked by the presence of species from the Atlantic Forest, birds such as *Cyanocorax caeruleus* (Vieillot, 1818), *Lepidocolaptes falcinellus* (Cabanis & Heine, 1859), *Phacellodomus ferrugineigula* (Pelzeln, 1858) (Azpiroz et al. 2012; Vale et al. 2018), and plants such as *Acianthera hygrophila* (Barb.Rodr.) Pridgeon & M.W.Chase, *Acianthera sonderiana* (Rchb.f.) Pridgeon & M.W.Chase and *Lepismium cruciforme* (Vell.) Miq. (Rossado et al. 2014; Mai et al. 2019; Flora do Brazil 2020). Numerous of the rarest species of plants, vertebrates and invertebrates of the country are recorded in this area (Faccio and Achkar 2008) and present the southernmost limit of their natural distribution here. A total of 51 species of mammals have been recorded in Paso Centurión, representing 43.5% of the total diversity of the group occurring in the country and 60% excluding marine species (González et al. 2013; Grattarola et al. 2019).

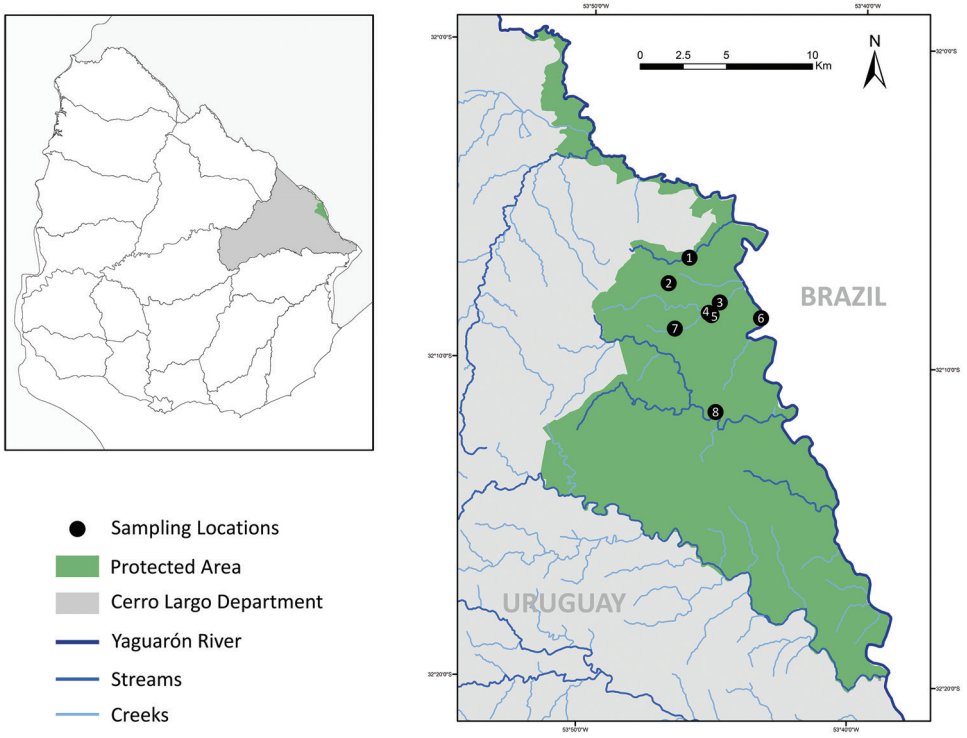

Figure 1. Sampling locations (1–8) in Paso Centurión, Uruguay. Elaborated with ArcGis 10.5 Projection WGS1984.

