

## Bird species diversity captured by protected areas in the Andes of Colombia: a gap analysis

Padu Franco, Carlos A. Saavedra-Rodríguez and Gustavo H. Kattan

**Abstract** Formed by three Andean ranges and two peripheral elements, the complex mountainous system of Colombia harbours a diverse avifauna (>1,500 spp.) characterized by high large-scale beta diversity and endemism. In these mountains there are 25 protected areas covering *c.* 3.5 million hectares but not all ecosystems are adequately represented. We conducted an analysis of representation of bird species in these protected areas for eight subregions of the Colombian mountains by means of a comparison between potential and recorded faunas in each area. Potential faunas were compiled by considering the distribution of species across the subregions, their elevational ranges, and the elevational extent covered by each protected area in each subregion. Analyses were performed separately for all species and for migrant species, with an emphasis on threatened species. Bird inventories are lacking for nine of the protected areas. Existing inventories have representation values of 4–91% for all species, and

3–72% for migrant species. Assuming that all potential species occur within protected areas, representation values for the subregions were high (74–100%) but may be as low as 26% when representation values are estimated using recorded species only. For most Andean subregions representation decreased with decreasing elevation, revealing a lack of protected areas at lower elevations. In addition, 31 threatened species (26% of total), which mainly occur at lower elevations and in adjacent lowlands, are not covered by protected areas. Thus, although birds are relatively well protected by the system of reserves in the mountains of Colombia, significant gaps remain, particularly for threatened species.

**Keywords** Andes, beta diversity, birds, Colombia, mountains, protected areas.

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### Introduction

A prominent feature of north-western South America's geography is the mountainous system of Colombia, which is formed by three Andean ranges, the Sierra Nevada de Santa Marta and Serranía de La Macarena (Fig. 1). The northern Andean region has been highlighted in global biodiversity assessments for its high levels of biodiversity, threat and endemism (McNeely *et al.*, 1990; Stattersfield *et al.*, 1998; Myers *et al.*, 2000; Orme *et al.*, 2005). More than 1,500 bird species occur in these mountain systems, representing almost 84% of Colombia's and 15% of the world's species. The complex physiography of the northern Andes has given rise to high large-scale beta diversity, or turnover in species composition, among slopes in the different mountain

ranges (Kattan *et al.*, 2004). Even within a given Andean slope, beta diversity is high because of species turnover among elevational zones and watersheds (Kattan & Franco, 2004; Kattan *et al.*, 2006). Thus, although species richness decreases with elevation and alpha (*i.e.* local) diversities are low in the Andes, gamma or regional diversity is high. Neotropical montane systems have diverse and unique avifaunas with many restricted range species (Bibby *et al.*, 1992; Renjifo *et al.*, 1997).

Colombia has 50 protected areas in the various categories of the National System of Protected Areas, administered by the National Parks Unit under the Ministry of the Environment. These protected areas cover *c.* 10.4 million hectares, but 66% of this area is in lowland ecosystems in Amazonia, the Orinoco basin, the Chocóan lowlands and the Caribbean plains. Half of the reserves cover montane ecosystems, but comprise only 3.5 million hectares.

