Journal of Environmental Management 202 (2017) 12–20

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Protected area coverage of threatened vertebrates and ecoregions in Peru: Comparison of communal, private and state reserves

Sam Shanee [a, b, c, *], Noga Shanee [a, b], Bruno Monteferri [d], Nestor Allgas [b], Alejandro Alarcon Pardo [b], Robert H. Horwich [e]

[a] Neotropical Primate Conservation, Manchester, UK
[b] Asociación Neotropical Primate Conservation Perú, Lima, Peru
[c] Nocturnal Primate Research Group, Oxford Brookes University, Oxford, UK
[d] Conservamos por Naturaleza, Sociedad Peruana de Derecho Ambiental, Lima, Peru
[e] Community Conservation, WI, USA

ARTICLE INFO

Article history:
Received 2 March 2017
Received in revised form
15 June 2017
Accepted 10 July 2017

Keywords:
IUCN red list
Conservation
Local initiatives
Private reserves
Community conservation

ABSTRACT

Protected areas (PAs) are a conservation mainstay and arguably the most effective conservation strategy for species protection. As a 'megadiverse' country, Peru is a priority for conservation actions. Peruvian legislation allows for the creation of state PAs and private/communal PAs. Using publicly available species distribution and protected area data sets we evaluated the coverage of Threatened terrestrial vertebrate species distributions and ecoregions provided by both kinds of PA in Peru. Peru's state PA system covers 217,879 km^2 and private/communal PAs cover 16,588 km^2. Of the 462 species of Threatened and Data Deficient species we evaluated, 75% had distributions that overlapped with at least one PA but only 53% had $\geq$10% of their distributions within PAs, with inclusion much reduced at higher coverage targets. Of the species we evaluated, 118 species are only found in national PAs and 29 species only found in private/communal PAs. Of the 17 terrestrial ecoregions found in Peru all are represented in PAs; the national PA system included coverage of 16 and private/communal PAs protect 13. One ecoregion is only protected in private/communal PAs, whereas four are only covered in national PAs. Our results show the important role private/communal PAs can play in the protection of ecological diversity.

1. Introduction

The current global extinction crisis is predicted to increase in severity in the coming decades (Ceballos et al., 2015; Lewis, 2006; Purvis et al., 2000; Scheffers et al., 2016). Caused largely by anthropogenic activities (Asner et al., 2009; Estrada et al., 2017; Godfrey and Irwin, 2007; Moran and Kanemoto, 2017), current trends suggest that the world's tropical regions, home to the majority of terrestrial biodiversity (Dirzo and Raven, 2003; Myers et al., 2000), will be severely affected. A large loss of tropical vertebrate species diversity could have severe consequences for general ecosystem health (Hooper et al., 2005; Petchey, 2000). Other immediate consequences will be those effecting local human populations, including the loss of traditional natural resources, culturally important species and development opportunities from tourism and other forms of exploitation (Chapin Iii et al., 2000; Gascon et al., 2015).

Peru is considered one of the world's 'megadiverse' countries (McNeely et al., 1990; Noss, 1990). Its high level of species diversity is a result of the diversity of its ecosystems which are distributed between 19 terrestrial ecoregions (Fig. 1) (Olson and Dinerstein, 1998; Olson et al., 2001). The vast majority of Peru's vertebrate species are found in the Amazonian lowlands and Andean montane and pre-montane cloud forests (Pacheco et al., 2009). The remaining species are found distributed between its coastal deserts, dry forests, Andean Puna, and other habitats (ONERN, 1976; Rodríguez and Young, 2000).

Protected areas (PAs) have been a conservation mainstay for decades and are arguably the most effective conservation strategy for species protection (Gray et al., 2016; Hoffmann et al., 2010; Tognelli et al., 2008; Waldron et al., 2013). The locations of PAs are often chosen to protect representative ecosystems (Watson et al., 2010) or are based on socio-political criteria. This has often

* Corresponding author. Neotropical Primate Conservation, Manchester, UK.
E-mail addresses: samshanee@gmail.com, sam@neoprimate.org (S. Shanee).

http://dx.doi.org/10.1016/j.jenvman.2017.07.023
0301-4797/

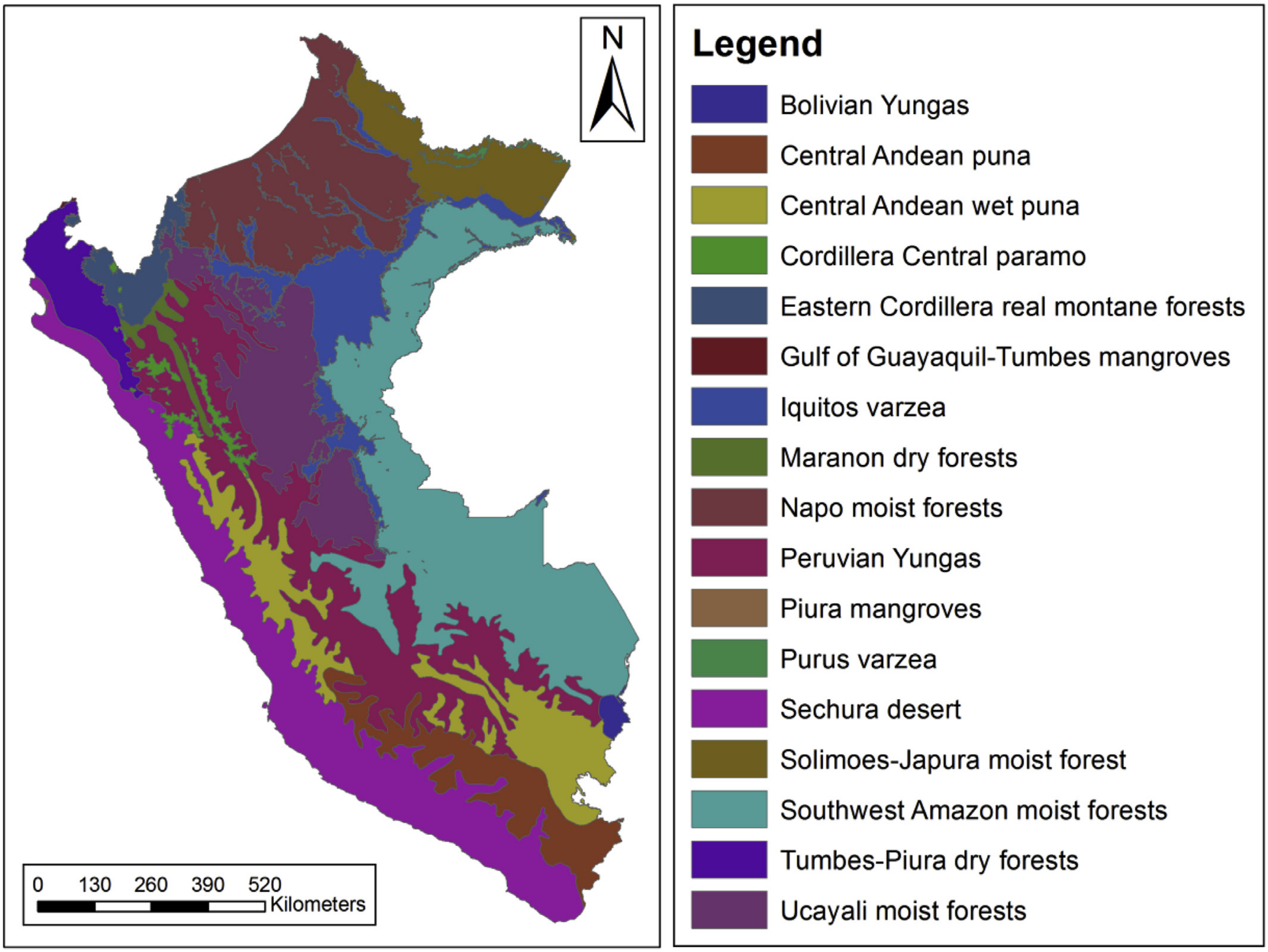

Fig. 1. Peru's major ecoregions, based on Olson and Dinerstein (1998) and Olson et al. (2001).

led to inadequate and unrepresentative coverage of species diversity, and does not prioritize Threatened species (Khan et al., 1997; Tognelli et al., 2008; Watson et al., 2010). Estimates suggest that globally only 15% of Threatened vertebrate species are 'adequately' covered by PAs (Venter et al., 2014). Previous studies in Peru have also reported inadequate coverage for a majority of species evaluated (Fajardo et al., 2014; Swenson et al., 2012; Young et al., 2009).

