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Artículo

AN UPDATED ANALYSIS OF THE DISTRIBUTION OF CITES-LISTED PERUVIAN CARNIVORES FOR CONSERVATION PRIORITIES

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ABSTRACT. Species in the Order Carnivora are susceptible to habitat fragmentation, deforestation, and climate change because of their medium to large size, large spatial requirements, and other species-specific requirements, providing challenges to conservation and management. Understanding their distributions and occurrence in the face of these threats is crucial for conservation. Peru has 21 carnivore species regulated by the CITES Convention (61.8% of all Peruvian carnivore species). The aims of this project were: a) to generate distribution maps of Peruvian carnivores listed by CITES, b) to describe their distribution by ecoregions, c) to describe changes in species richness through time, and d) to identify species and areas in need of further research and conservation efforts. Records were obtained from literature published from 1903 to 2014, museum databases and unpublished records from field notes. ArcGIS software version 9.3 was used to generate distribution maps and perform species richness analyses based on 1939 records. Four species occur only in one ecoregion: *Leopardus jacobita*, *L. tigrinus*, *Chrysocyon brachyurus,* and *Arctocephalus philippii*. Species richness was higher in northern Peru and the southern Amazonian region; however, contemporary records showed a potential richness reduction in the Pacific Tropical Rainforest and in one locality of the Amazon Lowland Rainforest in Cuzco. *Leopardus tigrinus, Lycalopex griseus, Galictis vittata,* and *Speothos venaticus* are in need of updated assessments. Also, historical records of *Tremarctos ornatus*, *Puma concolor*, and *Lycalopex culpaeus* are concentrated in coastal areas. We provide a regional perspective of carnivore distribution and make suggestions on priorities for species research and conservation emphasizing lacunae in geographic knowledge.

RESUMEN. Un análisis actualizado de la distribución de especies de carnívoros peruanos listados por CITES para prioridades de conservación. Las especies del Orden Carnivora son sensibles a la fragmentación de hábitat, deforestación y al cambio climático debido a su tamaño mediano a grande, grandes requerimientos espaciales, y otros requerimientos especie-específicos. Evaluar su distribución y ocurrencia es crucial para su conservación. Perú cuenta con 21 especies de carnívoros cuyo tráfico ilegal es regulado por la convención CITES (61.8% del total de carnívoros peruanos). Los objetivos de este proyecto fueron: a) generar mapas de distribución de las especies de carnívoros CITES, b) describir su distribución por ecorregión, c) describir cambios en riqueza de especies a través del tiempo, y d) identificar áreas y especies con necesidad de investigación y conservación. Los registros se obtuvieron de la literatura publicada entre 1903 y 2014, base de datos de museos y de informes de campo para actualizar la distribución de carnívoros CITES. El programa ArcGIS versión 9.3 fue utilizado para generar

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mapas de distribución y realizar el análisis de riqueza de especies basados en 1939 registros. Encontramos que cuatro especies ocurren en una sola ecorregión: *Leopardus jacobita*, *Leopardus tigrinus*, *Chrysocyon brachyurus* y *Arctocephalus philippii*. La riqueza de especies fue mayor en el norte de Perú y sur de la Amazonía; sin embargo, los registros contemporáneos muestran una potencial reducción en la riqueza de especies en el Bosque Tropical del Pacífico y en una localidad del Bosque Amazónico, Cusco. *Leopardus tigrinus, Lycalopex griseus, Galictis vittata* y *Speothos venaticus* necesitan evaluaciones actualizadas sobre su distribución y *Tremarctos ornatus, Puma concolor* y *Lycalopex culpaeus* cuentan con registros históricos concentrados en áreas costeras. Proporcionamos una perspectiva regional de la distribución de los carnívoros y sugerencias sobre priorización de la investigación y la conservación de las especies, así como áreas para estudios posteriores.

Key words: Information gaps. Mammals. Occurrence. Peru. Species richness.

Palabras clave: Mamíferos. Ocurrencia. Perú. Riqueza de especies. Vacíos de información.

INTRODUCTION

For effective conservation of species, researchers and managers require knowledge of its current distribution, population status, ecological requirements, among other factors (Wilson, 2000). Furthermore, the knowledge of historical and contemporary species distribution ranges is important especially for wide ranging and endangered species (Morrison et al., 2007). Baseline distributions can be used to assess changes in distribution ranges and determine expansions or reductions of populations after human colonization, exotic species introductions, extirpation of top predators, climate change, conservation efforts, and identify research gaps (Abbitt and Scott, 2001; Senyatso et al., 2012; Ripple et al., 2013; Rochlin et al., 2013; Ogutu et al., 2014; Parlato et al., 2015). The Order Carnivora consists of medium- to large-sized mammals that often need extensive areas to fulfill their basic habitat and resource requirements, and therefore are greatly affected by anthropogenic disturbances (Gittleman and Harvey, 1982; Noss et al., 1996). The need for large spatial areas, naturally low population densities, high persecution by humans, and vulnerability to habitat fragmentation, deforestation, and climate change make extinction risk higher for Carnivora than for other species (Woodroffe and Ginsberg, 1998; Crooks, 2002; Voigt et al., 2003; Cardillo et al., 2005; Ordeñana et al., 2010; McCain and King, 2014). Moreover, because of their extensive spatial requirements and unique ecosystem functions, such as top-down control of a food chain (Terborgh, 1988), most carnivores can be considered keystone species, contributing to the balance of the ecosystem by maintaining its structure, regulating prey densities and avoiding competitive exclusion (Ucarli, 2011; Ripple et al., 2013; Ripple et al., 2014). Furthermore, the habitat conservation of large areas to protect some of these carnivores will indirectly aid the protection of co-distributed species (Branton and Richardson, 2011; Breckheimer et al., 2014).

