



Research Paper

Conservation prioritization when species distribution data are scarce

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HIGHLIGHTS

- Charismatic species function as an effective surrogate for bird species richness.
- Priority areas near protected areas secure bird species richness.
- Prioritization scheme suggested in this study is useful in regions with limited biodiversity data.

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ABSTRACT

Prioritizing candidate areas to achieve species richness representation is relatively straightforward when distributions are known for many taxa; however, it may be challenging in data-poor regions. One approach is to focus on the distribution of a few charismatic species in areas that overlap with areas with little human influence, and another is to expand protection in the vicinity of existing protected areas. We assessed the effectiveness of these two approaches for protecting the potential distribution of 21 bird species affiliated with the piedmont dry forest in Argentina. We assessed the degree to which current protected areas met the representation target for each bird species. We found that 8% of the piedmont dry forest and 11% of the extent of occurrence of the bird species within piedmont dry forest were protected, indicating a shortfall. Areas with little human influence that overlap with the distribution of charismatic species had a higher number of bird species than areas with high human influence. Areas within the vicinity of protected areas performed similarly to priority areas, but included high human influence areas. We suggest that a prioritization scheme based on areas of charismatic species distribution that overlap with areas of low human influence can function as an effective surrogate for bird species affiliated with the piedmont dry forest in Argentina. Our results have operational implications for conservation planning in those regions of the world where biodiversity data are poor, but where decisions and actions to sustain biodiversity are urgently needed.

1. Introduction

Protected areas are areas set aside from unsustainable human activities for a variety of reasons, including biodiversity protection (Fabricius et al., 2003; Pressey, 1994; Rodrigues et al., 2004); yet, most of them were established opportunistically and often on residual land not suitable for agriculture (Venter et al., 2014). The Convention on Biological Diversity Aichi Target 11 sets a goal of conserving $\geq 17\%$ of terrestrial land as protected areas by 2020 (<https://www.cbd.int/sp/targets/>). As of 2017, there are > 202,000 protected areas covering 14.7% of the world's terrestrial area (www.protectedplanet.net).

However, the existing networks of protected areas do not ensure biodiversity persistence, partly because they do not protect all habitat types and landscape contexts (Bruner et al., 2001; Cantú-Salazar et al., 2013; Greve et al., 2011). Effective conservation areas require representative coverage of ecoregions and species, and identification of important biodiversity areas (Venter et al., 2014).

To fill knowledge gaps about the habitat types needed by species in the current protected area network, prioritization approaches are required. Ideally, conservationists should know every species' distribution and abundance, and then identify optimal sets of protected areas that meet goals for species representation and long-term persistence

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(Kukkala & Moilanen, 2013; Margules & Pressey, 2000). Systematic conservation planning aiming at safeguarding the maximum number of species is very efficient when species occurrences are thoroughly known (Carvalho et al., 2011; Moilanen et al., 2006). However, in many parts of the world it is almost impossible to have a complete tally of species at any given site, or even distribution data for most species, due to the resources required; therefore, pinpointing places of importance for biodiversity can be challenging (Di Minin & Moilanen, 2014). However, while information on distribution of all species in a given habitat or area is typically lacking, often there is information on the distribution of a few high-profile species.

Focusing on the distribution of threatened and charismatic species as surrogates of biodiversity is a widely used approach to the prioritization of areas for protection (Noss, 1990). This approach has been used, for example, in the United States focusing on sage grouse (*Centrocercus* sp.) (Runge et al., 2019), in China on giant panda (*Ailuropoda melanoleuca*) (Shen et al., 2020), and in Indonesia on tiger (*Panthera tigris*) and Asian elephant (*Elephas maximus*) (Sibarani et al., 2019). The key assumption underlying this approach is that the habitat requirements of the surrogate charismatic species encompass the habitat needs of a large number of other species for which distribution and abundance data are lacking (Li & Pimm, 2016; Thornton et al., 2016). Protected area selection based on the distributions of not just one, but several threatened and charismatic species can broaden the range of protected species (Lambeck, 1997; Sattler et al., 2014).

A strategy that combines areas used by multiple threatened charismatic species with areas with minimal human influence or wilderness areas (i.e., undeveloped areas where land conversion, urban settlements, or other human pressures are unnoticeable, minimal or absent; Mittermeier et al., 2003) is a powerful and efficient tool to expand a protected area network when distributions of most species are unknown (Klein et al., 2009). Prioritizing schemes that emphasize areas with minimal human influence reduces species loss, because in those areas the species extinction risk is less than half than that in areas with human influence (Cox & Underwood, 2011; Di Marco et al., 2019; Lindenmayer & Franklin, 2002).