Conservation initiatives involving PAs in Peru have increased dramatically over the past few decades (Jenkins and Joppa, 2009; SERNANP, 2017). Protected area legislation in Peru began by following the traditional 'fines and fences' approach (Adams, 2004; Brockington, 2002; Hutton et al., 2005) but now also includes more inclusive conservation models, such as community conservation initiatives; those run by local stakeholders (Horwich and Lyon, 2007; Horwich et al., 2015; Kitamura and Clapp, 2013; Shanee et al., 2014), which include private/communal PAs (Hajek et al., 2011; Monteferri and Coll, 2009; Shanee et al., 2014; Stolton et al., 2014). Government PAs are divided between those that are run by the state (National Parks, National Sanctuaries, etc) and those run by regional governments (Regional Conservation Areas) (Monteferri and Coll, 2009). In Peru non-government PAs can be awarded to those with land titles, such as owners of family plots or on communally held lands, as a Private Conservation Areas (ACP) through application to the Ministry of the Environment (Law No. 26834 of 1997) or through conservation agreements based on the civil code. On un-titled lands with forest cover, individuals and organizations can request non-timber forestry concessions. The two most common are Conservation Concessions (CC) and Ecotourism Concessions (CE) (Law No. 29763 of 2015). There is no limit to the size of a CC, although CEs are limited to areas of $\leq$10,000 ha and are subject to an annual fee.

The first state PA, the 8214 ha Parque Nacional de Cutervo, was created in 1961. In contrast the first private PA, the 34,412 ha ACP Chaparri, wasn't created until 2001 as legal frameworks for ACPs were not previously available. The first Conservation Concession, the 135,955 ha Los Amigos CC, was also granted in 2001. The first Ecotourism Concessions weren't created until 2004, when four were formalized in the same year.

We use publicly available data to evaluate coverage of the distributions of terrestrial mammal, bird, reptile and amphibian species listed in one of the IUCN Red List Threatened categories or as Data Deficient (IUCN, 2016), and ecoregions (Olson and Dinerstein, 1998; Olson et al., 2001) provided by state and private/communal PAs in Peru. We pay particular attention to species and ecoregions that are found in only one type of PA.

2. Methods

Peru lies between 0°05′5″ and 18°25′3″ degrees south and 69°52′14″ and 81°26′25″ degrees west, covering ~1,285,216 km^2, with elevations ranging from sea level up to 6768 m above sea level (m.a.s.l.) (ONERN, 1976; Rodríguez and Young, 2000). Major terrestrial ecosystems found in Peru include mangrove, desert, dry forests, high mountain Sierras, *Puna*, montane and pre-montane cloud forests, *terra firme* and *varzea* Amazonian rainforests (ONERN, 1976; Rodríguez and Young, 2000). Thirty of 32 world climates are found in Peru with temperatures ranging from bellow 0 °C in the Andean peaks to 38 °C in the northern coastal deserts, rainfall is similarly variable with 10 mm annual rainfall in the southern coastal deserts to over 2800 mm in the north eastern Amazonian rainforests (www.senamhi.gob.pe). Habitat loss across Peru is high (Llactayo et al., 2013a, b). Approximately 7 million hectares of the country's humid forests were lost by the year 2011 (Llactayo et al., 2013a, b).

We gathered data on species distribution for amphibians, mammals and reptiles from the IUCN Redlist (IUCN, 2016), birds from Birdlife International (BirdLife International and NatureServe, 2015) and ecoregions from the World Wildlife Foundation (Olson and Dinerstein, 1998; Olson et al., 2001). All species and ecoregion data layers were clipped within the national boundary. From these we extracted the geographic distributions of all species in Threatened categories (Vulnerable, Endangered and Critically Endangered) and those considered Data Deficient. We included Data Deficient species following recommendations for the use of the IUCN red list categories that Data Deficient species should not be considered as non Threatened as they have not been evaluated (IUCN, 2001), and as many DD species are rare or have restricted ranges they have a high chance of falling within one of the Threatened categories (IUCN, 2001).

For analysis we only considered species and ecoregions present on the Peruvian mainland, discarding marine, primarily aquatic and island taxa (for example marine turtles, seals and sea birds). Marine and aquatic animals were not evaluated as marine areas cannot be included in CCs, CEs or ACPs. Similarly larger bodies of water are less likely to be included in private land titles, and as such the inclusion of fresh water species would skew results. We cross referenced distribution data from other sources (Amphibiaweb, 2016; Cornell lab of Ornithology, 2016; ebird, 2016; Eisenberg and Redford, 1999; Emmons and Feer, 1997; AMONH, 2016; IUCN, 2016; Pacheco et al., 2009; Rowe and Myers, 2012; Schulenberg et al., 2010; Wilson et al., 2013; Xeno-canto, 2016) and our own expert knowledge. This enabled us to avoid possible errors in predicted distributions (Ocampo-Peñuela et al., 2016; Rodrigues, 2011), particularly important as the coarse nature of maps often meant that distributional limits were not accurately mapped, for example species limited by rivers along national boundaries showing false positive presence in Peru.

Geographic data on state PAs (Table 1) and private conservation areas (ACPs, Table 2) was taken from the Peruvian Ministry of the Environment (http://www.sernanp.gob.pe). Geographic data on CCs and CEs (Table 2) were taken from the *Organismo de Supervisión de los Recursos Forestales* (http://sisfor.osinfor.gob.pe/visor/). We did not include Communal Reserves (*Reserva Communal*) as part of the Private/Communal PA category as these areas are state funded initiatives with participation of indigenous communities and so do not qualify under our definition of private/communal PAs. We did not include *Cotos de Caza* (hunting areas) in analyses as, although considered part of the state PA system they are gazetted for the breeding of species for trophy hunting and not for species conservation.

To analyze levels of PA coverage we overlaid the PA layers (State, ACP, CC and CE) on the species distribution and ecoregion layers and extracted overlapping areas, calculating how much of each species' distribution was within PAs. We set four simple coverage targets 1) any coincidence of species distribution or ecoregions with PAs 2) ≥10 area within PAs, based on IUCN threat criteria A2, 3 and 4 for CR category 3) ≥17% of area within PAs, based on Aichi target 11 and 4) ≥50% are within PAs, based on IUCN threat criteria A2, 3 and 4 for VU category (CBD, 2014; IUCN, 2001, 2014; Rodrigues et al., 2004).

Table 1
Number and terrestrial coverage of different state PAs in Peru.

Type	No	Size	% of country
National Park	14	8,170,748	6.2
National Sanctuary	9	317,367	0.25
Historic Sanctuary	4	41,279	0.03
National Reserve	15	4,652,449	3.62
Wildlife Refuge	3	20,775	0.02
Protected Forest	6	389,987	0.30
Scenic Reserve	2	711,819	0.55
Communal Reserve	10	2,166,588	1.38
Hunting Area	2	124,735	0.10
Reserved Zone	12	1,505,921	2.74
Regional Conservation Area	18	28,000	0.02
Total	77	19,456,761	17.27

Table 2
Number and terrestrial coverage of private/communal protected areas in Peru.