Given the peculiar biological characteristics of this area, it has been legally protected since 2007 as a Departmental Reserve (Junta Departamental de Cerro Largo 2007) and categorised as 'Rural Natural Protected Soil' since 2016 (Junta Departamental de Cerro Largo 2016). Additionally, the area of Paso Centurión and Sierra de Ríos has recently been declared 'Protected Landscape' by the National System of Protected Areas (SNAP) (Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente 2019), and it is now – for the first time – undergoing the phase of Management Plan definition. The primary objective of the proposed conservation category is "To protect and sustain important landscapes/seascapes and the associated nature conservation and other values created by interactions with humans through traditional management practices" (IUCN 2020a). In this regard, the locality is populated by nearly 129 families, spread over an area of 630 km^2 (Dirección General de Desarrollo Rural 2018). The main socio-economic activity in the area is small-scale livestock production and subsistence farming (Papadópulos et al. 2008). Yet, in the last decades, the population has gradually decreased and aged given, amongst other causes, the emigration of families as a result of changes in land use from traditional agriculture to forestry (Chouhy et al. 2019). Despite the competing interests over the use and management of the territory in Paso Centurión (i.e. conservation of biodiversity and local culture versus large private production), the condition of geographic isolation of the locality, together with the low-impact production practices implemented by the local people, have resulted in a highly conserved biodiversity hotspot (Chouhy et al. 2019; Grattarola et al. 2016).

Since 2012, a participatory monitoring process has been established in this locality by the non-governmental organization (NGO) JULANA (Bergós et al. 2018). This is an association of early career researchers and professionals with diverse profiles (e.g.: environmental education, genetics, zoology, conservation, ecology, bioengineering and psychology) that seeks to approach the territory through a critical environmental education framework (Sauvé 2005). During the past 8 years the organisation's work has involved addressing different socio-ecological aspects of the tension between conservation and production in the rural area of Paso Centurión. Activities have focused on aspects of human-wildlife relationships, valuation of local knowledge, livestock production with Holistic Management, and ecotourism initiatives, amongst others. The use of camera traps in the area was introduced in the project 'Fogones de Fauna' (Bergós et al. 2018). The emphasis of the activities in this project has been on documenting the biodiversity knowledge of Paso Centurión, along with the relationships of the local community with nature, using camera traps as recording methods and the local mammal fauna as the focal point of the dialogue.

Despite the importance of the area for the conservation of mammals in Uruguay, the group has been poorly studied here. Therefore, this work aims to report the mammal species recorded in Paso Centurión by JULANA's monitoring activities between 2013 and 2017, including, amongst other relevant records, a new species cited for Uruguay (Grattarola et al. 2016). Also, we present notes on a series of observed behaviours, relevant for the conservation of the species and ecosystems associated to the area. Finally, a standardised and open access dataset of the occurrence records collated is provided

(Grattarola et al. 2020), a resource which can be used by the scientific, governmental, and environmental bodies for research, conservation planning and future decision making.

Methods

In 2013, eight trap cameras (Bushnell Trophy Trail Camera and NatureView Cam HD) were set, covering an area of 25 km^2 within the surroundings of Paso Centurión (Fig. 1; Table 1). All cameras were adapted with an external re-chargeable 6V battery for power supply. The management of the cameras and records was carried out by JULANA members, the landowners where the cameras were set, and other people from the local community involved in the monitoring process. It included the decision-making about the location of the cameras, the maintenance of the equipment, as well as the identification of the species recorded and the analysis of behavioural features. Cameras were placed on native forest patches associated with freshwater streams, no farther than 2000 metres from the houses of the landowners so that they could be easily monitored. Parameters were allowed to vary greatly because the main aim was placed in exploring the tool. Some were set to take photos, others to record 10-seconds videos and, in other cases, 3 photos were obtained together with a 10-seconds video after a 5-seconds interval. After exploring varying parameters, a procedure was established for the installation of cameras traps in new places. The camera was first set to take photos. After a period of time active, the data were collated and by exploring the records the place was assessed in terms of the behaviour of animals passing by and the livestock load (cattle, horse, sheep and pig). If the last was too high (i.e.: more than half of the total records), the camera was moved to a new location or pointed at a different direction. If the camera was generally clear of livestock records and the spot was detected as a place of animal crossing, then the camera was kept in the photo mode. However, in places where animals lingered in front of the camera, stopped to drink water or to eat, the camera was set to video mode or, if the model enabled it, a combination of three photos and a short video. In this way, the battery and card memory were optimised while the

Table 1. Locations of the sampling sites (1–8) in Paso Centurión (Uruguay), showing the camera sampling effort in days and the distance between the camera's position to human settlements in metres. Sites 4, 5, 6 and 7 belong to singular event records of species in the area for which camera effort was not assessed.