Globally, carnivores are facing large reductions in distribution range due to continuous anthropogenic land use change and urbanization (Kerr and Currie, 1995; Laliberte and Ripple, 2004). However, information about carnivore distribution in Peru is scarce and based mainly on new records or inventories in specific regions (Cossíos et al., 2007; Cossíos et al., 2012; García-Olaechea et al., 2013; Hurtado and Pacheco, 2015). Some probable reasons for this scarcity of knowledge may be explained by carnivores' elusive behavior, the cost of methods such as genetic sampling to confirm presence of a species from scat or hair, and the logistics of covering large study areas (Long et al., 2008). The Order Carnivora is represented in Peru by 34 species (Pacheco et al., 2009), 21 listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES, 2015) and five of them internationally threatened with extinction (IUCN, 2012).

The purpose of this research was to update and analyze the distributions and range maps of carnivore species, focusing on the 21 species that are considered at most risk from illegal trade (CITES species), which also include species in national threatened categories, with the exception of *Otaria flavescens*. Our specific objectives were: (a) to generate species range maps based on confirmed records, (b) to describe their distribution in Peruvian ecoregions, (c) to describe changes in species richness of these carnivores through time, and (d) to identify geographic areas and species in need of further research.

MATERIALS AND METHODS

We examined 21 species of Peruvian carnivores included in CITES (**Table 1**) and reviewed the available literature from 1903 to 2014. We also compiled carnivore localities from 13 museum databases: American Museum of Natural History, New York, USA (AMNH); Field Museum of Natural History, Chicago, USA (FMNH); Museo de Historia Natural, Lima, Peru (MUSM); Louisiana Museum of Natural History, Baton Rouge, USA (LSUMZ); Museum of Comparative Zoology, Harvard, USA (MCZ); Museum of Natural History at the University of Kansas, Lawrence, USA (KU); Georgian National Museum, Tbilisi, Georgia (GNM); Museum of Vertebrate Zoology, Berkeley, USA (MVZ); Royal Ontario Museum, Toronto, Canada (ROM); Texas Cooperative Wildlife Collection, College Station, USA (TCWC); Museum of Zoology, University of Michigan, Ann Arbor, USA (UMMZ); National Museum of Natural History, Smithsonian Institution, Washington D.C., USA (USNM); Yale Peabody Museum of Natural History, New Haven, USA (YPM); and non-published records from the authors and other biologists working in Peru (C. Jimenez, C. Mercord, C. Tello, E. Salas, E. Vivar, F. Cornejo, G. Llerena, J. Barrio, J. Onofre, M. Guissa, M. Mamani, P. Bueno, P. Venegas, P. Villegas, pers. comm.). All known localities, collection dates, record type, and geographic reference were entered into an Excel spreadsheet. Coordinates were taken from published literature, requested from the authors if unpublished, or obtained from the ornithological gazetteer of Stephens and Traylor (1983). Online gazetteers such as geonames.org and fallingrain.com were also used as supplementary source for an accurate geographic estimate. Doubtful records, such as unclear coordinates or lacking evidence, were not used for analyses.

Each record was classified according to the type of evidence in: direct evidence (sightings, photographic records, DNA analysis of scats, and captures for GPS/VHF collars), indirect evidence (scats, tracks, hair, dens, vocalizations and interviews), and specimen collections (skull, skin, complete or incomplete skeletons). Furthermore, we defined contemporary records as locations obtained after 2001 based on the increase in popularity (from 27% to 51%) of modern methods to register medium to large mammals such as remote cameras, DNA analyses and GPS equipment (Long et al., 2008). Historic records were considered those made prior to 2001. Differences among type of records were assessed using a chi-square analysis in R software (R Core Team, 2014) with the package MASS.

Mapping and geographical analysis was performed using the ArcGIS 9.3 software, we integrated record occurrences within 20 km for better definition and display in the figures. A point density analysis was used to identify geographic gaps and areas with concentrated number of records that were independent of species richness. To determine species occurrence per ecoregion we used a shape file approximation of the ecoregions classification of Brack-Egg (1986) and considered known elevational ranges when coordinates placed records on the border of two ecoregions. A raster file with grid cell size of 55 x 55 km was created to generate species richness maps and allow better resolution for the geographic area studied. We followed Wilson and Reeder (2005) and Pacheco et al. (2009) for nomenclature.

RESULTS

We obtained 1939 records for 21 carnivore species (**Table 1**): 411 from museum collections, 114 from field notes, and 1414 from the literature. The family Felidae, with eight species listed in CITES, had the highest number of records (815) followed by the families: Mustelidae (519), Canidae (208), Ursidae (156), Procyonidae (148), and Otariidae (93). *Leopardus colocolo* was the species with the most records (245), followed by *Lontra felina* (172), and *Puma concolor* and *Eira barbara* (158). The species with the fewest records in Peru were *Leopardus tigrinus* (10), *Chrysocyon brachyurus* (4), and *Arctocephalus philippii* (2).