Type	No	Size	% of country
Private Conservation Area	100	349,500	0.27
Conservation Concession	57	1,200,800	0.93
Ecotourism Concession	47	108,400	0.08
TOTAL	204	1,658,100	1.29

3. Results

Our analysis shows that the national PA system of Peru, including all categories of PA covers 217,879 km^2 of terrestrial habitats (17% of Peru's total land surface) (Fig. 2). Within this, 28,800 km^2 (13.2%) are in Regional Conservation Areas and 21,682 km^2 (10.0%) in Communal Reserves. Private/communal PAs cover 16,588 km^2 (1.29% of Peru's total land surface and 7.6% of the PA network), of which 3495 km^2 (21.1%) are in Private Conservation Areas, 12,009 km^2 (72.4%) in Conservation Concessions and 1085 km^2 (6.5%) in Ecotourism Concession.

Available data for the 486 possible terrestrial and mainland vertebrate species that we included in this study are incomplete and we were only able to get geographic distribution data for 462 species (95%). This included 247 Amphibians, 102 Birds, 86 Mammals and 27 Reptiles, all of which were used in analysis. Of these 347 (75%) had distributions that at least partially overlapped with at least one PA (Table 3). When including our three conservation target levels this fell to 53% for ≥10% coverage, 45% for ≥17% coverage and only 13% for ≥50% coverage. Of the groups of terrestrial vertebrates included in our analysis mammals received the best coverage at all target levels except ≥50% (Table 4). The PA network performed considerably worse for reptiles and amphibians at all target levels, except ≥50% coverage provided for Amphibians (Table 4). There was also considerable variation in coverage of different IUCN categories by PAs, with PAs performing best for EN and VU species in most categories (Table 4). PA coverage for CR species was worst at all levels except ≥50, although this only included 17% of CR species (Table 5).

The national PA system overlapped with 68% (315) of species,

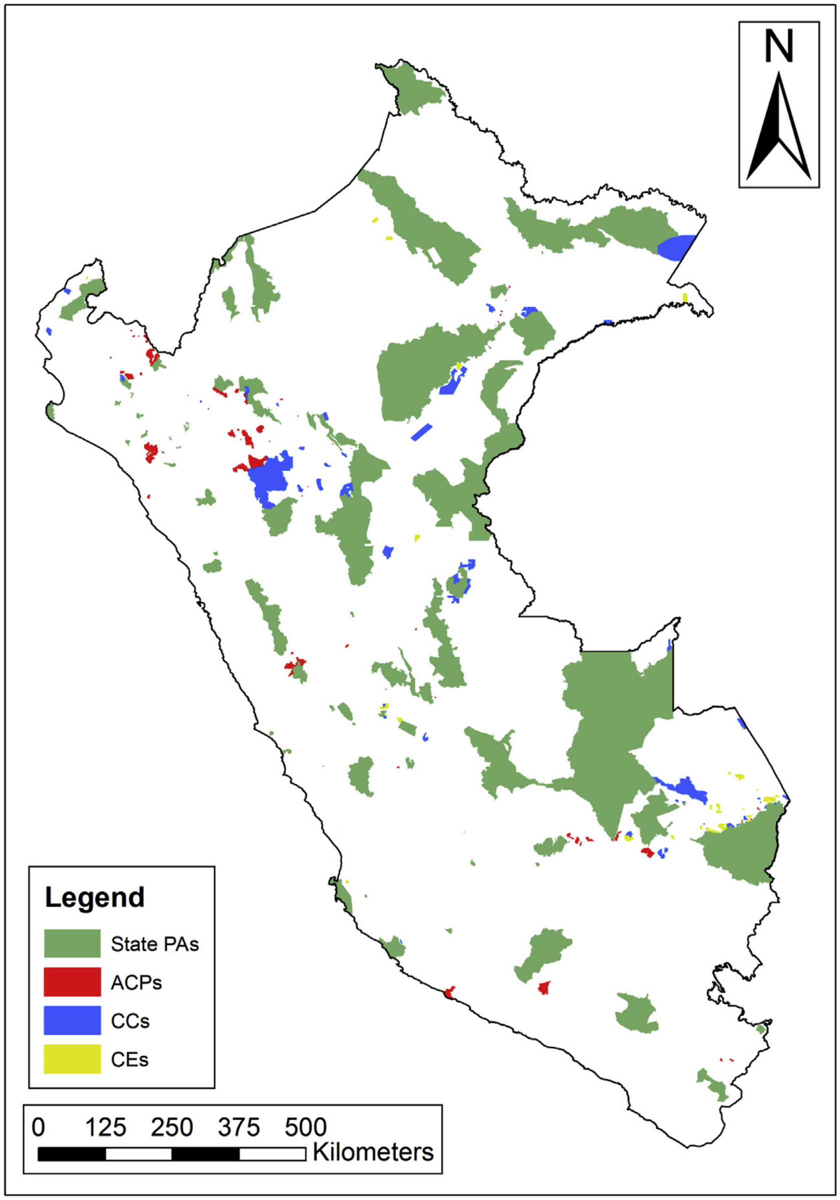

Fig. 2. Distribution of the Peruvian protected area system, showing state and Private/Communal PAs.

Table 3
Number of Threatened and Data Deficient species and ecoregions with distributions that overlap with different PAs management types in Peru.

Class	Total	IUCN Category	Present in State PA (%)	Present Private/Communal PA (%)	Total (%)
Amphibian	27	CR	7 (26)	4 (15)	8 (30)
Amphibian	42	EN	25 (60)	18 (43)	31 (74)
Amphibian	39	VU	27 (69)	16 (41)	26 (67)
Amphibian	139	DD	69 (50)	41 (29)	85 (61)
Bird	9	CR	8 (89)	3 (33)	8 (89)
Bird	27	EN	25 (93)	18 (67)	25 (93)
Bird	66	VU	60 (91)	53 (80)	63 (95)
Bird	0	DD	–	–	–
Mammal	3	CR	1 (33)	2 (67)	2 (67)
Mammal	10	EN	10 (100)	8 (80)	10 (100)
Mammal	34	VU	33 (97)	29 (85)	33 (97)
Mammal	39	DD	36 (92)	26 (67)	37 (95)
Reptile	2	CR	1 (50)	0 (0)	1 (50)
Reptile	3	EN	2 (67)	1 (33)	3 (100)
Reptile	3	VU	3 (100)	2 (67)	3 (100)
Reptile	19	DD	8 (42)	5 (26)	8 (42)
Ecoregion	17	–	16 (94)	13 (76)	17 (100)

Table 4
Percentage coverage of Threatened and Data Deficient species distributions and ecoregions by PA network in Peru.

Class	Total	IUCN Category	Overlapping distribution (%)	≥10% coverage (%)	≥17% coverage (%)	≥50% coverage (%)
Amphibian	27	CR	8 (30)	5 (19)	4 (15)	3 (11)
Amphibian	42	EN	30 (71)	22 (52)	17 (40)	7 (17)
Amphibian	39	VU	28 (72)	19 (49)	17 (44)	4 (10)
Amphibian	139	DD	85 (61)	62 (45)	57 (41)	29 (21)
Total	247		151 (61)	108 (44)	95 (39)	43 (17)
Bird	9	CR	8 (89)	5 (56)	5 (56)	4 (44)
Bird	27	EN	24 (89)	19 (70)	16 (59)	5 (19)
Bird	66	VU	63 (95)	45 (68)	36 (55)	7 (11)
Bird	0	DD	–	–	–	–
Total	102		95 (93)	69 (68)	57 (56)	16 (16)
Mammal	3	CR	2 (67)	1 (33)	1 (33)	0 (0)
Mammal	10	EN	10 (100)	6 (60)	6 (60)	0 (0)
Mammal	34	VU	33 (97)	27 (79)	20 (59)	4 (12)
Mammal	39	DD	37 (95)	29 (74)	28 (72)	5 (13)
Total	86		82 (95)	63 (73)	55 (64)	9 (11)
Reptile	2	CR	1 (50)	0 (0)	0 (0)	(0)
Reptile	3	EN	3 (100)	1 (33)	1 (33)	1 (33)
Reptile	3	VU	3 (100)	1 (33)	0 (0)	0 (0)
Reptile	19	DD	8 (42)	5 (26)	4 (21)	1 (5)
Total	27		12 (44)	7 (26)	5 (19)	2 (7)
Ecoregion	17	–	17 (100)	8 (47)	6 (35)	0 (0)

Table 5
Percentage coverage by Peruvian PA network for different IUCN threat categories.