Site	Latitude / Longitude	Camera Effort (days)	Distance to Human Settlements (m)
1	-32.1119, -53.771529	700	401
2	-32.1255, -53.783936	756	269
3	-32.1349, -53.752056	688	587
4	-32.1406, -53.758523	NA	105
5	-32.1416, -53.757030	NA	100
6	-32.1424, -53.726487	NA	497
7	-32.1492, 53.779228	NA	355
8	-32.1923, -53.752719	489	2285

detection of non-domestic species and interesting behaviours were improved. Data were downloaded with a periodicity of every one to four months.

A list of mammals was assembled combining all the species recorded during the period of 2013 to 2017. The records from 2014 to 2016 of four sites (Fig. 1, sampling locations 1, 2, 3 and 8) were systematised and used by students for their undergraduate thesis projects (Cavalli 2019; Rondoni 2019). These records were standardised and enriched following FAIR (Findability, Accessibility, Interoperability, Reusability) Principles (Wilkinson et al. 2016) to enable the maximum re-use of the data. The dataset with the primary biodiversity data including 1,690 records is available at the GBIF (Global Biodiversity Information Facility) portal (Grattarola et al. 2020). Scientific names, scientific names' authorities and vernacular names were retrieved using the package 'taxize' (Chamberlain et al. 2020) and the American Society of Mammalogists Mammal Diversity Database as backbone taxonomy (ASM, 2020). To estimate the expected species richness, rarefaction and extrapolation of Hill numbers were performed using the R package iNEXT (Chao et al. 2014; Hsieh et al. 2016). A threshold of one hour was used to define independent detection events (Burton et al. 2015) and days were defined as sampling units. A sample-size-based sampling curve with 95% confidence interval computed by 1000 bootstrap replicates was generated considering all species.

Results

A total of 23 medium and large-size mammal species were recorded, distributed in 7 orders and 13 families (Table 2; see photographic album at JULANA 2017). The most represented order was Carnivora (47.8% of the total number of species), followed by Artiodactyla, Cingulata and Rodentia (13% of the total species number each; Table 2). Pooled data from 8 survey sites summed a total sampling effort of 2,634 trap-days (Table 1), from which, in 604 days when at least one incidence was found, 1,041 independent photographs/videos were obtained. A sampling coverage of 99.6% (±0.3%) was reached. The estimated richness based on the sample-size was 26 (±3). Additional sampling up to double the sample size is likely to yield 2 new species detections (Fig. 2).

Three particular records resulted in the most relevant species observations: the first record of a *Herpailurus yagouaroundi* (É.Geoffroy Saint-Hilaire, 1803) reported in Uruguay (Grattarola et al. 2016), the last observation of a *Chrysocyon brachyurus* Illiger, 1815 in the country, and the second record of *Leopardus munoai* (Ximénez, 1961) in the area of Paso Centurión. The other native species were seen in more than one site, even the rarest and most range restricted such as *Tamandua tetradactyla* Linnaeus, 1758, *Leopardus wiedii* Schinz, 1821, *Cabassous tatouay* Desmarest, 1804, *Coendou spinosus* F.Cuvier, 1823 and *Cuniculus paca* Linnaeus, 1766. 40% of the observed species are considered threatened at the national level (González et al. 2013; Table 2). In addition, three exotic species were recorded, *Sus scrofa* Linnaeus, 1758, *Lepus europaeus* Pallas, 1778 and *Axis axis* Erxleben, 1777.