Table 1

Species list of CITES-listed carnivores and the number of total and contemporary records per species. The conservation status of each species as designated by the International Union for Conservation of Nature (IUCN) (2012) is included, with their population trend and the Peruvian Government D.S. 004-2014 category. NT: near threatened, EN: endangered, VU: vulnerable, DD: data deficient; De: decreasing, In: increasing, Un: Unknown, St: stable; TR: Total records, CR: Contemporary records (2001-2014).

Species	Common Names	CITES	IUCN		DS.	TR	CR
			2012	Population trend	004-2014		
Felidae						815	424
Leopardus colocolo (Molina, 1782)	Pampas cat	II	NT	De	DD	245	198
Puma concolor (Linnaeus, 1771)	Cougar, Puma	II		De	NT	158	74
Leopardus pardalis (Linnaeus, 1758)	Ocelot	I		De		143	41
Panthera onca (Linnaeus, 1758)	Jaguar	I	NT	De	NT	114	48
Puma yagouaroundi (É. Geoffroy Saint-Hilaire, 1803)	Jaguarundi	II				65	15
Leopardus wiedii (Schinz, 1821)	Margay	I	NT	De	DD	47	15
Leopardus jacobita (Cornalia, 1865)	Andean Cat	I	EN	De	EN	33	30
Leopardus tigrinus (Schreber, 1775)	Oncilla	I	VU	De	DD	10	3
Mustelidae						519	244
Lontra felina (Molina, 1782)	Marine otter	I	EN	De	EN	172	149
Eira barbara (Linnaeus, 1758)	Tayra	III		De		158	39
Lontra longicaudis (Olfers, 1818)	Neotropical otter	I	NT	De		90	31
Pteronura brasiliensis (Gmelin, 1788)	Giant otter	I	EN	De	EN	64	18
Galictis vittata (Schreber, 1776)	Greater grison	III		St		35	7
Canidae						208	72
Lycalopex culpaeus (Molina, 1782)	Andean fox	II		St		150	60
Speothos venaticus (Lund, 1842)	Bush dog	I	NT	De		37	10
Lycalopex griseus (Gray 1837)	South American grey fox	II		St	DD	17	1
Chrysocyon brachyurus (Illiger, 1815)	Maned wolf	II	NT	Un		4	1
Ursidae						156	88
Tremarctos ornatus (F. G. Cuvier, 1825)	Andean bear	I	VU	De	VU	156	88
Procyonidae						148	40
Potos flavus (Schreber, 1774)	Kinkajou	III		De		148	40
Otaridae						93	4
Arctocephalus australis (Zimmermann, 1783)	South American fur seal	II		In	EN	91	4
Arctocephalus philippii (Peters, 1866)	Juan Fernandez fur seal	II		In		2	0

The ecoregions with the highest total number of records (75-104), independent of species number, were concentrated in the Amazon Lowland Rainforest around Parque Nacional Manu (11.88° S, 71.41° W) in Madre de Dios Department, and in the Puna ecoregion, around the Reserva Paisajistica Nor Yauyos-Cochas (12.03° S, 75.86° W) in Lima and Junín departments (**Fig. 1**). We found that large geographic areas in Loreto, Piura, Huancavelica, and Ayacucho departments lacked carnivore records (**Fig. 1**).

At least one species was documented in each ecoregion (Brack-Egg, 1986), and the Amazon Lowland Forest had the highest number of CITES carnivores with 12 species (**Table 2**). The Tropical Ocean was represented by only one species, whose taxonomic identity is still under debate and is here designated *Arctocephalus* cf. *australis* but may represent a new species (Camaratta et al., 2008) (**Table 2**). *Leopardus jacobita*, *L. tigrinus,* and *C. brachyurus* were restricted to a single region, found only in the Puna, Montane Forest, and Sabana de Palmeras, respectively (**Fig. 2**). *Puma concolor* was the only carnivore documented in all terrestrial habitats except for the Sabana de Palmeras ecoregion (**Table 2**).

Richness analysis

The richness analysis, including historic and contemporary records (1903-2014), showed that northern Peru (Tumbes, Cajamarca and Loreto) and Madre de Dios Department, including its adjacent areas in the Cuzco and Ucayali departments, had the highest species richness of CITES carnivores. These areas correspond to the Pacific Tropical Rainforest, northern Montane Forest, and Amazon Lowland Rainforest (**Fig. 3**A), each with 9 to 11 species of carnivores.

When the same analysis was performed including only recent records (2001-2014), the highest richness was in the northern Montane Forest and Amazon Lowland Rainforest in Loreto and Ucayali departments (**Fig. 3**B). Furthermore, the Pacific Tropical Rainforest species richness in Tumbes was reduced by at least three species while northern Cuzco species number was reduced by one.