Category	Total	Overlapping distribution (%)	>10 (%)	>17 (%)	>50 (%)
CR	41	19 (46)	11 (27)	10 (24)	7 (17)
EN	82	67 (82)	48 (60)	40 (49)	13 (15)
VU	142	131 (92)	100 (70)	74 (52)	18 (13)
DD	197	130 (66)	96 (49)	89 (45)	35 (18)
Total	462	347 (75)	255 (55)	213 (46)	73 (16)

while private/communal PAs overlapped with 49% (226) of species. The distributions of 118 species only overlapped with the national PA system (Table 3). Similarly, there were 29 species whose distributions only overlapped with private/communal PAs (Table 3). Of Threatened and Data Deficient species found within PAs, there were 10 (53%) Critically Endangered species, 22 (33%) Endangered species, 24 (19%) Vulnerable species and 58 (45%) Data Deficient Species in Peru that are only protected within state PAs (Supplementary Table 1). Similarly, there is 1 (5%) Critically Endangered species, 7 (10%) Endangered species, 4 (3%) Vulnerable species and 21 (16%) Data Deficient species that are only protected within private/communal PAs (Supplementary Table 1).

All 17 terrestrial ecoregions (Olson et al., 2001) found in Peru are represented within PAs. The national PA system includes coverage of 16 (89%) terrestrial ecoregions, whereas private/communal PAs included 13 (72%). One terrestrial ecoregion, Rio Marañón dry forest, is only protected in private/communal PAs, whereas three ecoregions are only covered by the national PA system (Table 3). PAs provided ≥17% (Aichi target 11) coverage for six ecoregions (35%) (Table 4).

4. Discussion

The Convention on Biological Diversity Aichi Target 11 is to have 17% coverage of terrestrial land area in PAs by 2020 (CBD, 2014; Venter et al., 2014), increasing from the 10% target set in 2003 (Brooks et al., 2004), with an additional target (12) of preventing the extinction of Threatened species (Venter et al., 2014). Based on our results, Peru has already passed the Aichi target (11) of 17% of its territory in PAs, three years ahead of schedule. However our results show that Peru's PA network does not provide coverage representative of the diversity of Threatened terrestrial vertebrates. Although the network at least partially overlaps the distributions of 76% of species, this is much reduced when including our target protection levels, with just over half of species receiving at least 10% coverage of their distributions, the minimum needed to maintain them above CR status and only 16% of species distributions covered to over 50%. Similarly only 35% of ecoregions are covered to Aichi target 11 level (Table 4). The national parks system overlaps with 69% of species and 16 of 17 ecoregions. However, there still remain many Threatened species that would lack protection without the presence of the substantial number of private/communal PAs in Peru. This is also true for the Rio Marañón dry forest which is restricted to Peru (Fig. 1) and only protected in private/communal PAs.

Previous studies have evaluated PA coverage of species distributions in Peru and neighboring countries. Young et al. (2009) found that 77% of birds species endemic to the eastern Andean slopes of Peru and Bolivia had minimal protection (≥1000 km^2 within PAs, or 80% coverage for species with distributions <1000 km^2). In another evaluation of 800 endemic birds, mammals, amphibians and plants, across the eastern Andes in Peru and Bolivia, Swenson et al. (2012) found that a third of species they evaluated were not protected at all and that 40% of ecological systems had <2% coverage in PAs. Although differences in methods and conservation targets used make direct comparison difficult, we found lower coverage, even at the minimal 10% target for Threatened vertebrates as well as for ecoregions. Fajardo et al. (2014) evaluated coverage of 2869 species of terrestrial amphibian, reptile, mammal, birds, helicoiine butterflies and plants in Peru, modeling species distributions and overlaying their models on a state PA layer, evaluating coverage scaled for species distribution size between 5% for species with distributions ≥200,000 km^2 and 25% for species with distributions ≤1000 km^2. They found that 71% of species were well represented in the PA network but that only 28% of Threatened and Data Deficient species met conservation goals, lower than our results.

At the global level, previous studies have found between 75 and 88% PA coverage of Threatened species distributions (Brooks et al., 2004; Butchart et al., 2015; Rodrigues et al., 2004; Venter et al., 2014). This places Peru below the global average, highlighting one of the issues raised about targets based on area coverage of PAs, such as Aichi target 11 (Gaston, 2000; Kamdem-Toham et al., 2003; Pressey, 1994) which do not consider distributions of Threatened species. Brooks et al. (2004) found that globally, mammals were the best protected group, followed by amphibians and then birds. They did not evaluate reptiles as a whole, only turtles, finding that this group was the best protected (Brooks et al., 2004). Fajardo et al. (2014) found that in Peru birds and amphibians were best protected followed by reptiles and mammals. In contrast, we found mammals and birds are the best protected and less than half of Threatened amphibians reach even the $\geq$10% target.

The important contribution made by private/communal PAs is highlighted by the additional coverage provided to Peru's Threatened vertebrates and ecoregions. Our analyses show that there are Threatened species from all vertebrate groups and ecoregions that are only represented in private/communal PAs, including some amphibians that receive up to 99% coverage of their known distributions in these types of PA (Supplementary Table 1). Species protection in PAs is more difficult in areas of high human population density. In such areas more small PAs are needed to provide protection where PAs of large geographic scale are not viable or are un-common (Bergl et al., 2007; García et al., 2005; Gaston, 2000; Hansen and Rotella, 2002; Muench and Martinez-Ramos, 2016; Pressey, 1994). Many species requiring the most urgent conservation action are restricted range, endemic species (Brooks et al., 2006; Peterson et al., 2000; Peterson and Navarro-Sigüenza, 1999). For such species perhaps the only practicable protection is through private/communal PAs, especially for those species only found in comparatively densely populated areas (Bergl et al., 2007; Muench and Martinez-Ramos, 2016; Rodrigues et al., 2004; Shanee et al., 2011; Venter et al., 2014). This is particularly important as only 20% of areas of high endemism and 20% of irreplaceable areas in the eastern Andes of Peru and Bolivia were found to be protected (Swenson et al., 2012) and at least 5 species of endemic bird in the same area are completely up-protected (Young et al., 2009).

Publicly available distribution maps are limited and open to error (Butchart et al., 2015; Gaston et al., 2008; Gray et al., 2016; Le Saout et al., 2013), particularly from extrapolation often based on geographically uneven sampling effort which can generate geographic and taxonomic bias (Soberón and Peterson, 2004). These inaccuracies in distribution maps can lead to errors of omission or commission (Ocampo-Peñuela et al., 2016; Rodrigues, 2011). That being said, they still remain the best option for large scale modeling when considering the difficulties of accurately modeling distributions. We reduced the possible effect of these errors in this analysis by cross referencing distribution data with published and un-published sources.

Most previous studies using publicly available data of PAs only included PAs in IUCN categories I-IV (IUCN, 2017), which exclude protected landscapes (category 5) and PAs with sustainable use of natural resources (Category 6). We used a more inclusive approach, including these types of reserves, as this better represents the actual state of PA coverage in Peru. The trend for PAs that include use is growing globally (Breunig, 2006; Buscher and Whande, 2007; Stolton and Dudley, 2010), with Peru enthusiastically promoting such schemes. The current WDPA database does not include any CCs or CEs for Peru, although it does include ACPs. One study conducted in southern Peru (Vuohelainen et al., 2012) found that these initiatives provided more effective protection then other types of PA; and therefore should be included in the WDPA database.