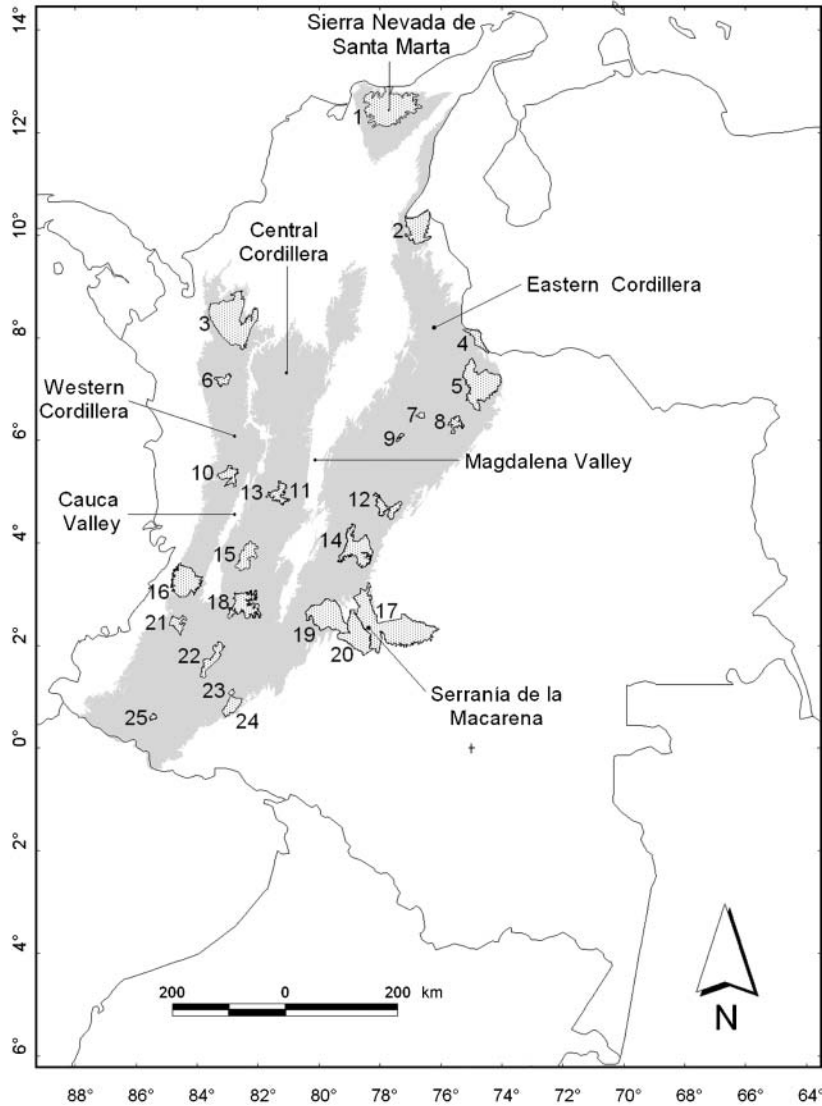
An important goal of reserve systems is obtaining representation of the regional diversity of ecosystems, communities and species (Groves, 2003). All these components of biodiversity must be considered independently when planning reserves because focusing on a single component does not guarantee protection of

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**Fig. 1** Colombia showing the Andean region and the National Natural Parks (PNN) and Flora and Fauna Sanctuaries (SFF): 1, PNN Sierra Nevada de Santa Marta; 2, PNN Catatumbo Barí; 3, PNN Paramillo; 4, PNN Tamá; 5, PNN El Cocuy; 6, PNN Las Orquídeas; 7, SFF Guanentá Alto Río Fonce; 8, PNN Pisba; 9, SFF Iguaque; 10, PNN Tatamá; 11, PNN Los Nevados; 12, PNN Chingaza; 13, SFF Otún Quimbaya; 14, PNN Sumapaz; 15, PNN Las Hermosas; 16, PNN Farallones de Cali; 17, PNN Sierra de la Macarena; 18, PNN Nevado del Huila; 19, PNN Cordillera de los Picachos; 20, PNN Tinigua; 21, PNN Munchique; 22, PNN Puracé; 23, PNN Cueva de los Guácharos; 24, PNN Alto Fragua Indi Wasi; 25, SFF Galeras.

other components (Bonn & Gaston, 2005). In many cases reserves have been established at different times, following idiosyncratic criteria and needs (Pressey, 1994). In the case of the Colombian Andes many protected areas were established to protect the headwaters of important river systems. Thus, these reserves only protect the upper elevations, leaving lower slopes and inter-Andean valleys unrepresented. A recent analysis of representation of mammals, amphibians, freshwater turtles and threatened birds in the global network of protected areas identified the northern Andes as a critical ecoregion (Rodríguez *et al.*, 2004). In Colombia, all the terrestrial biogeographical provinces defined by Hernández-Camacho *et al.* (1992) are represented in the National Parks System, but at a finer scale many biogeographical districts are not represented (Arango, 1998). Likewise, 20 of the 64 terrestrial ecosystems of Colombia defined by Etter (1998) are not

represented in the system (including six Andean ecosystems; Arango *et al.*, 2003).

Here we present an analysis of representation of bird species for eight subregions in the Andean reserve system of Colombia (including Sierra Nevada de Santa Marta and Serranía de La Macarena). We obtained bird inventories for 16 of the 25 protected areas (no inventories were available for the other nine protected areas), and compared them to the potential bird fauna occurring in the subregion based on general geographic distributions, taking into account elevational ranges of species and altitudinal zones covered by reserves. We asked three questions. Firstly, how many of the species potentially occurring in each reserve have actually been recorded in species inventories? As this may reflect not only lack of representation but also lack of knowledge (incomplete inventories), we asked a second question: assuming all potential species occur in the reserves

(which is unlikely), how many species are unrepresented in each subregion? Thirdly, how many threatened species are represented and in how many reserves?

