Threatened diurnal raptors species in Peru: are existing strictly protected areas enough for their conservation?

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ABSTRACT

Protected area systems are the corner stone for biodiversity conservation globally yet their spatial distribution is key to fulfil this. In this study, I evaluated the role of strictly protected areas in Peru in protecting the potential distribution area (PDA) of eight threatened diurnal raptor species. PDA of species ranged from 5 766 km^2 (Gray-backed Hawk –*Pseudastur occidentalis*) to 699 229 km^2 (Gray-bellied Hawk –*Accipiter poliogaster*). On average, strictly protected areas covered 11.3% of species PDA, with higher percentages for the most range-restricted species (Gray-backed Hawk; 26.3% of PDA). This was not the case for the wide ranging and locally threatened (Andean Condor –*Vultur gryphus*; 2% of PDA) or for small species restricted to montane forests (Semicollared Hawk –*Accipiter collaris*; 3.5% of PDA). My results call for an integrated conservation approach for threatened raptor species that focus on habitat preservation beyond protected area limits. This is particularly urgent for the Andean Condor and the Black-and-chestnut Eagle (*Spizaetus isidori*), two species with diminishing populations globally. For the latter, habitat conservation through the protection of montane forests inside indigenous communities in the north and central Andes could be a viable option to the creation of protected areas.

Especies amenazadas de rapaces diurnas en Perú: ¿Son suficientes las áreas protegidas de protección estricta existentes para su conservación?

RESUMEN

Los sistemas de áreas naturales protegidas son la piedra angular para la conservación de la biodiversidad a nivel global, sin embargo su disposición espacial es fundamental para cumplir esto. En este estudio, evalué el rol de las áreas naturales de protección estricta en Perú para la protección del área de distribución potencial (ADP) de ocho especies amenazadas de rapaces diurnas. El ADP de las especies fluctuó entre 5766 km^2 (Gavilán Dorsigrís –*Pseudastur occidentalis*) y 699 229 km^2 (Gavilán de Vientre Gris –*Accipiter poliogaster*). En promedio, las áreas protegidas de protección estricta cubrieron el 11.3% del ADP de las especies, con un mayor porcentaje para las especies de distribución restringida (Gavilán Dorsigrís).

Este no fue el caso para las especies de amplia distribución y que están amenazadas a nivel nacional (Cóndor Andino –*Vultur gryphus*; 2% de ADP) o aquellas pequeñas que habitan los bosques montanos al este de los Andes (Gavilán Semiacollarado –*Accipiter collaris*; 3.5% de ADP). Mis resultados hacen un llamado a una aproximación integral para la conservación de las especies de rapaces amenazadas de Perú que debe enfocarse en la conservación de sus hábitats más allá de los límites de las áreas protegidas. Esto es particularmente urgente para el Cóndor Andino y el Águila Negra y Castaña (*Spizaetus isidori*), dos especies, cuyas poblaciones están disminuyendo a nivel global. Para el Águila Negra y Castaña, la conservación de su hábitat mediante la protección de los bosques montanos en comunidades nativas en los Andes del norte y centro de Perú puede sustituir la creación de nuevas áreas naturales protegidas.

Key Words: Diurnal raptors, Extent of Occurrence, Falconiformes, montane forest, national parks, sanctuaries.

INTRODUCTION

Creation of protected areas continue to be the cornerstone of biodiversity and habitat conservation but since these are generally interspaced in the landscape cannot cover all areas of high biodiversity value (Margules & Pressey 2000, Hoffman *et al*. 2010, LeSaout *et al*. 2013). Despite an increased rate in the creation of protected areas during the past three decades (West 2006, Hoffman *et al*. 2010), habitat loss is still one of the major threats to wildlife globally and diurnal raptor species are no exception to this (Bierregaard 1998). For tropical diurnal raptors, persecution, direct and indirect poisoning have lately been regarded as a major cause of populations decline (Virani *et al*. 2011).

With 72 diurnal raptor species, Peru is among the most raptor diverse countries in the world (Global Raptor Information Network 2016). Diversity within this taxon is particularly high along altitudinal gradients east of the Andes where most species are restricted to narrow elevation bands from the puna grasslands to lowland rainforest and are associated to particular habitats (Piana 2016a).