An alternative strategy for expanding a protected area network is to focus on currently unprotected areas that are adjacent to protected ones, assuming that established protected areas are already ensuring persistence of some species (Pringle, 2017). Expanding the size of existing protected areas, especially isolated and small ones, increases their capacity to conserve biodiversity due to the positive relationship between area and species richness (DeFries et al., 2005); this strategy can result in greater conservation benefit than establishing new isolated protected areas (Alexandre et al., 2010; Martinuzzi et al., 2015). Using protected areas as nuclei for expansion can be politically more acceptable and may entail lower transaction costs than creating new protected areas (Mascia & Pailler, 2010; Mascia & Pailler et al., 2014). However, the effectiveness of the two alternative approaches (i.e., identifying areas with minimal human influence that overlap with the distribution of multiple threatened charismatic species or expanding the size of existing protected areas) for potential biodiversity conservation is not clear.

Neotropical seasonally dry forests are one of the most threatened tropical forests types in the world; indeed, only 44% of the 520,000 km² original extent from Mexico to Argentina is left, and merely 4.5% (23,000 km²) of the original extent is protected (Portillo-Quintero & Sánchez-Azofeifa, 2010). The soils and climate in this forest ecosystem have favored cultivation of crops such as sugarcane and soybeans, transformation to pasture, and human settlement, contributing to forest loss (Banda et al., 2016). These forests hold high levels of species richness and endemism (Miles et al., 2006; Prieto-Torres et al., 2019; Sánchez-Azofeifa et al., 2013); therefore, failure to protect or sustainably manage the remaining high quality patches will result in major loss of biodiversity (Prado, 2000).

Our aims here were to identify and rank potential additions of neotropical seasonally dry forest to northwest Argentina's protected

area network that maximizes conservation benefits for bird species affiliated with the mature forests, and to test approaches that can handle that the distribution of most species is not known. Our specific objectives were to (1) assess if the current protected areas represent the distribution of the bird species occurring in the piedmont dry forest, and to (2) evaluate two strategies for guiding establishment of additions to protected areas in the mature piedmont dry forest to achieve Aichi Target 11 of 17% of protection.

2. Materials and methods

2.1. Study area

The neotropical seasonally dry forest in the foothills of the Andes of Bolivia and Argentina is often lumped together with Southern Yungas forest (Brown et al., 2009; Cabrera, 1976). The dry forest in the foothills of the Andes of Bolivia and Argentina (hereafter referred to as piedmont dry forest) is similar to other seasonally dry forests of the neotropics in terms of species composition and climatic conditions (Prado, 1995, 2000); however, it is different from the Southern Yungas, which occurs at higher elevations with more precipitation. As other neotropical dry forests, the piedmont dry forest harbors high levels of endemism and rare species (Zenteno-Ruiz & López, 2010), which are different from those of Southern Yungas. There are approximately 700 woody species in the piedmont dry forest, 35% of which are endemic, plus approximately 130 bird species, and ~100 mammal species (Banda et al., 2016; Brown et al., 2009). The piedmont dry forest of Argentina extends from 22° S to 29° S along the Subandean Mountains and from 400 to 900 m asl (Malizia et al., 2012).

We studied the piedmont dry forest in the provinces of Jujuy and Salta (Fig. 1), because this is where most of this ecosystem remains in Argentina (Brown et al., 2009). Indeed, most of the piedmont dry forest in Argentina has been cleared and converted to other uses (Brown & Malizia, 2004). Precipitation varies from 600 to 1000 mm among years, and has monsoonal patterns. <100 mm/month occurs during the 3–6-month dry period, when the deciduous vegetation, including about 70% of the trees, is without leaves (Blackie et al., 2014; Gentry et al., 1995). Canopy height in the piedmont dry forest can reach 30 m, and typically there is a dense shrub stratum of up to 2 m accompanied by vines and epiphytes, which are higher (Prado, 1995). In Jujuy and Salta provinces, the piedmont dry forest is dominated by *Calycophyllum multiflorum* (Rubiaceae) and *Phyllostylon rhamnoides* (Ulmaceae) (Cabrera, 1976, 1971).

2.2. Methods

2.2.1. Bird data collection and distribution modeling

We conducted 463 10-min bird point counts from August to April between 2010 and 2017 and each point count location was visited once. Point count stations were randomly placed in 16 sites (approximately 100 ha each) within continuous, interior piedmont dry forest, spanning the latitudinal gradient of Jujuy and Salta, Argentina (Fig. 1). At each bird point count station, we recorded all species seen or heard within 50 m, excluding birds in flight (Bibby et al., 2000). Point counts started 30 min after sunrise and finished 2.5 h after the start of the first point count, no point counts were conducted under inclement weather conditions (e.g., heavy rain, fog, wind, etc.). All point counts were located > 300 m from an anthropogenic forest edge, separated by > 200 m to ensure independence (Ralph et al., 1995), and conducted by NP and LR. Species names follow those proposed by the South American Classification Committee (Remsen et al., 2020).