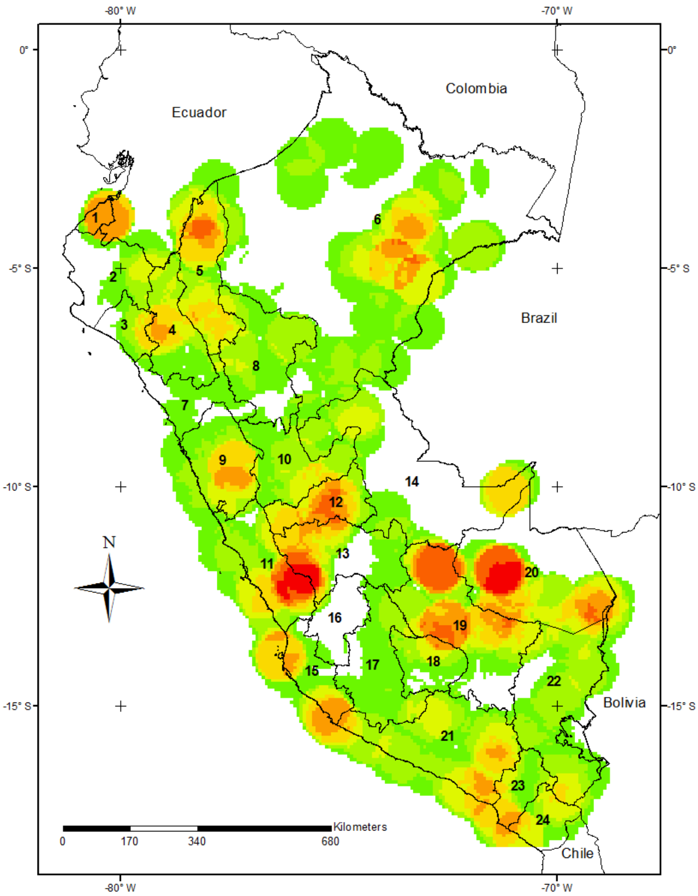

Fig. 1: Total number of carnivores records, indicating intensity of existing surveys. Red areas show more carnivore records whereas greener areas, less. 1: Tumbes, 2: Piura, 3: Lambayeque, 4: Cajamarca, 5: Amazonas, 6: Loreto, 7: La Libertad, 8: San Martin, 9: Ancash, 10: Huanuco, 11: Lima, 12: Pasco, 13: Junin, 14: Ucayali, 15: Ica, 16: Huancavelica, 17: Ayacucho, 18: Apurimac, 19: Cuzco, 20: Madre de Dios, 21: Arequipa, 22: Puno, 23: Moquegua, 24: Tacna.

Table 2

Percentage of CITES-listed carnivore records from Peru per ecoregion (sensu Brack-Egg, 1986) and total number of records per ecoregion. TO: Tropical Ocean, PCO-D: Peruvian Current Ocean and Desert, De: Desert, EDF: Equatorial Dry Forest, PTR: Pacific Tropical Rainforest, SE: Serrania Esteparia, Pu: Puna, Pa: Paramo, MF: Montane Forest, LR: Amazon Lowland Rainforest, SP: Sabana de Palmeras

Species	TO	PCO-D	De	EDF	PTR	SE	Pu	Pa	MF	LR	SP
Leopardus colocolo			4	1	1	4	82		8		
Leopardus jacobita							100				
Leopardus pardalis				3	8				19	70	
Leopardus tigrinus									100		
Leopardus wiedii					11				4	79	6
Puma concolor			2	6	3	6	28	1	15	39	
Puma yagouaroundi					2	2			23	73	
Panthera onca					4				6	86	4
Chrysocyon brachyurus											100
Lycalopex culpaeus			9			17	58		16		
Lycalopex griseus			76			24					
Speothos venaticus									3	97	
Tremarctos ornatus				5	1	4		2	82	6	
Arctocephalus australis	1	99									
Arctocephalus philippii		100									
Lontra felina		99				1					
Lontra longicaudis			1		9				19	71	
Pteronura brasiliensis										98	2
Eira barbara				1	5				25	68	1
Galictis vittata									18	82	
Potos flavus					1				22	75	2
Total number of records	1	262	43	28	51	58	361	4	361	754	16

Historic and contemporary distribution

We found that 879 of 1939 records (45.3%) were obtained after the year 2001 (**Table 1**) and were characterized by greater number of direct evidence (51%) and indirect evidence (38%), while specimen collections represented only 11% of the total. Historic records showed a significantly higher number of records ($X^2 = 326.7$, d.f. = 2 $p<0.005$) derived from specimen collections (51%), whereas direct and indirect evidence constituted only 27% and 22%, respectively (**Fig. 4**).

Lontra felina was the only species with detailed, updated information about its distribution whereas species with few contemporary records were *Leopardus tigrinus*, *Lycalopex griseus, Speothos venaticus,* and *Galictis vittata* (**Fig. 2**). *Arctocephalus philippii* and *C. brachyurus* were represented only by four and two records, respectively. Furthermore, historic records of *Tremarctos ornatus*, *Puma concolor*, and *Lycalopex culpaeus* were concentrated in coastal areas (**Fig. 2**). For *Lontra longicaudis, Potos flavus, Panthera onca*, *Pteronura brasiliensis*, *E. barbara*, and