Numerous behavioural features were observed. Individuals of *T. tetradactyla* were seen carrying offspring several times. In one case, an individual almost the

Table 2. List of mammal species recorded with camera traps in Paso Centurión (Uruguay) between 2013–2017. Priority for conservation at national level (González et al. 2013) and global conservation status are included (IUCN 2020b), LC: least concern, NT: near threatened, NA: not assessed. Exotic species are indicated with a star (*).

Taxon	Vernacular name (English | Spanish)	National Conservation Status	IUCN Conservation Status
Artiodactyla			
Cervidae			
*Axis axis**	Axis Deer | Ciervo Axis	–	LC
Mazama gouazoubira	South American Brown Brocket | Guazubirá	–	LC
Suidae			
*Sus scrofa**	Wild Boar | Jabalí	–	LC
Carnivora			
Canidae			
Cerdocyon thous	Crab-eating Fox | Zorro de Monte	Priority	LC
Chrysocyon brachyurus	Maned Wolf | Aguará Guazú	Priority, Threatened	NT
Lycalopex gymnocercus	Pampas Fox | Zorro Gris	Priority	LC
Felidae			
Leopardus munoai	Uruguayan Pampas Cat | Gato de Pajonal	Priority, Threatened	NE
Leopardus geoffroyi	Geoffroy's Cat | Gato Montés	Priority	LC
Leopardus wiedii	Margay | Margay	Priority, Threatened	NT
Herpailurus yagouaroundi	Jaguarundi | Yaguraundí	NA	LC
Mephitidae			
Conepatus chinga	Molina's Hog-nosed Skunk | Zorrillo	–	LC
Mustelidae			
Galictis cuja	Lesser Grison | Hurón	–	LC
Lontra longicaudis		Priority	NT
Procyonidae			
Procyon cancrivorus	Crab-eating Raccoon | Mano Pelada	–	LC
Cingulata			
Dasypodidae			
Cabassous tatouay	Greater Naked-tailed Armadillo | Tatú Rabo Molle	Priority, Threatened	LC
Dasypus novemcinctus	Nine-banded Armadillo | Tatú	Priority, Threatened	LC
Euphractus sexcinctus	Six-banded Armadillo | Peludo	–	LC
Didelphimorphia			
Didelphidae			
Didelphis albiventris	White-eared Opossum | Comadreja Overa	–	LC
Lagomorpha			
Leporidae			
*Lepus europaeus**	Brown Hare | Liebre	–	LC
Pilosa			
Myrmecophagidae			
Tamandua tetradactyla	Lesser Anteater | Tamanduá	Priority, Threatened	LC
Rodentia			
Caviidae			
Hydrochoerus hydrochaeris	Capybara | Carpincho	Priority	LC
Cuniculidae			
Cuniculus paca	Lowland Paca | Paca	Priority, Threatened	LC
Erethizontidae			
Coendou spinosus	Paraguaian Hairy Dwarf Porcupine | Coendú	Priority, Threatened	LC