We did not analyze raptors (e.g., Falconiformes, Strigiformes), hummingbirds or swifts (Apodiformes), nightjars (Caprimulgiformes), or species that use the piedmont dry forest only marginally (e.g., *Taraba major*, *Cyanoloxia brissonii*) because we were interested in bird species that are strongly affiliated with the mature piedmont dry forest

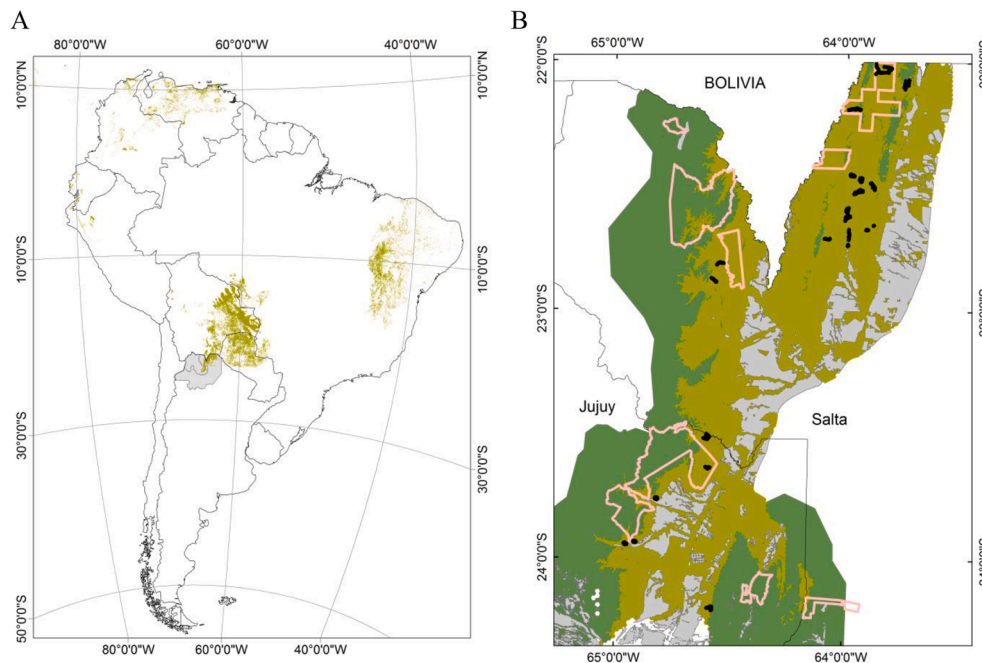


Fig. 1. Neotropical seasonally dry forest in (A) South America (from Miles et al., 2006), and (B) northwestern Argentina. The piedmont dry forest (light green), non-forest (grey), Southern Yungas forest (dark green), protected areas (pink outline), and location of bird point counts (black points) in Salta and Jujuy provinces (light grey in map A), Argentina, are indicated. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

(Blendinger & Álvarez, 2009; Malizia et al., 2005). We analyzed only those bird species with ≥ 20 occurrence records that were ≥ 1 km apart to avoid modeling poorly surveyed species and used only one observation in the same bioclimatic grid cell (1-km resolution) (Elith & Leathwick, 2007; Owens et al., 2013). To determine the potential distribution of each of these species, we modeled their occurrence points based on eight 1-km resolution bioclimatic variables representing current conditions from 1950 to 2000. Bioclimatic variables were downloaded from the WorldClim database (www.worldclim.org), and included: annual mean temperature (BIO1), seasonality of temperature (BIO4), maximum temperature of warmest month (BIO5), minimum temperature of coldest month (BIO6), annual precipitation (BIO12), seasonality of precipitation (BIO15), extreme data for precipitation of wettest quarter (BIO16), and precipitation of driest quarter (BIO17); Hijmans et al., 2005). We selected these eight variables because they were previously found to have the minimum correlation and to be useful for wildlife modeling in the study area (Martinuzzi et al., 2018; Pidgeon et al., 2015). We modeled species distributions using MaxEnt software Version 3.4.1 (Elith et al., 2011; Phillips et al., 2020, 2006), to make bird distribution maps consistent with the approach previously used for modeling charismatic species in the study area (Martinuzzi et al., 2018). As background data for model training, we generated 10,000 pseudo-absence locations within 100 km of species occurrences; this buffer size provided the most accurate and biologically meaningful results compared to other buffer sizes (Martinuzzi et al., 2018; Pidgeon et al., 2015). We assessed model performance using 10-fold cross-validation, and by calculating the area under the receiver operating curve (AUC) (Phillips et al., 2020). We converted predictions from MaxEnt into a binary habitat map, using the 10th percentile presence logistic threshold to separate suitable from unsuitable habitat; thus, we created a map of each bird species' potential distribution (Phillips et al., 2020). We selected the 10th percentile threshold because it maximizes the percentage of presences and absences predicted correctly compared to other percentile thresholds, thereby providing conservative species distributional range (Liu et al., 2016). We calculated the areal extent for each bird species and summed the areal extent of all bird species potential distribution in order to obtain the potential bird species richness patterns within piedmont dry