In Peru, nine diurnal raptor species are protected by law (Ministerio de Agricultura y Riego 2014). These include three large-sized species that occur all along the Andes (Andean Condor, Solitary Eagle –*Buteogallus solitarius*, and Black-and-chestnut Eagle), two species that occur in the eastern lowlands (Harpy Eagle –*Harpia harpyja* and Crested Eagle –*Morphnus guianensis*), and one medium-sized species that is endemic to the Tumbesian zone (Gray-backed Hawk) (Schulenberg *et al*. 2007). Most of these species have very low reproductive rates and long breeding seasons (Global Raptor Information Network 2016). In addition, the Semicollared and the Gray-bellied Hawks are two small bird eating species than inhabit forest interiors and edges on the eastern lowlands and montane forests respectively. Of these, two species are globally threatened (Gray-backed Hawk –EN, and Black-and-chestnut Eagle -EN) with population declines mainly caused by habitat loss and fragmentation (BirdLife International 2018). I did not include the Orange-breasted Falcon (*Falco deiroleucus*) in my analysis because data on the species presence was not available through e-bird.

Peru´s protected area system cover almost 17% of its terrestrial surface and forest cover loss is still high outside protected areas. Forest destruction and fragmentation for agriculture and the establishment of pastures are among the major causes of deforestation along the country (Ministerio del Ambiente 2009). This is particularly high east of the Andes, in the departments of San Martín, Amazonas, Loreto, and Junín (Ministerio del Ambiente 2009). Although forest loss inside protected areas is small, the opposite is the case in areas adjacent to parks and reserves (i. e. buffer areas of Parque Nacional Cordillera Azul and Reserva Nacional Pacaya Samiria), and indigenous lands (Ministerio del Ambiente 2015a). Increased fragmentation of natural ecosystems beyond protected area limits may pose a serious threat for wildlife conservation, particularly for large-sized species with low reproduction rates and/ or with limited dispersal abilities (Terborgh 1974, Pimm *et al.* 1988). Among raptors, this might be particularly relevant for species with large spatial requirements that are associated to forested ecosystems, and for small species that favour forest interiors (Thiollay & Meyburg 1988, Bierregaard 1998, Thiollay 2006). Categorization of globally threatened species is based on two main parameters: population size (and reduction of population size in time), and geographic range of species (International Union for the Conservation of Nature 2012).

Defining a species distribution range and estimating its range size is relevant because the later it is strongly correlated with species extinction risk (Gaston & Fuller 2009). Species ranges that are extrapolated from point data, tend to assume that a species is uniformly distributed within its range and increase commission errors (i. e., that the species is present in areas where is not) (Rondinini *et al*. 2006, Gaston & Fuller 2009). Predicted species distribution and range maps obtained from point data and environmental variables can produce an ordinal scale of habitat suitability, thus providing information on the variations of the likelihood of occurrence of the species within its predicted range. However, range maps obtained from a few sampled populations can increase omission errors (i. e., that a species is absent in areas where is not) and thus are likely to be less representative that those generated from many populations (Rondinini *et al*. 2006).

I used Maxent 3.3.3k (Phillips et al. 2006, Elith *et al*. 2011) to model the potential distribution of eight threatened diurnal raptor species that occur in Peru. Maxent is frequently used to produce species distribution maps from presence only data that is combined with environmental variables at those locations were the species is present (Tinoco *et al*. 2009, Piana 2016b). Species included in analysis were: Andean Condor, Gray-backed Hawk, Solitary Eagle, Black-and-chestnut Eagle, Semicollared Hawk, Gray-bellied Hawk, Harpy Eagle, and Crested Eagle.

The objectives of this study were: 1. Model the potential distribution of eight threatened diurnal raptor species that occur in Peru. 2. Measure the area (potential distribution area –PDA) where these species occur and use this metric as a surrogate of the species extent of occurrence (EOO) in Peru (Gaston 1991, Gaston & Fuller 2009), and 3. Measure how much of the species PDA is covered by strictly protected areas in Peru. These findings are used as a proxy of habitat and species protection in Peru and are analysed to generate recommendations for the conservation of these species in the long term.

METHODOLOGY

For all species, I obtained presence points from ebird (www.ebird.org) and for the Gray-bellied and Semicollared Hawks, I also obtained coordinates of specimens collected in Peru, Colombia and Brazil from the Global Biodiversity Information Facility (GBIF -http://www.gbif.org/species). To minimize confusion between similar species (i. e., Harpy Eagle with Crested Eagle, Solitary Eagle with Great Black Hawk –*Buteogallus urubitinga*), and reduce commission errors, I prioritized the selection of ebird reports that included pictures of the species to be modelled. I minimized omission and commission errors (Gaston & Fuller 2009) in obtaining PDA of species by selecting presence points that were more than 20 km apart from each other for smaller species and 50 km for the larger ones.