## Study area

The Andean system of Colombia is formed by three independent ranges with different geological histories (Bürgl, 1961; Irving, 1975); the Western, Central and Eastern mountain chains (Cordilleras), which lie parallel to one other with a south-north orientation (Fig. 1). The Sierra Nevada de Santa Marta is an independent massif rising to high elevations (>5,000 m) next to the Caribbean coast, north of the Andes. Serranía de La Macarena is a low-rising massif east of the Andes that geologically is part of the Guianan Shield. Based on previous work that revealed differences in species composition among mountain ranges and between east and west slopes of the three Andean ranges (Kattan *et al.*, 2004), we defined eight subregions: Santa Marta, Macarena, and east and west slopes of the three Andean ranges. The two external Andean slopes, i.e. the western slope of the Western Cordillera facing the Pacific Ocean, and the eastern slope of the Eastern Cordillera facing the Orinoco and Amazonian lowlands, have continuity with lowland biotas (see Kattan & Franco, 2004). The other four slopes form the internal Andean slopes of the Cauca and Magdalena river valleys (Fig. 1).

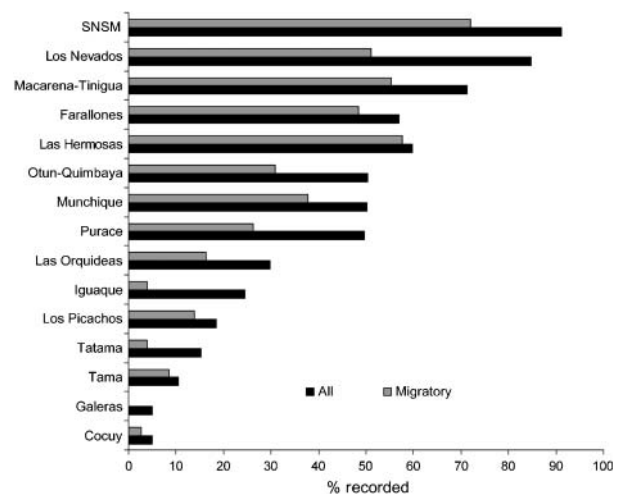
## Methods

We conducted an extensive literature review to obtain bird lists for all Andean protected areas in two categories: Parque Nacional Natural (National Natural Park; PNN) and Santuario de Flora y Fauna (Flora and Fauna Sanctuary; SFF; Appendix 1). SFF Isla de la Corota was excluded because of its small size (8 ha), and PNN Tinigua was merged with its neighbouring PNN, Sierra de la Macarena. We compiled a list of potential avifauna for each subregion, based on Hilty & Brown (1986) and Stotz *et al.* (1996) and complemented by other published lists, unpublished reports and our personal knowledge. From these lists we produced a list of the potential avifauna of each protected area, taking into account the elevational ranges of the species and the elevational extent covered by each reserve. For reserves straddling mountain ranges and occupying two subregions (e.g. PNN Farallones de Cali, which encompasses both slopes of the Western Cordillera), we analysed each subregion separately. From these lists we obtained the percentage of species for each subregion occurring within protected areas, and then

obtained percentages separately for different elevational zones (every 500 m over 0–3,000 m, and an upper elevational zone above 3,000 m). We made these analyses for all species, and for northern and southern temperate zone migrants separately. In addition, we obtained lists of species at risk (in the Critically Endangered, Endangered, Vulnerable, and Near Threatened categories; IUCN, 2001) from Renjifo *et al.* (2002), and tallied their representation in the reserve system.

## Results

Overall, 83% of 1,502 bird species occurring in Colombian montane systems are represented in at least one of the 16 protected areas for which inventories were obtained. This representation, however, varied widely (Fig. 2). The highest representation was found in PNN Sierra Nevada de Santa Marta, where 91% of species potentially occurring in the Park have been recorded in species inventories. In contrast, in PNN Sierra Nevada del Cocuy only 4% of species potentially occurring have been recorded. Representation of potential migrant species was 3–72%. In six of the eight subregions the proportion of potential species that has actually been recorded within protected areas was >50% (Table 1). Representation on both slopes of the Eastern Cordillera was <27%. Compared to the Western and Central Cordilleras, this mountain range has the greater number of protected areas and bird species (Appendix 1; Kattan *et al.*, 2004) but few have been well studied (Fig. 2).