forests.

2.2.2. Representation of birds' distribution and richness in different land categories

We obtained protected area boundaries from Argentina's National Park Administration Biodiversity Information System dataset (www.sib.gov.ar) and included only the elevation range of the piedmont dry forest (Malizia et al., 2012). To simulate the approach of expanding size of existing protected areas, we mapped the 10-km area surrounding each of them.

Our dataset of charismatic species consisted of available maps on potential distribution of five threatened species: Tucuman parrot (*Amazona tucumana*), jaguar (*Panthera onca*), tapir (*Tapirus terrestris*), white-lipped peccary (*Tayassu pecari*), and Southern oak (*Amburana cearensis*) (Martinuzzi et al., 2018). We identified areas where the potential distribution of ≥ 3 of these species overlapped with areas with little human influence (i.e., minimal human footprint; Sanderson et al., 2002; Martinuzzi et al., 2018). We designated as *priority areas* those currently unprotected areas that provided habitat for ≥ 3 of the charismatic species and that overlapped with areas with minimal human influence; the remaining unprotected areas were designated as non-priority areas. Because our focus was on forests, we removed non-forested areas based on the Global Land Cover 2000 map (<http://www.eea.europa.eu/data-and-maps/data/global-land-cover-2000-europe>).

We calculated the areal extent of the intersection of summed potential bird species distributions with different land categories: a) protected areas, b) priority unprotected areas, c) non-priority unprotected areas, d) forests within a 10-km buffer area surrounding protected areas, and e) overlap of priority areas within a 10-km buffer area surrounding protected areas. We also calculated the areal extent of overlap within the different land categories with $\geq 75\%$ piedmont dry forest bird species (i.e., ≥ 16 bird species).

To determine bird species richness in protected areas, priority unprotected areas, and non-priority unprotected areas, we divided the study area into a grid of 346-ha hexagonal cells (1 km apothem length) and considered only whole cells (i.e., 1,954 whole cells). We calculated

the mean and standard deviation of the number of species within cells whose entire area was in a single category and tested whether there was a significant difference ($p < 0.05$) in bird species richness among protected areas, priority areas, and non-priority areas using a Kruskal-Wallis test (Quinn & Keough, 2002).