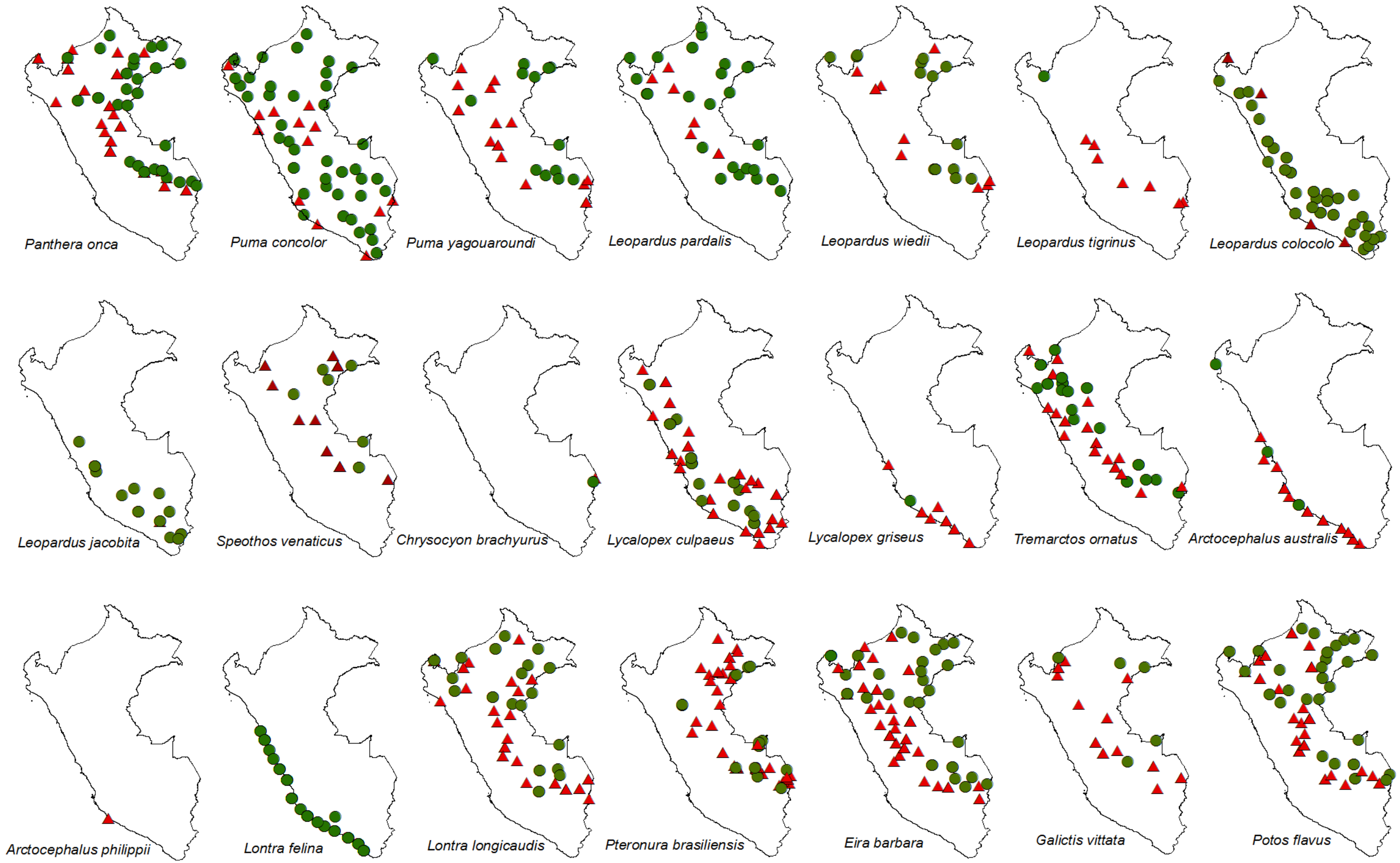

Fig. 2: Distribution maps of 21 carnivore species. Circles represent contemporary records (from 2001-2014) and triangles represent historic records (before 2001).