Number of points used for models were: 13 for Semicollared Hawk, 15 for Solitary

Eagle, 16 for Harpy Eagle, 18 for Crested Eagle, 19 for Black-and-chestnut Eagle, 23 for Gray-bellied Hawk, 29 for Gray-backed Hawk and 36 for the Andean Condor. For all species, at least 90% of the location points used in models were from Peru, and the rest from locations next to the Peruvian border in adjacent countries. Maximum entropy models for species were constructed using the Auto features and logistic output format with a jacknife to measure importance of variables in all models. Environmental variables were obtained from http://biodiversityinformatics.amnh.org/open_source/maxent/ with a resolution of 0.05° x 0.05° and were later cut to fit the map of South America; this area was used as background area for all models. Best models were those with higher Area Under the Curve (AUC) values (Fielding & Bell 1997, Elith *et al*. 2011). Climatic variables included in all models (from 1961 to 1990) were mean and maximum annual temperature (only minimum temperature for the Andean Condor) and elevation and ecoregions (only elevation for Black-and-chestnut eagle). Precipitation for January and July were included in models for Harpy and Crested eagles and Gray-bellied Hawk. Additionally, annual vapor pressure was included in models for Solitary and Black-and-Chestnut eagles and Semicollared Hawk. Annual frost frequency was included in models for Harpy and Crested eagles and the Andean Condor.

PDA of species was calculated from potential distribution maps of species obtained from Maxent. PDA of species were those polygons where the habitat suitability Maxent values ranged from 40 to 100, and thus represented areas where potential distribution of the species in Peru was the highest. A similar threshold was used by (Piana 2016b) and Piana and Vargas (2018) to establish best potential habitats for Gray-backed hawks and Andean condors in Peru. PDA of species was then overlaid with a shapefile of strictly protected areas in Peru (national parks, national sanctuaries, historic sanctuaries) that were established until August 2016 and that was produced by the Protected Area Service (Servicio Nacional de Areas Naturales Protegidas por el Estado –Sernanp). Measurements of PDA of raptor species, their overlap with strictly protected areas and distance between non-contiguous protected areas was done with ArcGis release 10.1 (ESRI 2011).

RESULTS

In Peru, the protected area system has 28 strictly protected areas. Of these, 15 are national parks, nine are national sanctuaries and four historical sanctuaries. Areas range from 3 km^2 (Pampa de Ayacucho Historical Sanctuary) to 25 107 km^2 (Purus National Park). However, most strictly protected areas are small, with 14 having areas smaller than 500 km^2 and six larger than 3 000 km^2. Among the largest (≥ 3 000 km^2), only Huascarán National Park is on the western Andean slope. Otishi National Park protect forest above 750 m on the eastern slope of the central Andes while Bahuaja Sonene and Manu National Parks (≥ 10 000 km^2), in southeast Peru, protect small portions of montane forests east of the Andes. Average closest distance between non-contiguous strictly protected areas that protect montane forests in north and central Peru (Abiseo and Yanachaga-Chemillen National Parks and Tabaconas-Namballe National Sanctuary) is 304.9 km while that of areas in the south east (Manu and Bahuaja-Sonene National Parks) is 115.2 km.

Except for the Gray-bellied Hawk, all species included in this study have declining populations (BirdLife International 2018). For the Semicollared Hawk, population trend is stable (BirdLife International 2018). PDA of the Gray-bellied Hawk was the largest (699 229 km^2), while that of the Gray-backed Hawk (5 766 km^2) was the smallest. Mean PDA for all species was 295 189.7 km^2, %CV = 82.2, N = 8. On average, strictly protected areas covered 11.3%, %CV = 64.9, N = 8 of all species PDA. See table 1.

For the Tumbesian endemic and endangered Gray-backed Hawk, 26.3% of its PDA overlapped with one strictly protected area (Cerros de Amotape National Park) however, the PDA of the wide-ranging and near threatened Andean Condor overlapped with 17 strictly protected areas, yet these only protected 2% of the species range. PDA of Black-and-chestnut Eagle and Semicollared Hawk were among the smallest and the less protected (see Fig. 1).

Mean number of strictly protected areas that overlapped completely with PDA of raptor species more associated to lowland areas in the east (Harpy Eagle, Crested Eagle and Gray-bellied Hawk) was higher to those that overlapped with the PDA of species associated to montane forests (Solitary Eagle, Semicollared Hawk and Black-and-chestnut Eagle): 4.7, %CV = 32.5, N = 3, and 3, %CV = 25.0, N = 3, respectively, while the total number of strictly protected areas that overlapped partially with PDA of lowland species was 17 vs 14 for montane species. Mean percentage of PDA of lowland species covered by strictly protected areas was also higher than that of montane species: 12.1, %CV = 4.8, N = 3, and 8.5, %CV = 51.5, N = 3 respectively. See Table 1.