2.2.3. Status of the Aichi target for piedmont dry forests and bird species representation target

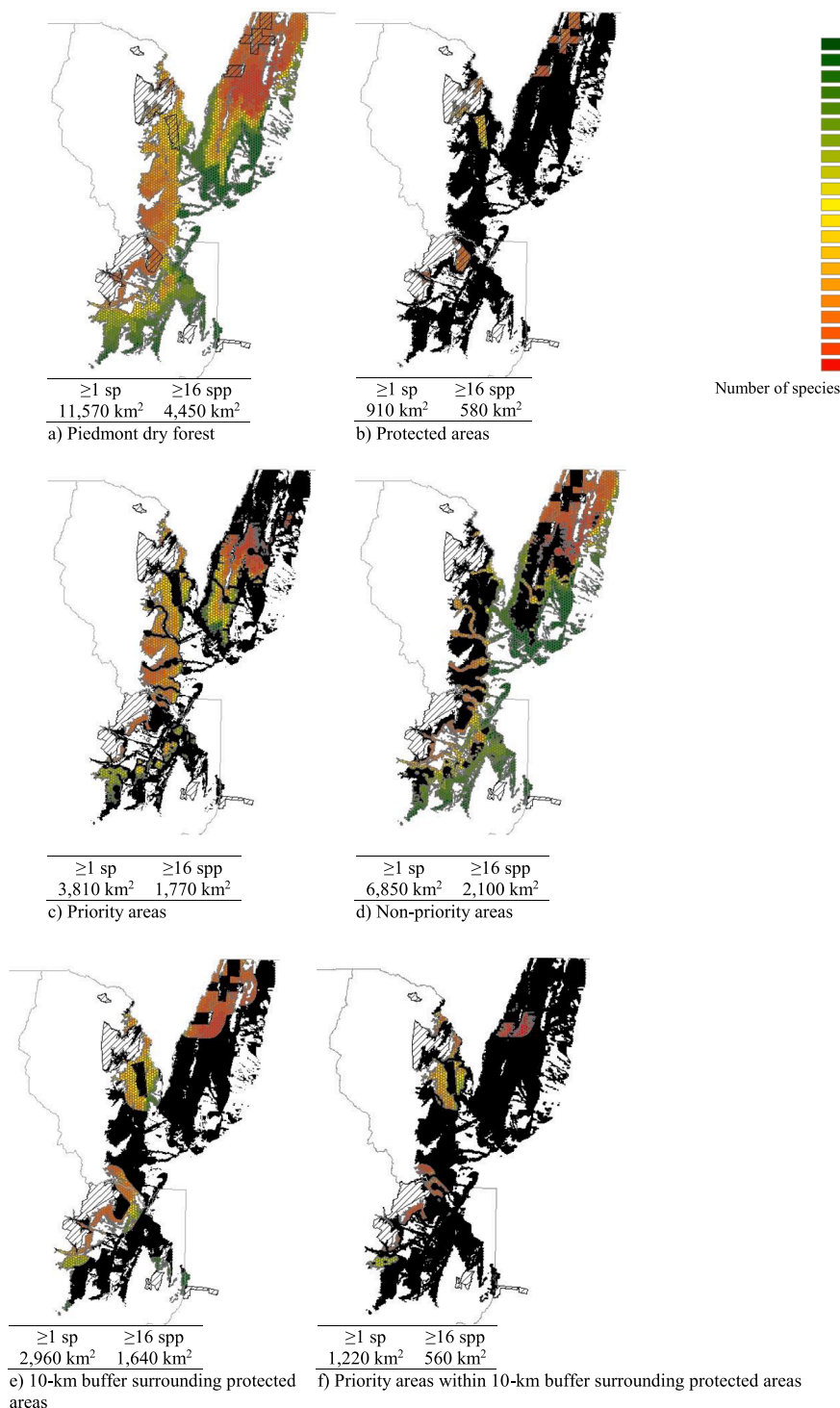
We determined if the current extent of the protected area network in the piedmont dry forest achieved the Aichi Target 11 of 17% protection. If there was a shortfall, we calculated the additional extent that should

be protected. Additionally, we estimated a representation target of protected habitat for each bird species, considering only their potential distribution in the piedmont dry forest of Argentina. To do this, we followed Rodrigues et al. (2004) and Pidgeon et al. (2015), using the equation:

$$y = -0.1631 \ln(x) + 2.1131$$

where y is the representation target (proportion of habitat) and x is the areal extent in km^2 of the potential distribution in the piedmont dry forest of each bird species.

Fig. 2. Potential distribution and areal extent of 21 bird species occurring in the piedmont dry forest of Salta and Jujuy provinces, Argentina (a), and overlap with protected areas (b), priority areas (c), non-priority areas (d), 10-km buffer area surrounding protected areas (e), and priority areas in the 10-km buffer area surrounding protected areas (f). Color ramp indicates the number of bird species in a given pixel. ≥ 1 sp: indicates the occurrence of \geq one bird species; ≥ 16 spp: indicates overlap of ≥ 16 of the 21 bird species. Black area represents the piedmont dry forest distribution in Salta and Jujuy provinces, Argentina.



3. Results

3.1. Study area characterization

The study area included 11,570 km² of piedmont dry forest. Of this, only 8% (926 km²), was in protected areas, 33% was within priority areas (i.e., areas with minimal human influence that overlap with the potential distribution of ≥ 3 threatened and charismatic species), and 59% was in non-priority areas (Fig. 2). In the 10-km buffer area surrounding the existing protected areas, there were 2,960 km² of piedmont dry forest (26% of the total) (Fig. 2). Of this, 41% fit our definition of priority areas and 59% were non-priority areas (Fig. 2).

3.2. Dry forest birds and distribution models

Over seven years, we recorded a total of 8,781 individual birds belonging to 25 families and 86 species (10.75 ± 3.98 species/point count). Our models of the potential distribution of 21 resident bird species strongly affiliated with mature dry forests (Table 1) discriminated well between bird species potential habitat and non-habitat (18 species models had AUC scores > 96; Table S1). The bioclimatic variable precipitation of the driest quarter (BIO17) made the most important contribution (> 40%), being included in the models of 16 bird species (Table S1). In total, 38% of the study area contained ≥ 16 of the 21 bird species of the piedmont dry forest (Fig. 2a).