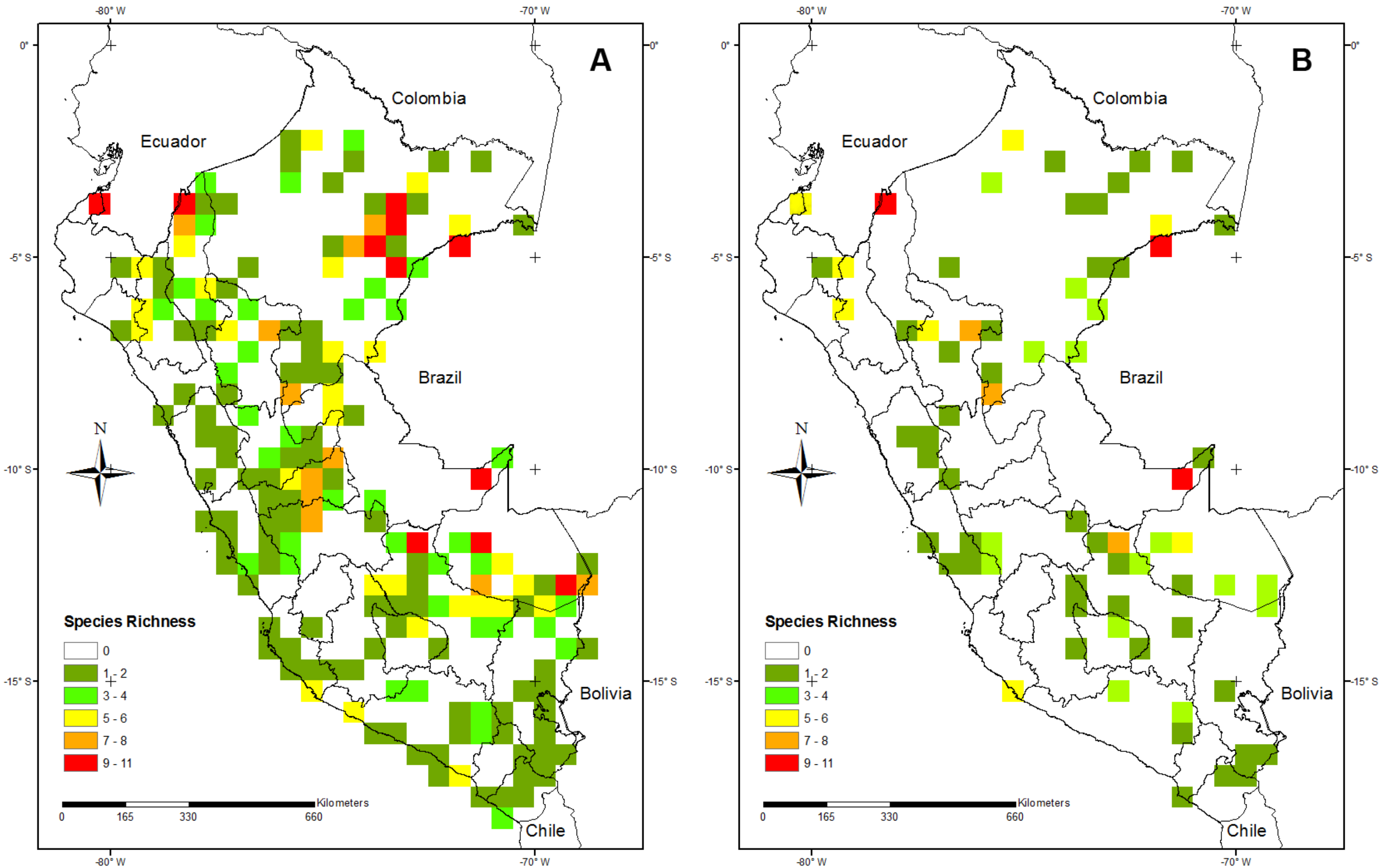

Fig. 3: Species richness of CITES-listed carnivores from Peru. A: based on all records. B: based on contemporary records (2001-2014).

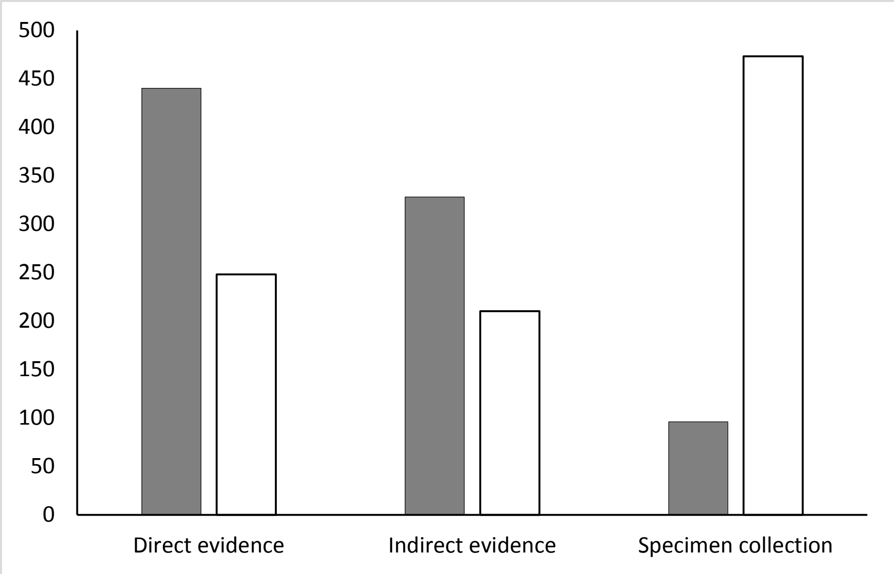

Fig. 4. Type of evidence for historic records (white bars) and contemporary records (grey bars). Direct evidence: sightings, photographic records, DNA scat analysis, and captures. Indirect evidence: scats, tracks, footprints, vocalizations, dens and interviews. Specimen collection: skins, skulls, skeletons from museums and private collections.

Puma yagouaroundi, there is little knowledge concerning their occurrence in central Peru.

DISCUSSION

Distribution assessments are extensive for *Lontra felina* (Apaza and Romero, 2012), *T. ornatus* (García-Rangel, 2012), *Leopardus colocolo*, and *Leopardus jacobita* (Cossíos et al., 2007). This is probably a consequence of their restricted distributions (to one or a few ecoregions) and their at-risk categorization (endangered for *Lontra felina* and *Leopardus jacobita*, vulnerable for *T. ornatus*, and near threatened for *Leopardus colocolo*). However, *L. colocolo* still requires direct evidence that its distribution reaches to northwestern Peru and the northern limits of its distribution (Cossíos et al., 2012). Cossíos et al. (2007) considered *L. jacobita* distribution in the northern region of Ancash Department as unknown, suggesting two natural protected areas (Reserva Paisajistica Huayhuash and Parque Nacional Huascarán in the Ancash Department) as the northern distribution for this species.

Despite a considerable reduction in the *A. australis* population (Arias-Schreiber, 2000; Oliveira et al., 2009), there have been no recent published analyses of the distributions of viable colonies on the Peruvian coast. Furthermore, the small colony of *Arctocephalus* cf. *australis*, found on Foca Island in Piura Department (Novoa et al., 2010), more than 700 km from the nearest locality in Peru, is living in an ecotone of warm and cold oceanic currents with average ocean temperatures of about 19-23 °C (IMARPE, 2010); this compares with *A. australis*, whose distribution suggests that it prefers temperatures ranging from 13-16 °C (Brack-Egg, 1986). Camaratta et al. (2008) reported preliminary genetic analysis that suggests that *Arctocephalus* cf. *australis* could be a hybrid population of *A. galapagoensis* and *A. australis*; in any case, its taxonomic status needs to be resolved.