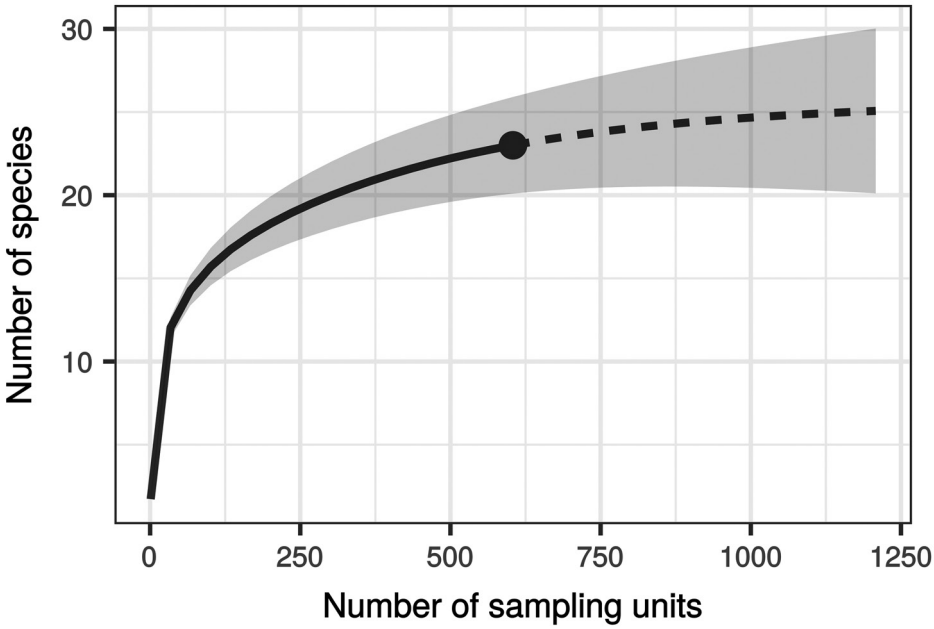

Figure 2. Sample-size-based rarefaction (solid line) and extrapolation (dashed line) for the species sampling curve up to double the reference sample size, for mammals at Paso Centurión, Uruguay. The 95% confidence intervals (grey-shaded area) was obtained by a bootstrap method based on 1000 replications.

same size as the adult was observed. Likewise, *Procyon cancrivorus* G. Cuvier, 1798 and *Hydrochoerus hydrochaeris* Linnaeus, 1766 were similarly recorded in video format moving around with offspring and in family groups. *P. cancrivorus* was also reported displaying a "food-washing" behaviour, a pattern considered to be related to searching for aquatic prey (Zeveloff 2002). A *P. cancrivorus* specimen, together with *Conepatus chinga* Molina, 1782 and *Mazama gouazoubira* Fischer, 1814, were also registered feeding on fruits of pindó palm *Syagrus romanzoffiana* (Cham.) Glassman (Fig. 3). Regarding time partitioning behaviours, it was noted that the canid species appeared to be temporally segregated, with *Cerdocyon thous* Linnaeus, 1766 mostly active at crepuscular-nocturnal times, with a main peak between 6pm and 11pm and a second peak between 3am and 5am, and *Lycalopex gymnocercus* G. Fischer, 1814 most daily-active, with a main peak between 7am and 9am. This was not the case with felids, as *L. wiedii* and *Leopardus geoffroyi* d'Orbigny & Gervais, 1844 – the most abundant species within the group – were not seen at any delimited time of the day.

Discussion

This study provides the first open-access dataset of occurrence records of mammal species in Paso Centurión, a locality that stands out as one of Uruguay's most

Figure 3. *Mazama gouazoubira* eating *Syagrus romanzoffiana*, recorded by JULANA's trap camera in Paso Centurión, Uruguay (sampling location 3). Corrected timestamp 27th March 2017. See photographic album at JULANA (2017).

biodiverse areas (Soutullo et al. 2013; Brazeiro 2015). The results have revealed the common presence of many species that are rare in the rest of the country (González and Martínez-Lanfranco 2010). Many of these are considered threatened at national level (González et al. 2013) and find their most southern distribution limits here (González and Martínez-Lanfranco 2010). Therefore, the locality embodies an area of high ecosystem value, critical for the conservation of species, many of them representative of the Atlantic Forest. Our work highlights the importance of the recent inclusion of Paso Centurión and Sierra de Ríos under the proposed category to the SNAP, one that also aims to preserve tangible and intangible historical and cultural values and contributes to rooting the inhabitants to the area.

Species occurrence

The mammal records reported here represent valuable new data for improving biodiversity knowledge in Uruguay and the region. Until Grattarola et al. (2016) and despite its wide Neotropical distribution (Caso et al. 2015), *H. yagouaroundi* was considered absent from the country and had only been recorded in nearby localities