3.3. Bird species distributions and richness within different land categories

Only in 666 km² was there an overlap of the 21 bird species (Fig. 2a). No single protected area was part of the potential distributions of all 21 bird species, but 65% of existing protected areas included the potential distribution of ≥ 16 bird species (Fig. 2b). Similarly, almost half of the priority areas (46%) overlapped with the potential distribution of ≥ 16 of the 21 bird species. However, non-priority areas had only 31% overlap with the potential distribution of ≥ 16 bird species (Fig. 2c, d).

Table 1

Bird species potential distribution area (km²) in the piedmont dry forest (PDF), in protected areas (PA), in priority areas (Prio), in the 10-km buffer area surrounding protected areas (Buffer), and in priority areas within the 10-km buffer area surrounding protected areas (PrioBuffer); representation target for protection, and the shortfall in the areal extent of the current protected area network in Salta and Jujuy provinces, Argentina.

Family	Species	Extent in PDF	Extent in PA (%)	Target for protection (%)	Shortfall extent	Extent in Prio	Extent in Buffer	Extent in PrioBuffer
Columbidae	<i>Patagioenas cayennensis</i>	3,780	450 (12)	77	2,460	1,380	1,490	470
	<i>Leptotila verreauxi</i>	3,650	530 (15)	78	2,300	980	1,440	500
Psittacidae	<i>Primolius auricollis</i>	3,680	290 (8)	77	2,560	1,820	1,210	490
	<i>Psittacara leucophthalmus</i>	1,150	130 (12)	96	980	550	470	260
	<i>Pyrrhura molinae</i>	6,430	540 (8)	68	3,850	2,830	1,930	710
Trogonidae	<i>Trogon curucui</i>	4,460	480 (11)	74	2,830	1,970	1,520	550
Momotidae	<i>Momotus momota</i>	4,940	580 (12)	73	3,010	2,020	1,670	620
Picidae	<i>Dryobates frontalis</i>	1,940	150 (8)	88	1,550	890	720	320
Furnariidae	<i>Synallaxis azarae</i>	7,530	840 (11)	66	4,110	3,240	2,460	1,100
	<i>Sittasomus griseicapillus</i>	7,090	660 (9)	67	4,070	3,060	2,200	900
	<i>Dendrocolaptes picumnus</i>	6,340	820 (13)	69	3,520	2,620	2,370	1,100
	<i>Lepidocolaptes angustirostris</i>	11,460	910 (8)	59	5,840	3,810	2,910	1,210
Thamnophilidae	<i>Batara cinerea</i>	5,030	600 (12)	72	3,040	2,200	1,690	700
	<i>Herpsilochmus atricapillus</i>	4,730	510 (11)	73	2,960	1,950	1,500	430
	<i>Leptopogon amaurocephalus</i>	2,690	400 (15)	83	1,820	500	1,170	320
Tyrannidae	<i>Poecilatriccus plumbeiceps</i>	5,550	610 (11)	71	3,310	2,710	1,810	810
	<i>Tolmomyias sulphureus</i>	5,230	630 (12)	72	3,120	2,220	2,060	850
	<i>Hemithraupis guira</i>	3,690	540 (15)	77	2,310	1,140	1,430	520
Emberizidae	<i>Arremon flavirostris</i>	7,500	770 (10)	66	4,160	3,000	2,370	1,000
Parulidae	<i>Myiothlypis bivittata</i>	5,630	740 (13)	70	3,230	2,590	2,140	980
Icteridae	<i>Cacicus chrysopterus</i>	6,900	840 (12)	67	3,790	2,910	2,320	1,100
Average of all the species		5,210	(11)	72				

Regarding the 10-km buffer areas surrounding protected areas, 55% overlapped with the potential distribution of ≥ 16 bird species (Fig. 2e). Of those buffer areas, two-thirds (1,080 km²) were non-priority areas, and one-third (560 km²) were priority areas (Fig. 2f). There were significantly higher levels of bird species richness in protected areas than in priority areas, but significantly fewer bird species in non-priority areas than in priority areas (H = 143.96; p < 0.01) (Fig. 3).