The lack of records for *A. philippii* and *C. brachyurus* could be due to their restricted distribution in Peru or constituting occasional vagrants. *Chrysocyon brachyurus* in Peru is restricted to a grassland type ecosystem found in the Parque Nacional Bahuaja Sonene. According to a recent distribution update, this species was photographed again since 1996 confirming that it still remains within Peruvian boundaries (Williams et al., 2012). In the case of *A. philippii*, lack of records could be attributed to its accidental appearance on the Peruvian coast, as described by some authors (Jefferson et al., 2011; Cossíos et al., 2012). However, Pacheco et al. (2009) and Aurioles-Gamboa (2015) considered *A. philippii* a resident, probably because of its ability to travel long distances. The northernmost record for this species is at Buenaventura, Colombia, 3700-4600 km from its primary range (Avila et al., 2014), suggesting a larger distribution range than previously thought. Moreover, Majluf and Reyes (1989) indicated that mixed colonies of this species and *A. australis* were seen for at least 12 consecutive years in the Peruvian coast (1973-1984) and highlighted the possibility of undetected individuals inhabiting southern areas. If mixed colonies existed in the past, we suggest that trained biologists able to detect the differences between this two similar species in the field should assess southern localities and update the knowledge of this species for Peru.

Richness analysis

Even though *Nasua narica* is listed for Peru (Pacheco et al., 2009) and is listed on Appendix III of CITES, we did not include this species in the analyses because of the ambiguous evidence for its occurrence in Peru. Records of this species were based on observations made on specimens from Tumbes (Pacheco et al., 2009) that have a snout coloration lighter than the Amazonian coati *Nasua nasua*; however, this pattern is not similar to the white coloration of the *N. narica* from Central America (Gompper, 1995). Furthermore, the closest collected specimen and confirmed sightings are from northeastern Colombia on the Gulf of Uraba (Gonzáles-Maya et al., 2011), approximately 1378 km north of Tumbes. After reviewing the five specimens from Tumbes, this population differs from *N. narica* not only in external morphology but dental characteristics as well (CMH unpublished data).

Tropical rainforests are considered among the most diverse ecosystems for mammals (Ceballos and Ehrlich, 2006; Kier et al., 2009), and in Peru the Lowland Rainforest, Montane Forest, and Pacific Tropical Rainforest contain between 9 and 11 species of CITES carnivores. Contemporary records showed a decrease in record localities, especially for central Peru; however, the number of species was maintained in certain localities of Loreto, Madre de Dios and Cajamarca. Furthermore, the reduction in the Pacific Tropical Rainforest species richness in Tumbes has being described as potential local extinction of *T. ornatus*, *Panthera onca* and the lack of confirmed records of *Leopardus colocolo* (Hurtado and Pacheco, 2015). Similar situations in other Peruvian areas may be going through the same local process and the need of exhaustive distribution assessments becomes necessary to develop conservation measures.

Historic and contemporary distribution

According to Dirzo et al. (2014) who followed IUCN bird and mammal species categorized as declining, South America is the largest geographic area experiencing this decline in population. Usually, the reduction in species ranges is attributed to areas of high urban development (Kerr, 1995; Channell and Lomolino, 2000; Ogutu et al., 2014; Li et al., 2015). Our maps show that *T. ornatus, Lycalopex culpaeus,* and *Puma concolor* lack confirmed contemporary records in coastal areas where the biggest Peruvian cities are found, a pattern that may suggest range contractions. A distributional assessment of *Puma concolor* in Latin America found that 40% of its range is lost or threatened, including populations in coastal and central regions of Peru (Laundré and Hernández, 2010). Furthermore, the most important factor in record reduction appears to have been concentrated urban development, which pushes species to less urbanized areas that were not formerly occupied (Laundré and Hernández, 2010).

Previous distribution maps of *Lycalopex culpaeus* did not include the Peruvian desert ecoregion as part of its distribution range (Novaro, 1997). However, updated assessments consider the southern desert as a current habitat for this fox (IUCN, 2008a; Wilson et al., 2009). In this research, we found that historic records in the desert were primarily from Lomas type ecosystem (Velarde Falconi, 1983; Falero and Sánchez, 1986, Zeballos et al., 2000), which are episodic phytogeographic units within the desert characterized by seasonal development of plant communities under winter fog influences (Sotomayor Melo and Jimenez Milon, 2008). Therefore, the Peruvian desert ecoregion should be assessed to determine if *L. culpaeus* distribution is limited only to Lomas and to identify its distribution limits.

Furthermore, in Tumbes, both *Panthera onca* and *T. ornatus* have suffered local extinction due to population isolation (García-Rangel et al., 2012; Hurtado and Pacheco, 2015). Therefore, special attention to urban development and anthropogenic activities such as agriculture, farming, mining, hunting, logging and roads need to be taken into consideration because habitat fragmentation is inversely correlated with species richness and loss of connectivity within populations (Crooks et al., 2011).

Other anthropogenic activities such as the construction of the Interoceanic highway Peru-Brazil, mining, and oil and gas extraction might generate general and localized impacts (Finer et al., 2008). Therefore, large-scale distributional assessments of poorly known species and analyses of changes in distributional patterns of wide spread species at a regional scale should be explored and used as indicators of risk to prevent biodiversity loss. Also, previous and rapid inventories mainly using transect census and interviews may have failed to detect rare species and therefore underestimated total carnivore richness. New reliable methods such as camera traps would improve understanding of carnivore's distribution.