Species	IUCN/Pop. trend	MINAGRI	PDA (Km^2)	PA (total)	PA (Partial)	%PDA in PA
Andean Condor	NT/decreasing	EN	481 760	10	7	2.0%
Gray-backed Hawk	EN/decreasing	EN	5 766	1	0	26.3%
Solitary Eagle	NT/decreasing	NI	176 982	5	5	11.7%
Black-and-chestnut Eagle	EN/decreasing	VU	108 153	2	7	10.3%
Semicollared Hawk	NT/stable	VU	81 763	2	2	3.5%
Gray-bellied Hawk	NT/increasing	NI	699 229	6	7	11.8%
Harpy Eagle	NT/decreasing	VU	653 076	3	5	11.8%
Crested Eagle	NT/decreasing	VU	667 161	5	5	12.8%

Table 1. Potential Distribution Area (PDA) of diurnal raptors in Peru and percentage of PDA covered by strictly protected areas (%PDA in PA). IUCN/Pop. trend and MINAGRI are the global and national categories of threat for species and global population trend according to IUCN/BirdLife International. PA (total) is the number of entire strictly protected areas included on each species PDA, PA (Partial) is the number of protected areas that are included partially. NI: Not included.

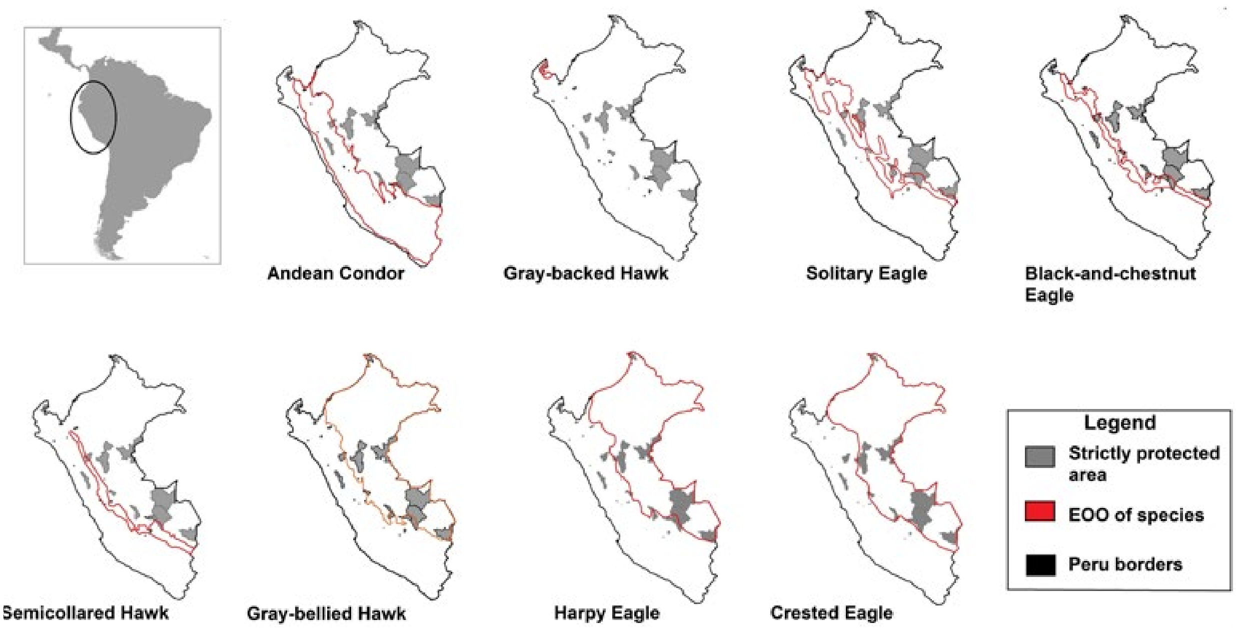

Figure 1. Potential Distribution Area of eight endangered diurnal raptor species in Peru and overlap with strictly protected areas

DISCUSSION

In this study I used a species distribution model (SDM) from presence-only data to define the potential distribution area of eight endangered diurnal raptor species in Peru and to measure how much of these polygons were inside strictly protected areas within the country. My results show that for range restricted species such as the Gray-backed Hawk and large lowland eagles, strictly protected areas are protecting enough habitat and individuals. However, for large montane eagle species and for the Andean Condor strictly protected areas might not be enough to sustain viable populations.