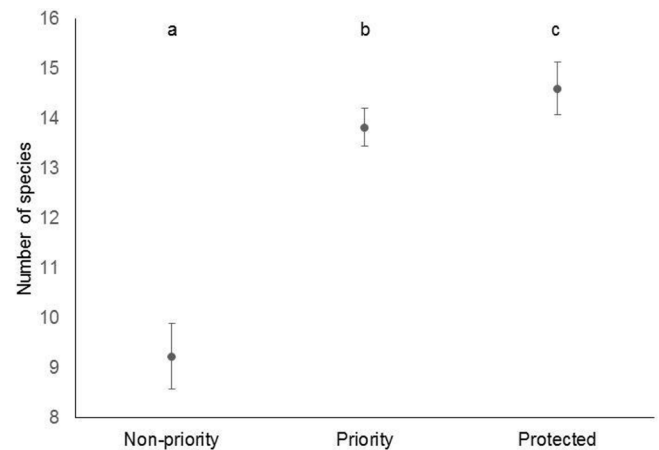


Fig. 3. Number of mature piedmont dry forest bird species (mean ± standard deviation) in non-priority areas, priority areas, and protected area cells in the piedmont dry forest of Salta and Jujuy provinces, Argentina. Priority areas are defined as areas of minimal human influence that overlap with areas that contain potential habitat of ≥ 3 of 5 threatened and charismatic species, as evaluated in Martinuzzi et al. (2018). Different letters above categories indicate significant differences (p ≤ 0.05).

3.4. Achieving Aichi target and bird species representation target

To achieve the target of protecting 17% of piedmont dry forest established in the Aichi Target 11, it would be necessary to add 1,060 km² to the current protected area network. This increase in the extent of land requiring conservation (i.e., land harboring ≥ 16 birds species) could either be accomplished by including priority areas (1,770 km²; Fig. 2c) or areas within the 10-km buffer area surrounding protected areas (1,640 km²; Fig. 2e). Focusing on priority areas within 10-km buffer surrounding protected areas would only provide 560 km² (Fig. 2f).

Only 8 to 15% of the potential habitat distribution of the 21 dry forest-affiliated bird species is already protected (Table 1). Based on the representation target, i.e., the degree to which protected areas represent species' habitat suggests that for the bird species between 59 and 96% (average 72%; Table 1) of the remaining piedmont dry forest should be in protected status so that all species are considered 'covered' by the protected area network. Depending on the species, this translates into a shortfall of representation target of 980 to 5,840 km² (Table 1). The species with the smallest potential distribution in the piedmont forest were *Psittacara leucophthalma* (1,150 km²) and *Dryobates frontalis* (1,940 km²), whereas those with the largest potential distribution belong to the family Furnariidae, especially *Lepidocolaptes angustirostris*, with a potential distribution that covered almost the entire study area (11,460 km², Table 1). The species with the least (8%) representation of their potential distributions in protected areas were *Primolius auricollis*, *Pyrhura molinae*, *Dryobates frontalis*, and *Lepidocolaptes angustirostris*. With respect to the target of protection, *Lepidocolaptes angustirostris* and *Arremon flavirostris* showed the greatest protection shortfalls, but overlapped with a large portion of the priority areas and the area within a 10-km buffer surrounding protected areas (Table 1). The species with the smallest proportion of their potential distribution within priority areas were *Psittacara leucophthalma*, *Dryobates frontalis* and *Leptopogon amaurocephalus*, and the former two species had the least areal extent within 10-km buffer surrounding protected areas (Table 1).

4. Discussion and conclusion

Protection of Argentina's piedmont dry forest ecosystem as of 2020 falls short of the Aichi Target. In fact, we found that protected areas encompass only 8% of the remaining piedmont dry forest of Argentina, far less than the 17% target recommended in Aichi Target 11 (Tittensor et al., 2014), and a far lower proportion (4%) of the original 21,000 km² covered by this ecosystem in Argentina (Brown & Malizia, 2004). We also found that placing protected areas in non-priority areas would ensure the least number of bird species. In contrast, protecting priority areas, i.e., areas within the potential distribution of multiple threatened and charismatic species that overlap with areas with minimal human influence, would be a highly effective strategy for the establishment of protected areas in the future. This is exciting, because such a prioritization is much more feasible than systematic conservation planning, which requires potential distribution maps for a large number of species (Carvalho et al., 2011; Moilanen et al., 2006). Similarly, our results show that expanding existing protected areas would also be highly effective. Either strategy—protecting priority areas or expanding existing ones—would result in the conservation of a higher number of bird species. If increase coverage focuses on priority areas, more alternatives will be available, but some of the chosen areas might be isolated, which is suboptimal. If the focus is put on forest areas within the 10-km buffer surrounding protected areas, functional connectivity between the protected areas and the buffer areas may be maintained; nevertheless, these areas do not necessarily provide habitat for charismatic threatened species. Combining both strategies, i.e., focusing on priority areas within 10-km buffer surrounding protected areas, captures the best features of both strategies, making the approach more efficient. However, a lack of flexibility may make implementation challenging in some cases.