Research gaps and conservation priorities

Further research is needed in unexplored areas. Huancavelica Department and its surroundings, Ucayali Department, and the central region of Loreto are three main areas that lack carnivore records or are poorly documented, likely due to conflict and lack of access. In Huancavelica, constant social conflicts caused by drug trafficking, present since the 1980's, have made this area inaccessible and dangerous for research (Pacheco et al. 2007). For Ucayali and Loreto, the high cost and complicated logistics to access these remote areas limits research. Quintana et al. (2009) indicated that unexplored areas in Ucayali could hold higher diversity than hitherto reported, and indicated several threats to wildlife such as logging, highway construction, and lax control in natural protected areas, among others. These are difficult areas to explore, but future efforts should be made for research and to assess potential threats for carnivores and other species.

Even though a major effort to monitor terrestrial species is being made by the Tropical Ecology Assessment and Monitoring (TEAM) network in Central and South eastern Peru (Yanachaga and Cocha Cashu National Parks), central Peru still requires updated carnivore distribution assessments. Other natural protected areas such as Cordillera Azul and Rio Abiseo National Parks should be considered priorities to confirm presence and maintain connectivity between northern and southern populations. Special emphasis should be given to *G. vittata*, *Lontra longicaudis, Potos flavus, Panthera onca, Pteronura brasiliensis, E. barbara,* and *Puma yagouaroundi* to update their distribution in central Peru and assess the connectivity of their southern and northern populations.

For species priorities, *Leopardus tigrinus*, which has only a single published contemporary record (Amanzo et al., 2003), is the species that most urgently needs a distributional update; of the ten records found, four were from museum specimens and six from literature review, all within the Yungas region (**Fig. 2**). In Ecuador, this species inhabits coastal dry forests, lowland rainforests, and Yungas from 0 to 3000 m (Tirira, 2007), but its distribution and several records still need confirmation (Tirira, 2011). In Colombia, this species is considered rare but is widely distributed across montane forests (Payán and Gonzalez-Maya, 2011), whereas in Brazil it is found in the Atlantic rainforest (Bianchi et al., 2011). This distribution patterns across several habitats reinforces the need for an exhaustive distribution assessment of this species.

Lycalopex griseus population's trend is considered stable (IUCN, 2008b); however, the IUCN does not consider Peru as part of this species distribution range. According to Peruvian legislation, *L. griseus* is considered Data Deficient which is also reflected in the number of records obtained in this study, 17 total records including a single contemporary record. Based on morphological evidence, Vivar and Pacheco (2014) provided support for the presence of this species in southern Peru and suggested that Peruvian populations may represent a new subspecies, based on discontinuous distribution and the Atacama Desert as a potential geographic barrier. On the other hand, Iriarte and Jaksic (2012) acknowledged a continuous distribution of *L. griseus* from Peru to Argentina and described it as occurring in different extreme habitats from the Atacama Desert to cold forests in Tierra del Fuego. Further studies are needed to elucidate these contrasting distributional patterns and to determine habitat requirements for *L. griseus* in Peru.

Similarly, *Speothos venaticus*, which also has few contemporary records, should also be prioritized for a distribution and conservation assessment. This species is considered rare and extremely elusive which may represent a challenge for its study (Michalski and Peres, 2005; DeMatteo and Loiselle, 2008, DeMatteo et al., 2014). *Speothos venaticus* was categorized as Near Threatened by the IUCN, and although not much is known about it in Peru, it was not given a Data Deficient category. Several areas within its distributional range were, until recently, considered distributional gaps especially for Brazil (Guimarães et al., 2015; da Rocha et al., 2015). Similarly, northern Peru in Amazonas, where we have only historic records, is still a gap in knowledge even though this area was considered suitable for *S. venaticus* by DeMatteo and Loiselle (2008). We encourage an updated evaluation in this region using non-invasive techniques such as camera trapping and genetic identification of scats using trained dogs for collection; the latter technique was proven to be successful for rare species studies (DeMatteo et al., 2014).

Other techniques such as the use of VHF and GPS collars and specimen collections are important to the understanding of the ecology, morphology and function of these carnivores in their ecosystems (Long et al., 2008). Museum specimens and the importance of museum collections are well recognized (Suarez and Tsutsui, 2004; Gippoliti et al., 2014); however, our analysis showed contrasting patterns of carnivore records in which specimens collections were the best source of tangible information only for historic records. Whereas technology has improved providing other direct evidence such as photographs and direct sightings which form the base of most contemporary records, there is also the rejection of collecting charismatic species, such as carnivores (De Vivo, 2007). It is certain that carnivore collections must be well justified; nonetheless, opportunistic salvage operations involving hunted animals or their skeletal remains by field biologists provide an invaluable way to enrich museum collections and all the science they support, without the need to kill a single specimen. Moreover, contemporary data such as photographs involve difficulties in verifying the information they contain. This problem can be reduced by implementing a digital museum database, where low-density or rare species photographs can be found in one place and are available for other researchers.

In conclusion, different methods can provide information about distribution and habitat use of carnivores. This information is crucial for species conservation (Rondinini et al., 2011), especially under changing land-use, which is a global trend (Di Minin et al., 2016). We hope that this regional perspective of carnivore distribution assessment and recommendations will help conservation biologists and managers redirect efforts and funds to select areas for more research including possible biological corridors (Sepúlveda et al., 1997), as well as develop accurate monitoring plans and other tools to conserve carnivores.

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