Extent of occurrence (EOO), a measure of a species geographic range or of the area that encompasses all localities where a species is present (Gaston 1991, Gaston & Fuller 2009) has been previously used to assess the conservation status of diurnal raptors in South America (Naveda-Rodriguez *et al*. 2016). Although its use for species conservation has been considered over simplistic because is based on assumptions that are not always met (i. e., stationary elevation ranges, inclusion of forest/non-forest covers not used by species), EEOs can be refined through the use of data-driven techniques, like those employed in SDM (Peterson *et al*. 2016).

Strictly protected areas in the Peruvian central and south eastern lowlands protect more than 66 500 km^2 of mostly pristine habitat. Being part of the Vilcabamba-Amboró conservation corridor (Bennet 2004), they are well suited to maintain connectivity and protect populations of large and small endangered lowland raptor species such as the Harpy and Crested Eagles and the Gray-bellied Hawk. However, since 1999, approximately 500 km^2 of mostly pristine lowland forests have been completely cleared for mining including portions of Bahuaja Sonene National Park buffer area (Asner *et al*. 2013, Finer *et al*. 2016). Protection of large eagles here should focus in controlling logging of nesting trees, shooting and removal of adults and young individuals.

Large diurnal raptors have low densities, patchy distribution and large spatial requirements. For this, it is assumed that large and connected reserves are necessary to maintain populations that ensure their long-term survival (Thiollay 1989, Margules & Pressey 2000). In Asia and Africa, breeding areas of large raptor species in forested habitats were 2600 ha for the Mountain Hawk-eagle (*Nisaetus nipalensis* –Yamazaki 2000) and 6500 ha for the Crowned Eagle (*Stephanoetus coronatus*; Shultz 2002). For the endemic Javan Hawk-eagle -*Nizaetus bartelsi* it was 710 ha (Gjershaug *et al*. 2004). In south east Peru, Valdez & Osborn (2004) registered two pairs of Black-and-chestnut eagles in 5100 ha of pristine forest, while the breeding area used by pairs of Harpy Eagles in Madre de Dios was 4300 ha (Piana 2007).

If, conservatively, breeding areas of Black-and-chestnut and Solitary Eagles in Peru are assumed to be 2500 ha, strictly protected areas in montane areas could hold 557 and 828 breeding pairs of Black-and chestnut and Solitary eagles respectively. However, these estimates assume that territories of individuals are contiguous, that preferred habitat is homogeneous inside protected areas and that no exclusion occurs between species when breeding. Montane forest in Peru are severely threatened by human encroachment and forest degradation for agriculture and pastures (Myers *et al*. 2000, Ministerio del Ambiente 2015b). Although strictly protected areas along the eastern Andean slopes (from Cajamarca to Cusco) protect almost 10 000 km^2 of montane forests that are the habitat of the Black-and-chestnut and Solitary Eagles and the Semicollared Hawk, closest protected areas in the northern part of the species PDA are approximately 300 km from each other so it is uncertain if individuals will be able to disperse between them. If further forest fragmentation, land use changes and human encroachment occur between parks and sanctuaries in montane forests, individuals might become isolated and locally extirpated. In Peru, this is particularly relevant for the Black-and-chestnut and Solitary Eagles and the Semi-collared Hawk (Araoz *et al*. 2017).

Expansion of Otishi National Park and the creation of new protected areas between this and Yanachaga-Chemillen National Park, as recommended by Fajardo *et al*. (2014) could increase the amount of habitat protected for montane raptor species and can increase connectivity between populations in Manu National Park and central Peru. However, the creation of protected areas that are able to sustain viable populations of these species in the central slopes east of the Andes is very difficult given that most suitable habitat are located within mining and oil/gas concessions and indigenous and peasant communities (INGEMMET 2017, SICNA 2017). Probably the best option to preserve these habitats is to work with local communities in the conservation of remaining forested areas inside communal lands via agreements as those implemented by the national forest conservation program (Programa Nacional de Conservación de Bosques) that is helping to preserve almost 3 000 km^2 of forests in the departments of San Martin, Pasco and Junin (Programa Nacional de Conservación de Bosques 2016). Additionally, the increased protection of forested habitats inside large protected areas that allows direct use of resources (e. g., national reserves, communal reserves, etc.) could also foster the protection of threatened raptors in Peru.

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