We found that a small group of threatened and charismatic species can function as effective surrogates for a large number of bird species affiliated to mature piedmont dry forest, as reported for other ecosystems (Li & Pimm, 2016; Rodrigues & Brooks, 2007; Thornton et al., 2016). Combining charismatic species distribution maps with maps of areas with minimal human influence ensures that the pressure from human activities on species is minimized in the resulting priority areas (Newbold et al., 2015). Additionally, whenever possible, we recommend focusing on priority areas surrounding existing protected areas to improve their value for bird species richness persistence (Radeloff et al., 2010). Landscapes with small and isolated protected areas are less likely to support self-sustaining populations of species with limited dispersal abilities. Therefore, proximity to sources can lower extinction risk and increase recolonization (Roberts et al., 2001). However, as our results show, just expanding existing protected areas is not the most effective prioritization scheme, because areas surrounding protected areas often have high rates of development (Hamilton et al., 2015, 2016). Furthermore, proper biodiversity management should involve conservation strategies that consider the future impacts of global climate change and that take into account species' geographical range shifts (Loyola et al., 2013).

Our approach is designed to meet practical conservation challenges in developing countries with limited funding, knowledge, and time for action (Bonfim et al., 2019; Cayuela et al., 2009; Guisan et al., 2013). Having said that, we caution that having species-specific distribution models of a handful of threatened and charismatic species does not replace having comprehensive data to guide allocation of conservation efforts for biodiversity nor does it ensure species persistence within protected areas (Roberge & Angelstam, 2004). Much biodiversity may still remain unprotected, but because we validated the approach focusing on habitat specialists (i.e., bird species affiliated with mature piedmont dry forests), we assume that many other habitat specialist species could also be benefited (dos Anjos et al., 2015; Larsen et al., 2012).

We also found that protected areas had on average the highest bird species richness in the mature piedmont dry forest than in unprotected areas. This was a welcome surprise, given that the designation of protected areas in our study area was not based on a systematic conservation plan. It is often assumed that protected areas effectively represent the biodiversity of taxonomic groups for which their designation was not a primary or intentional goal; however, remarkably, to date few studies have been conducted to confirm such assumption (Coetzee et al., 2014; Gray et al., 2016). The greatest bird species richness found in protected areas could be due to established protected areas in sites where conditions were more favorable than in the surroundings or to a process of habitat loss or degradation outside protected areas after their establishment (Gaston et al., 2008). Regardless of the reasons, our finding suggests that the existing protected areas are already achieving a conservation benefit, and expanding them to surrounding unprotected priority areas would provide further conservation benefits (Pringle, 2017).

It has been suggested that targets for individual species must be tailored according to the species' range size (Pidgeon et al., 2015; Rodrigues et al., 2004). The representation target of 72% (between 59 and 96%) may be considered precautionary to minimize the risk of species extinction by retaining a high proportion of the remaining piedmont dry forest that is within bird species' potential distributions. We restricted our analysis to the distribution of the species in the piedmont dry forest of Argentina because this is a unique forest type and represents the southernmost population distribution of these bird species (Hanson et al., 2020). Given that human land use and that habitat transformation are increasing in the piedmont dry forest, designating protected areas is an increasingly important component of regional and national conservation strategies (Butchart et al., 2010; Korfanta et al., 2012; Vié et al., 2009). However, protected areas are not the only tactic available to conservation planners, and the strategic expansion of the protected-area network should go hand in hand with regional and

national land-use legislation and enforcement of business standards to reduce the negative effects of extractive industry on biodiversity and wilderness areas (Gaston et al., 2008, 2006; Greve et al., 2011; Pimm et al., 2001).

In conclusion, we found that a straightforward approach to conservation planning, i.e., combine information about areas of well-surveyed threatened and charismatic species distribution that overlap with areas with minimal human influence, would work well to conserve bird species richness in Argentina's piedmont dry forests. While our results are region-specific (Grantham et al., 2010), we suggest that such an approach could be implemented in parts of the world with limited data for many taxa and birds. Decisions about where to increase protected area coverage cannot wait until good distribution data are available for most species; yet, additional protected areas should be allocated effectively to maximize conservation gains (Grantham et al., 2009). We demonstrate the effectiveness of a practical strategy that can guide policies and help meet international commitments to take proactive conservation measures by focusing on the potential distributions of threatened, charismatic species in areas with low human influence that surround existing protected areas.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.landurbplan.2021.104067>.

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