Previous studies have found the global distribution of PAs, both geographically and in species coverage to be un-representative of biodiversity (Watson et al., 2010, 2014) and that often the most Threatened species and habitat types are poorly represented in PA systems (Beresford et al., 2011; Bergl et al., 2007; Rodríguez and Young, 2000; Tognelli et al., 2008; Watson et al., 2010). Conversely, one study showed that species endemism was the best predictor of PA presence (Loucks et al., 2008) and that, in the Neotropics, Threatened status was a good predictor of PA presence (Loucks et al., 2008). Globally the majority of PAs are found in areas of low economic value and/or human population densities (García et al., 2005; Gaston, 2000; Hansen and Rotella, 2002; Pressey, 1994). It has been suggested that new PAs and expansion of existing PAs and PA networks should be targeted to areas of highest pressure and greatest need (Bergl et al., 2007; Butchart et al., 2015).

One study showed that with just a 6% expansion of PA coverage, to 17.8%, Australia's PA network (Watson et al., 2010), and a global increase to between 22 and 31%, would provide coverage for all Threatened vertebrates (Gray et al., 2016). These targets are within Peru's reach; especially if private/communal PAs are prioritized in areas of high human population density. Expansion has been suggested to be prohibitively expensive (McCarthy et al., 2012) and meaningful levels of protection in expanded PA networks may not be possible considering that many existing PAs are poorly protected and managed (Bruner et al., 2001; Le Saout et al., 2013; Leverington et al., 2010; Scheffer et al., 2015; Watson et al., 2014). Similarly various studies suggest that current PA networks, including Peru's, are inadequate for species protection (Butchart et al., 2015; Khan et al., 1997; Swenson et al., 2012; Tognelli et al., 2008; Watson et al., 2010; Young et al., 2009). This is especially important to consider as political concerns and development demands mean that some countries are falling behind Aichi targets and even decreasing PA coverage (Bernard et al., 2014; Watson et al., 2014).

The current global coverage for terrestrial protected areas stands at 12.5%, with an additional 12% in indigenous reserves (IUCN, 2014; UNEP-WCMC, 2014). Although our analysis shows that Peru has already reached the 2020 Aichi target 11, coverage is not representative of species' conservation needs and so may fail to achieve Aichi target 12. Previous studies have suggested that targets based on percentage PA coverage are not desirable as they fail to take into account the distribution of species and habitat types (Pressey, 1994; Gaston, 2000; Kamdem-Toham et al., 2003; Rodrigues et al., 2004). This should be of particular importance for 'megadiverse' countries such as Peru (McNeely et al., 1990; Noss, 1990), where the high percentage of endemic species with limited geographical ranges (Pacheco et al., 2009) means untargeted PA coverage is unlikely to lead to adequate levels of protection, for both Threatened and non-threatened species, which is further compounded by gaps in knowledge of species distributions (Fajardo et al., 2014; Soberón and Peterson, 2004). As such, achievement of Aichi target 11 will be insufficient for species conservation in Peru and similarly biologically diverse countries.

We found that the PA network in Peru is lacking in coverage of Threatened species and ecoregions at even minimum target levels. Furthermore presence within state PAs does not ensure species protection as many of Peru's PAs can be considered "paper parks", where staff and funding are scarce and physical state presence absent (Naughton-Treves et al., 2006; Swenson et al., 2011). This has been exacerbated by the spate of creating of new state PAs, 21 of 62 state PAs have been created since 2007 (SERNANP, 2017), as such many of Peru's PAs suffer from legal and illegal mining operations, extraction of hydrocarbons, logging, forest clearing, hunting, land trafficking and road construction, among other threats (Shanee and Shanee, 2016; Swenson et al., 2011; Vuohelainen et al., 2012).

More funding and improved management of existing PAs is required to successfully meet conservation targets (Gray et al., 2016; Waldron et al., 2013; Watson et al., 2014) and all types of private/communal PAs should appear in national strategies and action plans (Butchart et al., 2015). The additional coverage provided to Threatened species and ecoregions by private/communal PAs could provide increased protection in priority areas where traditional, large, state PAs are not viable (Butchart et al., 1995;

Horwich et al., 2013, 2015; Shanee et al., 2014). It must be highlighted that we did not include any measure of quality of protection or management in this study. Including these additional variables would certainly reduce measures of effectiveness of the Peruvian PA system, for both state and private/communal PAs. Both kinds of PA can suffer from deficiencies related to many aspects of their management (Leverington et al., 2010). In some cases private/communal PAs can provide better protection for forests than state PAs thanks to good monitoring practices and good relations with surrounding communities (Vuohelainen et al., 2012). These kinds of PAs can also provide specific management solutions for local-level threats and politics (Le Saout et al., 2013). This is important if countries, including Peru, are to meet conservation targets and provide cost-effective avenues for the expansion of PA systems (Gray et al., 2016; Loucks et al., 2008).

Covering an area less than one order of magnitude of that covered by state PAs in Peru, private/communal PAs still provide important coverage in areas that lack state PAs. We recommend that conservation planners and funders focus more attention on the benefits of private/communal PAs. In Peru formal registration of private conservation initiatives is hindered by a complex and expensive legal process which discourages creation of private/communal PAs (Shanee, 2016; Shanee et al., 2014, Submitted). Facilitating legal mechanisms to ease the creation, management and reporting requirements would ease the burden on local stakeholders who often lack the proper education and access to economic resources currently required. Conservation funders should overhaul application processes, reducing focus on academic qualifications, in order to facilitate access to necessary resources, particularly for long term management. This is especially true as globally communities protect as much area as official reserves (Kothari, 2006).

Acknowledgements

We dedicate this manuscript to the memory of our co-author Dr Robert Horwich (1940–2017) for his contributions in developing community conservation work in Peru and across the globe. We wish to thank the two anonymous reviewers and the editor for their comments on a previous version that have greatly improved this manuscript. We are grateful to Brooke Aldrich, Luis Zari and Ashley Atkins for their help with this study. We would also like to acknowledge the contribution made by all private/communal PA managers in Peru for their dedication and contribution to conservation. Our work in Peru is supported by Neotropical Primate Conservation and the Sociedad Peruana de Derecho Ambiental.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2017.07.023.

References

Adams, W.M., 2004. Against Extinction: the Story of Conservation. Earthscan, London.

AMONH, 2016. Amphibian Species of the World 6.0. American Museum of Natural History.

Amphibiaweb, 2016. Amphibiaweb.

Asner, G.P., Rudel, T.K., Aide, T.M., Defries, R., Emerson, R., 2009. A contemporary assessment of change in humid tropical forests (Una Evaluación Contemporánea del Cambio en Bosques Tropicales Húmedos). Conserv. Biol. 23, 1386–1395.

Beresford, A.E., Buchanan, G.M., Donald, P.F., Butchart, S.H.M., Fishpool, L.D.C., Rondinini, C., 2011. Poor overlap between the distribution of protected areas and globally Threatened birds in Africa. Anim. Conserv. 14, 99–107.

Bergl, R.A., Oates, J.F., Fotso, R., 2007. Distribution and protected area coverage of endemic taxa in West Africa's Biafran forests and highlands. Biol. Conserv. 134, 195–208.

Bernard, E., Penna, L.A.O., AraÚJo, E., 2014. Downgrading, downsizing, degazettement, and reclassification of protected areas in Brazil. Conserv. Biol. 28, 939–950.

BirdLife International and NatureServe, 2015. Bird Species Distribution Maps of the World. BirdLife International, Cambridge, UK and NatureServe, Arlington, USA.

Breunig, L.A., 2006. Conservation in Context: Establishing Natural Protected Areas during Mexico's Neoliberal Reformation Department of Geography and Regional Development. University of Arizona.

Brockington, D., 2002. Fortress Conservation: the Preservation of the Mkomazi Game Reserve, Tanzania. James Currey, Bloomington.

Brooks, T.M., Bakarr, M.I., Boucher, T.I.M., Da Fonseca, G.A.B., Hilton-Taylor, C., Hoekstra, J.M., Moritz, T.O.M., Olivieri, S., Parrish, J., Pressey, R.L., Rodrigues, A.S.L., Sechrest, W.E.S., Stattersfield, A.L.I., Strahm, W., Stuart, S.N., 2004. Coverage provided by the global protected-area system: is it enough? Bioscience 54, 1081–1091.