of Brazil and Argentina. Remarkably, the species was photographed in Paso Centurión in the same site over two consecutive years, in 2015 and 2016. Additionally, in the last 30 years the only evidence of the presence of *C. brachyurus* in the country has been an animal shot in 2006 in the same locality (Queirolo et al. 2011). The species is categorized as "Possibly Extinct" for Uruguay (Paula and De Matteo 2015). In this study, a unique individual was recorded in 2013 and since then the species has not been formally documented again in the country. However, one of the locals involved in the monitoring claimed to have seen an individual of *C. brachyurus* in 2017, near the place where the last specimen was recorded (less than 400 metres distance). Moreover, the species of pampas cat here reported occurs exclusively in southern Brazil, Uruguay and north-eastern Argentina (Nascimento et al. 2020). Although it is considered widely distributed in the country (Lucherini et al. 2016), it has only been documented a few times recently and, consequently, its distribution and population status are poorly known (Bou et al. 2019).

The sample size-based rarefaction and extrapolation curve did not reach a saturation, indicating that increasing the number of samples could enable new species detection in the study area. The cameras were installed on native forest patches. However, it was not possible to record individuals of water opossum (*Chironectes minimus* Zimmermann, 1780) – a species which has only been recorded for Uruguay in Paso Centurión (González and Fregueiro 1998) – and brown-nosed coati (*Nasua nasua* Linnaeus, 1766) rarely registered in the country (González et al. 2013), despite both species inhabiting this type of habitat (González and Martínez-Lanfranco 2010). Conversely, a few common medium and large-size species were not detected, such as *Myocastor coypus* Molina, 1782 and *Dasypus hybridus* Desmarest, 1804, which are mainly associated to wetland and grasslands areas, respectively (González and Martínez-Lanfranco 2010). The increasing pattern observed in the sampling curve could also be related to the size of the area covered in our study (25 km^2). One of the main factors determining the number of species that can be found at any site is its size (Gaston and Blackburn 2008). Considering the species-area relationship (Gaston and Blackburn 2008), expanding the study area is expected to bring new records. However, the sampling effort and number of sites should be taken into account according to the rarity or commonness of the target species (MacKenzie and Royle 2005).

The three exotic species documented in this study are known to be widely distributed in Uruguay and are evaluated as invasive species in the country (Pereira-Garbero et al. 2013). They were introduced for hunting purposes between the end of the 19th century and the beginning of the 20th century (Vaz Ferreira 1969) but little information is available on their populations and impacts at the local level (Bonino et al. 2010, Pereira-Garbero et al. 2013). The individual of *A. axis* observed represents the second documented occurrence record in the department of Cerro Largo (EcoRegistros 2015). This species has been locally and globally associated with the transmission of infectious diseases that can affect domestic animals and livestock (e.g. González 1989, Cripps et al. 2019). Further, *L. europaeus* is consid-

ered an agricultural pest (Del Pino 1988), has been regionally linked to infectious diseases and has been thought to have indirect effects on interspecific interactions (Barbar and Lambertucci 2018). Similarly, negative effects on crops, livestock (Del Pino 1988) and native species by predation (Lombardi et al. 2007) are reported for *S. scrofa*. Thus, it is essential to generate more and better local knowledge about these species to develop strategies for the conservation of native species, especially given the protected status of this area (Liu et al. 2020).

Behaviour notes

The record of *P. cancrivorous* feeding on *S. romanzoffiana* fruits is consistent with studies indicating that this is a key resource for the species (Pellanda et al. 2010; Quintela et al. 2014). *C. chinga* is considered an omnivorous species which occasionally feeds on fruits (Donadio et al. 2004). However, studies recording pindó palm fruits in its diet are not known. The same occurs with *M. gouazoubira*, even though fruits are recognized as an important part of its diet (Richard et al. 1995). Given *S. romanzoffiana* has been suggested as a key species of the Atlantic Forest (Keuroghlian and Eaton 2008), our records hold great relevance for the study of the dispersal and conservation of the species.