Brooks, T.M., Mittermeier, R.A., da Fonseca, G.A.B., Gerlach, J., Hoffmann, M., Lamoreux, J.F., Mittermeier, C.G., Pilgrim, J.D., Rodrigues, A.S.L., 2006. Global biodiversity conservation priorities. Science 313, 58.

Bruner, A.G., Gullison, R.E., Rice, R.E., da Fonseca, G.A.B., 2001. Effectiveness of parks in protecting tropical biodiversity. Science 291, 125.

Buscher, B., Whande, W., 2007. Whims of the winds of time? Emerging trends in biodiversity conservation and protected area management. Conserv. Soc. 5, 22–43.

Butchart, S.H.M., Barnes, R., Davies, C.W.N., Fernandez, M., Seddon, N., 1995. Observations of two threatened primates in the peruvian Andes. Primate Conserv. 19, 15–19.

Butchart, S.H.M., Clarke, M., Smith, R.J., Sykes, R.E., Scharlemann, J.P.W., Harfoot, M., Buchanan, G.M., Angulo, A., Balmford, A., Bertzky, B., Brooks, T.M., Carpenter, K.E., Comeros-Raynal, M.T., Cornell, J., Ficetola, G.F., Fishpool, L.D.C., Fuller, R.A., Geldmann, J., Harwell, H., Hilton-Taylor, C., Hoffmann, M., Joolia, A., Joppa, L., Kingston, N., May, I., Milam, A., Polidoro, B., Ralph, G., Richman, N., Rondinini, C., Segan, D.B., Skolnik, B., Spalding, M.D., Stuart, S.N., Symes, A., Taylor, J., Visconti, P., Watson, J.E.M., Wood, L., Burgess, N.D., 2015. Shortfalls and solutions for meeting national and global conservation area targets. Conserv. Lett. 8, 329–337.

CBD, 2014. Strategic Plan for Biodiversity.

Ceballos, G., Ehrlich, P.R., Barnosky, A.D., García, A., Pringle, R.M., Palmer, T.M., 2015. Accelerated modern human–induced species losses: entering the sixth mass extinction. Sci. Adv. 1.

Chapin Iii, F.S., Zavaleta, E.S., Eviner, V.T., Naylor, R.L., Vitousek, P.M., Reynolds, H.L., Hooper, D.U., Lavorel, S., Sala, O.E., Hobbie, S.E., Mack, M.C., Diaz, S., 2000. Consequences of changing biodiversity. Nature 405, 234–242.

Cornell lab of Ornithology, 2016. Neotropical Birds. www.neotropical.birds.cornell.edu.

Dirzo, R., Raven, P.H., 2003. Global state of biodiversity and loss. Annu. Rev. Environ. Resour. 28, 137–167.

ebird, 2016. Ebird. www.ebird.org.

Eisenberg, J.F., Redford, K.H., 1999. Mammals of the Neotropics: the Central Neotropics, vol. 3. University of Chicago Press, Chicago, USA.

Emmons, L., Feer, F., 1997. Neotropical Rainforest Mammals: a Field Guide. University of Chicago Press, Chicago, USA.

Estrada, A., Garber, P.A., Rylands, A.B., Roos, C., Fernandez-Duque, E., Di Fiore, A., Nekaris, K.A.-I., Nijman, V., Heymann, E.W., Lambert, J.E., Rovero, F., Barelli, C., Setchell, J.M., Gillespie, T.R., Mittermeier, R.A., Arregoitia, L.V., de Guinea, M., Gouveia, S., Dobrovolski, R., Shanee, S., Shanee, N., Boyle, S.A., Fuentes, A., MacKinnon, K.C., Amato, K.R., Meyer, A.L.S., Wich, S., Sussman, R.W., Pan, R., Kone, I., Li, B., 2017. Impending extinction crisis of the world's primates: why primates matter. Sci. Adv. 3.

Fajardo, J., Lessmann, J., Bonaccorso, E., Devenish, C., Muñoz, J., 2014. Combined use of systematic conservation planning, species distribution modelling, and connectivity analysis Reveals severe conservation gaps in a megadiverse country (Peru). PLoS One 9, e114367.

García, D., Quevedo, M., Obeso, J.R., Abajo, A., 2005. Fragmentation patterns and protection of montane forest in the Cantabrian range (NW Spain). For. Ecol. Manag. 208, 29–43.

Gascon, C., Brooks, Thomas M., Contreras-MacBeath, T., Heard, N., Konstant, W., Lamoreux, J., Launay, F., Maunder, M., Mittermeier, Russell A., Molur, S., Al Mubarak, Razan K., Parr, Michael J., Rhodin, Anders G.J., Rylands, Anthony B., Soorae, P., Sanderson, James G., Vié, J.-C., 2015. The importance and benefits of species. Curr. Biol. 25, R431–R438.

Gaston, K.J., 2000. Global patterns in biodiversity. Nature 405, 220–227.

Gaston, K.J., Jackson, S.J., Cantu-Salazar, L., Cruz-Pinon, G., 2008. The ecological performance of protected areas. Annu. Rev. Ecol. Evol. Syst. 39, 93–119.

Godfrey, L.R., Irwin, M.T., 2007. The evolution of extinction risk: past and present anthropogenic impacts on the primate communities of Madagascar. Folia Primatol. 78, 405–419.

Gray, C.L., Hill, S.L.L., Newbold, T., Hudson, L.N., Börger, L., Contu, S., Hoskins, A.J., Ferrier, S., Purvis, A., Scharlemann, J.P.W., 2016. Local biodiversity is higher inside than outside terrestrial protected areas worldwide. Nat. Commun. 7, 12306.

Hajek, F., Ventresca, M.J., Scriven, J., Castro, A., 2011. Regime-building for REDD+: evidence from a cluster of local initiatives in south-eastern Peru. Environ. Sci. Policy 14, 201–215.

Hansen, A.J., Rotella, J.J., 2002. Biophysical factors, land use, and species viability in and around nature reserves. Conserv. Biol. 16, 1112–1122.

Hoffmann, M., Hilton-Taylor, C., Angulo, A., Böhm, M., Brooks, T.M., Butchart, S.H.M., Carpenter, K.E., Chanson, J., Collen, B., Cox, N.A., Darwall, W.R.T., Dulvy, N.K., Harrison, L.R., Katariya, V., Pollock, C.M., Quader, S., Richman, N.I., Rodrigues, A.S.L., Tognelli, M.F., Vié, J.-C., Aguiar, J.M., Allen, D.J., Allen, G.R., Amori, G., Ananjeva, N.B., Andreone, F., Andrew, P., Ortiz, A.L.A., Baillie, J.E.M., Baldi, R., Bell, B.D., Biju, S.D., Bird, J.P., Black-Decima, P., Blanc, J.J., Bolaños, F., Bolivar-G, W., Burfield, I.J., Burton, J.A., Capper, D.R., Castro, F., Catullo, G., Cavanagh, R.D., Channing, A., Chao, N.L., Chenery, A.M., Chiozza, F., Clausnitzer, V., Collar, N.J., Collett, L.C., Collette, B.B., Fernandez, C.F.C., Craig, M.T., Crosby, M.J., Cumberlidge, N., Cuttelod, A., Derocher, A.E., Diesmos, A.C., Donaldson, J.S., Duckworth, J.W., Dutson, G., Dutta, S.K., Emslie, R.H., Farjon, A., Fowler, S., Freyhof, J., Garshelis, D.L., Gerlach, J., Gower, D.J., Grant, T.D., Hammerson, G.A., Harris, R.B., Heaney, L.R., Hedges, S.B., Hero, J.-M., Hughes, B., Hussain, S.A., Icochea, M.J., Inger, R.F., Ishii, N., Iskandar, D.T., Jenkins, R.K.B., Kaneko, Y., Kottelat, M., Kovacs, K.M., Kuzmin, S.L., La Marca, E., Lamoreux, J.F., Lau, M.W.N., Lavilla, E.O., Leus, K., Lewison, R.L., Lichtenstein, G., Livingstone, S.R., Lukoschek, V., Mallon, D.P., McGowan, P.J.K., McIvor, A., Moehlman, P.D., Molur, S., Alonso, A.M., Musick, J.A., Nowell, K., Nussbaum, R.A., Olech, W., Orlov, N.L., Papenfuss, T.J., Parra-Olea, G., Perrin, W.F., Polidoro, B.A., Pourkazemi, M., Racey, P.A., Ragle, J.S., Ram, M., Rathbun, G., Reynolds, R.P., Rhodin, A.G.J., Richards, S.J., Rodríguez, L.O., Ron, S.R., Rondinini, C., Rylands, A.B., Sadovy de Mitcheson, Y., Sanciangco, J.C., Sanders, K.L., Santos-Barrera, G., Schipper, J., Self-Sullivan, C., Shi, Y., Shoemaker, A., Short, F.T., Sillero-Zubiri, C., Silvano, D.L., Smith, K.G., Smith, A.T., Snoeks, J., Stattersfield, A.J., Symes, A.J., Taber, A.B., Talukdar, B.K., Temple, H.J., Timmins, R., Tobias, J.A., Tsytsulina, K., Tweddle, D., Ubeda, C., Valenti, S.V., Paul van Dijk, P., Veiga, L.M., Veloso, A., Wege, D.C., Wilkinson, M., Williamson, E.A., Xie, F., Young, B.E., Akçakaya, H.R., Bennun, L., Blackburn, T.M., Boitani, L., Dublin, H.T., da Fonseca, G.A.B., Gascon, C., Lacher, T.E., Mace, G.M., Mainka, S.A., McNeely, J.A., Mittermeier, R.A., Reid, G.M., Rodriguez, J.P., Rosenberg, A.A., Samways, M.J., Smart, J., Stein, B.A., Stuart, S.N., 2010. The impact of conservation on the status of the World's vertebrates. Science 330, 1503.

Hooper, D.U., Chapin, F.S., Ewel, J.J., Hector, A., Inchausti, P., Lavorel, S., Lawton, J.H., Lodge, D.M., Loreau, M., Naeem, S., Schmid, B., Setälä, H., Symstad, A.J., Vandermeer, J., Wardle, D.A., 2005. Effects of biodiveristy on ecosystem functioning: a consensus of current knowledge. Ecol. Monogr. 75, 3–35.

Horwich, R.H., Das, R., Bose, A., 2013. Conservation and the current status of the golden langur in Assam, India, with reference to Bhutan. Primate Conserv. 27 (On-line early edition).

Horwich, R.H., Lyon, J., 2007. Community conservation: practitioners' answer to critics. Oryx 41, 376–385.

Horwich, R.H., Shanee, S., Shanee, N., Bose, A., Fenn, M., Chakraborty, L., 2015. Creating Modern Community Conservation Organizations and Institutions to Effect Successful Forest Conservation Change. INTECH.

Hutton, J., Adams, W.M., Murombedzi, J.C., 2005. Back to the barriers? Changing narratives in biodiversity conservation. Forum Dev. Stud. 32, 341–370.

IUCN, 2001. IUCN Red List Catagories and Criteria: Version 3.1. IUCN, Gland, Switzerland and Cambridge, UK.

IUCN, 2014. IUCN World Parks Congress 2014.

IUCN, 2016. IUCN Red List of Threatened Species.

IUCN, 2017. Protected Area Categories.

Jenkins, C.N., Joppa, L., 2009. Expansion of the global terrestrial protected area system. Biol. Conserv. 142, 2166–2174.

Kamdem-Toham, A., Adeleke, A.W., Burgess, N.D., Carroll, R., Amico, J., Dinerstein, E., Olson, D.M., Some, L., 2003. Forest conservation in the Congo basin. Science 299, 346.

Khan, M.L., Menon, S., Bawa, K.S., 1997. Effectiveness of the protected area network in biodiversity conservation: a case-study of Meghalaya state. Biodivers. Conserv. 6, 853–868.

Kitamura, K., Clapp, R.A., 2013. Common property protected areas: community control in forest conservation. Land Use Policy 34, 204–212.

Kothari, A., 2006. Community conserved areas. Parks 16, 3–13.

Le Saout, S., Hoffmann, M., Shi, Y., Hughes, A., Bernard, C., Brooks, T.M., Bertzky, B., Butchart, S.H.M., Stuart, S.N., Badman, T., Rodrigues, A.S.L., 2013. Protected areas and effective biodiversity conservation. Science 342, 803.

Leverington, F., Costa, K.L., Pavese, H., Lisle, A., Hockings, M., 2010. A global analysis of protected area management effectiveness. Environ. Manag. 46, 685–698.

Lewis, O.T., 2006. Climate change, species–area curves and the extinction crisis. Philos. Trans. R. Soc. B Biol. Sci. 361, 163–171.

Llactayo, W., Salcedo, K., Victoria, E., 2013a. Memoria Técnica de la Cuantificación de Cambios de la Cobertura de Bosque a no Bosque por Deforestación en el Ambito de la Amazonía Peruana Periódo 2009-2010-2011. Minesterio del Ambiente, Dirrecion General de Ordanamiento territorial, Lima, Peru, p. 50.

Llactayo, W., Salcedo, K., Victoria, E., 2013b. Memoria Técnica de la Cuantificación de la Cobertura de Bosque y Cambio de Bosque a no Bosque de la Amazonia Peruana Periódo 2000-2005-2009. Ministerio del Ambiente, Direccion General de Ordanamiento Territorial, Lima, Peru, p. 34.

Loucks, C., Ricketts, T.H., Naidoo, R., Lamoreux, J., Hoekstra, J., 2008. Explaining the global pattern of protected area coverage: relative importance of vertebrate biodiversity, human activities and agricultural suitability. J. Biogeogr. 35, 1337–1348.

McCarthy, D.P., Donald, P.F., Scharlemann, J.P.W., Buchanan, G.M., Balmford, A., Green, J.M.H., Bennun, L.A., Burgess, N.D., Fishpool, L.D.C., Garnett, S.T., Leonard, D.L., Maloney, R.F., Morling, P., Schaefer, H.M., Symes, A., Wiedenfeld, D.A., Butchart, S.H.M., 2012. Financial costs of meeting global biodiversity conservation targets: current spending and unmet needs. Science 338, 946.

McNeely, J.A., Miller, K.R., Reid, W.V., Mittermeier, R.A., Werner, T.B., 1990. Conserving the Worlds Biodiversity. IUCN, Gland.

Monteferri, B., Coll, D., 2009. Conservacion privada and comunitaria en los paises Amazonicos. Sociedad Peruana de Derecho Ambiental - SPDA, Lima.

Moran, D., Kanemoto, K., 2017. Identifying species threat hotspots from global supply chains. Nat. Ecol. Evol. 1, 0023.

Muench, C., Martinez-Ramos, M., 2016. Can community-protected areas conserve biodiversity in human-modified tropical landscapes? The case of terrestrial mammals in southern Mexico. Trop. Conserv. Sci. 9, 178–202.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., Kent, J., 2000. Biodiversity hotspots for conservation priorities. Nature 403, 853–858.

Naughton-Treves, L., Alvarez-Berrios, N., Brandon, K., Brunner, A., Buck Holland, M., Ponce, C., Saenz, M., Suarez, L., Treves, A., 2006. Expanding protected areas and incorporating human resource use: a study of 15 forest parks in Ecuador and Peru. Sustain. Sci. Pract. Policy 2, 32–44.

Noss, R.F., 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conserv. Biol. 4, 355–364.

Ocampo-Peñuela, N., Jenkins, C.N., Vijay, V., Li, B.V., Pimm, S.L., 2016. Incorporating explicit geospatial data shows more species at risk of extinction than the current Red List. Sci. Adv. 2.