The daily activity patterns suggested by our results are in accordance with what is reported (e.g., Vieira and Port 2007): crab-eating fox is crepuscular or nocturnal, and pampas fox is mostly diurnal. Considering that both foxes present similar diets (Di Bitetti et al. 2009), the temporal patterns observed could imply a reduction in their encounter and competition for food items, allowing their co-occurrence. Due to their preference of habitat (Vieira and Port 2007), future studies should consider different microhabitats to enhance analysis robustness. In contrast, the absence of an apparent temporal segregation for *L. wiedii* and *L. geoffroyi* could be expected considering that they have similar activity patterns (Di Bitetti et al. 2010; Sousa and Bager 2008) yet not necessarily similar dietary habits (Migliorini et al. 2018).

Conservation implications

Many of the native species detected by the camera traps are considered rare or range-restricted in Uruguay (González et al. 2013), such as *T. tetradactyla*, *L. wiedii*, *L. munoai*, *C. spinosus*, *C. tatouay* and *C. paca*. Yet, all the species observed are listed as Least Concern by the IUCN Red List of Threatened Species globally (IUCN 2020b), except *C. brachyurus*, *L. wiedii* and *Lontra longicaudis* Olfers, 1818 which are considered as Near Threatened globally. The pampas cat complex, for long under debate, has been recently taxonomically revised (Nascimento et al. 2020) and the former subspecies occurring in Uruguay has been designated as a new monotypic species, *Leoparuds munoai*. The conservation status of this species has not been assessed, yet, considering the species range is restricted, it should be regarded of high priority for conservation globally. A red list IUCN assessment of Mammals

at the national level has not yet been produced, though recent efforts have been made for the bats group (Botto et al. 2019). Nevertheless, if we consider the national assessment produced for the SNAP (Soutullo et al. 2013), thirteen of the species here reported are listed as priority for conservation in Uruguay (65%), given their restricted ranges of distribution or levels of local threat.

Human and wildlife co-existence

The cameras were located only within a few metres from the houses of the people involved in the monitoring process, yet some of the rarest and most elusive species in the country were reported there. This alludes to the possible coexistence between people – their socio-economic practices – and non-human fauna in the area. Although this had not been studied here, there is global evidence that allows it to be considered (Woodroffe et al. 2005). Human population density, food availability, habitat quality and human activities are commonly cited as drivers of human-wildlife conflicts (Distefano 2005, Nyhus 2016). Thus, future studies that evaluate these relationships and provide knowledge for the development of management strategies in the area are crucial. Importantly, these actions should be conceived from an interdisciplinary perspective (Dickman 2010), allowing broad participation of all the stakeholders, and not restricted to the administrative national border (Nyhus 2016).

Contributions from citizen-science

Citizen-science has proven to bare a remarkable potential towards monitoring the status and trends of global biodiversity (Chandler et al. 2017), for generating new knowledge, creating learning opportunities, and enabling civic engagement (Turrini et al. 2018). The participatory monitoring approach that JULANA established in Paso Centurión using camera traps as promoters of community engagement (Bergós et al. 2018) and the record of a new mammal species in Uruguay (Grattarola et al. 2016), have been published elsewhere. Here, the complete list of species along with the primary data and notes on observed species' behaviours are communicated. Given that publishing the citizen science-collected data in peer-reviewed literature is rarely accomplished (Theobald et al. 2015), we highlight the value of this study.

Conclusion

All in all, this endeavour is an important contribution to the knowledge of biodiversity of mammals in Uruguay, especially for the poorly known and restricted distributed species. The records here reported, and in particular those with offspring, stress the importance of the area for the conservation of these species populations and open new questions such as which are the reproductive and foraging patterns of the animals present in the area. Likewise, it becomes pertinent to monitor the

exotic species and assess the impact of their presence on native communities. As a perspective, new sampling sites should be taken into consideration, which include different habitat types and camera trap positions with respect to the ones here considered, to target mammal species not yet detected. There are still severe knowledge gaps on the distribution of species in the country (Grattarola et al. 2019). Thus, in a context of major global environmental change (IPCC 2014), habitat fragmentation (Haddad et al. 2015) and biodiversity loss (Cardinale et al. 2012), we highlight the value of enabling digital accessible knowledge and the need to extend and continue monitoring this area.

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