Olson, D.M., Dinerstein, E., 1998. The global 200: a representation approach to conserving the Earth's most biologically valuable ecoregions. Conserv. Biol. 12, 502–515.

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D., Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand, H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura, Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., Kassem, K.R., 2001. Terrestrial ecoregions of the world: a new map of life on Earth. Bioscience 51, 933–938.

ONERN, 1976. Mapa ecologica del Peru. Oficina Nacional de Evaluacion de Recursos Naturales, Lima.

Pacheco, V., Cadenillas, R., Salas, E., Tello, C., Zeballos, H., 2009. Diversity and endemism of Peruvian mammals. Rev. Peru. Biol. 16, 5–32.

Petchey, O.L., 2000. Species diversity, species extinction, and ecosystem function. Am. Nat. 155, 696–702.

Peterson, A.T., Egbert, S.L., Sánchez-Cordero, V., Price, K.P., 2000. Geographic analysis of conservation priority: endemic birds and mammals in Veracruz, Mexico. Biol. Conserv. 93, 85–94.

Peterson, A.T., Navarro-Sigüenza, A.G., 1999. Alternate Species Concepts as Bases for Determining Priority Conservation Areas Conceptos Alternos de Especie como Base para la Determinación de Areas de Conservación Prioritarias. Conserv. Biol. 13, 427–431.

Pressey, R.L., 1994. Ad hoc reservations: forward or backward steps in developing representative reserve systems? Conserv. Biol. 8, 662–668.

Purvis, A., Jones, K.E., Mace, G.M., 2000. Extinction. BioEssays 22, 1123–1133.

Rodrigues, A.S.L., 2011. Improving coarse species distribution data for conservation planning in biodiversity-rich, data-poor, regions: no easy shortcuts. Anim. Conserv. 14, 108–110.

Rodrigues, A.S.L., Andelman, S.J., Bakarr, M.I., Boitani, L., Brooks, T.M., Cowling, R.M., Fishpool, L.D.C., da Fonseca, G.A.B., Gaston, K.J., Hoffmann, M., Long, J.S., Marquet, P.A., Pilgrim, J.D., Pressey, R.L., Schipper, J., Sechrest, W., Stuart, S.N., Underhill, L.G., Waller, R.W., Watts, M.E.J., Yan, X., 2004. Effectiveness of the global protected area network in representing species diversity. Nature 428, 640–643.

Rodríguez, L.O., Young, K.R., 2000. Biological diversity of Peru: determining priority areas for conservation. AMBIO A J. Hum. Environ. 29, 329–337.

Rowe, N., Myers, M., 2012. All the Worlds Primates. Primate Conservation Inc.

Scheffer, M., Barrett, S., Carpenter, S.R., Folke, C., Green, A.J., Holmgren, M., Hughes, T.P., Kosten, S., van de Leemput, I.A., Nepstad, D.C., van Nes, E.H., Peeters, E.T.H.M., Walker, B., 2015. Creating a safe operating space for iconic ecosystems. Science 347, 1317.

Scheffers, B.R., De Meester, L., Bridge, T.C.L., Hoffmann, A.A., Pandolfi, J.M., Corlett, R.T., Butchart, S.H.M., Pearce-Kelly, P., Kovacs, K.M., Dudgeon, D., Pacifici, M., Rondinini, C., Foden, W.B., Martin, T.G., Mora, C., Bickford, D., Watson, J.E.M., 2016. The broad footprint of climate change from genes to biomes to people. Science 354.

Schulenberg, T.S., Stotz, D.F., Lane, D.E., O'Neill, J.P., Parker, T.A., 2010. Birds of Peru, 2 ed. Princeton University Press, New Jersey.

SERNANP, 2017. Sistema National de Areas Naturales Protegidas por el Estado (SINANPE). SERNANP, Lima, Peru.

Shanee, N., 2016. Government and community based primate conservation initiatives in Peru. In: Waler, M. (Ed.), Ethnoprimatology: Primate Conservation in the 21st Ceatury. Springer International Publishing.

Shanee, N., Shanee, S., 2016. Land trafficking, migration, and conservation in the "no-man's land" of northeastern Peru. Trop. Conserv. Sci. 9, 1–16.

Shanee, N., Shanee, S., Horwich, R.H., 2014. Effectivness of locally run conservation initiatives in north-east Peru. Oryx (On-line early edition).

Shanee, S., Tello-Alvarado, J.C., Vermeer, J., Boveda-Penalba, A.J., 2011. GIS risk assessment and GAP analysis for the Andean titi monkey (*Callicebus oenanthe*). Primate Conserv. 26, 17–23.

Soberón, J., Peterson, T., 2004. Biodiversity informatics: managing and applying primary biodiversity data. Philos. Trans. R. Soc. Lond. Series B: Biol. Sci. 359, 689.

Stolton, S., Dudley, N., 2010. Arguments for Protected Areas: Multiple Benefits for

Conservation and Us. Earthscan.
Stolton, S., Redford, K.H., Dudley, N., 2014. The Futures of Privately Protected Areas. Protected Area Technical Report Series No. 1, p. 128.
Swenson, J.J., Carter, C.E., Domec, J.-C., Delgado, C.I., 2011. Gold mining in the peruvian amazon: global prices, deforestation, and mercury imports. PLoS One 6, e18875.
Swenson, J.J., Young, B.E., Beck, S., Comer, P., Cordova, J.H., Dyson, J., Embert, D., Encarnacion, F., Ferreira, W., Franke, I., Grossmas, D., Hernandez, P., Herzog, S.K., Josse, C., Navarro, G., Pacheco, V., Stein, B.A., Timana, M., Tovar, A., Tovar, C., Vargas, J., Zambrana-Torrelio, C.M., 2012. Plant and animal endemism in the eastern Andean slope: challanges to conservation. BMC Ecol. 12, 1–19.
Tognelli, M.F., de Arellano, P.I.R., Marquet, P.A., 2008. How well do the existing and proposed reserve networks represent vertebrate species in Chile? Divers. Distrib. 14, 148–158.
UNEP-WCMC, 2014. World Database on Protected Areas.
Venter, O., Fuller, R.A., Segan, D.B., Carwardine, J., Brooks, T., Butchart, S.H.M., Di Marco, M., Iwamura, T., Joseph, L., O'Grady, D., Possingham, H.P., Rondinini, C., Smith, R.J., Venter, M., Watson, J.E.M., 2014. Targeting global protected area expansion for imperiled biodiversity. PLoS Biol. 12, e1001891.
Vuohelainen, A.J., Coad, L., Marthews, T.R., Malhi, Y., Killeen, T.J., 2012. The Effectiveness of Contrasting Protected Areas in Preventing Deforestation in Madre de Dios, Peru. Environ. Manag. 50, 645–663.
Waldron, A., Mooers, A.O., Miller, D.C., Nibbelink, N., Redding, D., Kuhn, T.S., Roberts, J.T., Gittleman, J.L., 2013. Targeting global conservation funding to limit immediate biodiversity declines. Proc. Natl. Acad. Sci. 110, 12144–12148.
Watson, J.E.M., Dudley, N., Segan, D.B., Hockings, M., 2014. The performance and potential of protected areas. Nature 515, 67–73.
Watson, J.E.M., Evans, M.C., Carwardine, J., Fuller, R.A., Joseph, L.N., Segan, D.B., Taylor, M.F.J., Fensham, R.J., Possingham, H.P., 2010. The capacity of Australia's protected-area system to represent Threatened secies. Conserv. Biol. 25, 324–332.
Wilson, D.E., Mittermeier, R.A., Ruff, S., Martinez-Vilalta, A., Llobet, T., 2013. Handbook of the Mammals of the World: Primates. Buteo Books.
Xeno-canto, 2016. Xeno-canto.
Young, B.E., Franke, I., Hernandez, P.A., Herzog, S.K., Paniagua, L., Tovar, C., Valqui, T., 2009. Using spatial models to predict areas of endemism and gaps in the protection of andean slope birds. Auk 126, 554–565.