**Fig. 2** Percentages of potential bird species (for all and migratory species separately) recorded in 16 protected areas (SNSM, Sierra Nevada de Santa Marta) of the Colombian Andes (see Fig. 1 for locations). PNN Tinigua is merged with PNN Sierra de la Macarena (see text for details).

**Table 1** Representation of potential and recorded bird species in protected areas in eight subregions of the Colombian Andes.

Subregion	No. of Parks	Total spp. in subregion	% of spp. potentially occurring in Parks	% of spp. recorded in Parks
Western Cordillera				
W versant	6	851	100.0	70.9
E versant	5	504	94.6	84.1
Central Cordillera				
W versant	5	562	87.5	75.8
E versant	4	611	79.2	59.6
Eastern Cordillera				
W versant	7	682	74.5	15.5
E versant	8	1087	100.0	26.5
Serranía de la Macarena	2	606	100.0	71.3
Sierra Nevada de Santa Marta	1	647	100.0	91.0

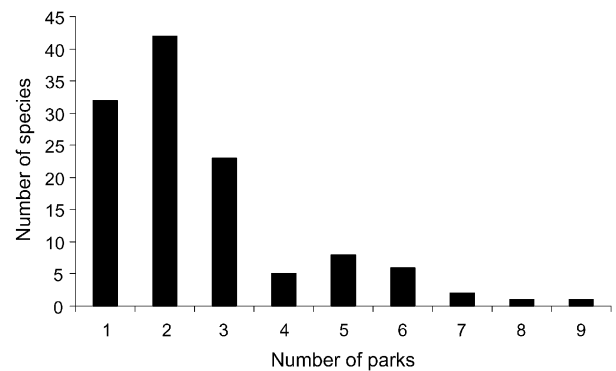
The percentage of potential species occurring within elevational zones that have actually been recorded in protected areas was uneven among elevational zones and subregions (Table 2). PNN Sierra Nevada de Santa Marta, which covers the entire altitudinal range, has *c.* 90% representation in all elevational zones, but only *c.* 70% representation of migrants. In contrast, in the internal Andean slopes (i.e. slopes of the Cauca and Magdalena river valleys) representation decreased drastically with decreasing elevation, reflecting the lack of protected areas at lower altitudes. Representation is particularly poor on the Magdalena valley slopes (eastern slope of Central Cordillera and western slope of Eastern Cordillera), even at higher elevations. If all potential species occur within each of the protected areas, representation values for each subregion would be high, reaching 100% in some cases (Table 1).

Of 152 species classified in a threat category in Colombia (Renjifo *et al.*, 2002), 121 occur in the mountain systems included in this analysis (Appendix 2). Eighty-eight of these species are recorded in at least one protected area, but most are represented in less than three (Fig. 3). The other 33 species have not been recorded in any protected area, but eight are potentially present in at least one (Renjifo *et al.*, 2002). Thus, there

are 25 species under some category of threat that have no populations in protected areas.

## Discussion

Although birds are the best studied taxonomic group, detailed knowledge of geographic distributions of many species is still fragmentary (e.g. Beltrán & Kattan, 2001), in particular concerning migrants. This is a limiting factor for assessing levels of representation of regional

**Fig. 3** Representation of threatened and near-threatened species in protected areas in the Colombian Andes.**Table 2** Percentage of potential bird species (and percentage of migratory birds in parentheses) recorded in protected areas occurring within each elevational zone of each subregion of the Colombian Andes.

Elevational zone (m)	Western Cordillera		Central Cordillera		Eastern Cordillera		Serranía de la Macarena	Sierra Nevada de Santa Marta
	W versant	E versant	W versant	E versant	W versant	E versant		
0–500	69(55)					15(23)	73(55)	88(69)
500–1,000	73(56)			44(66)	4(3)	24(23)	66(55)	88(69)
1,000–1,500	79(61)	73(54)	71(71)	54(69)	6(3)	36(25)	60(55)	87(70)
1,500–2,000	80(58)	78(56)	80(73)	67(72)	12(3)	42(25)	52(54)	87(72)
2,000–2,500	77(58)	79(58)	88(75)	79(74)	19(4)	48(24)	55(58)	87(70)
2,500–3,000	67(56)	83(56)	93(73)	93(73)	27(4)	50(24)		86(69)
>3,500	55(38)	85(64)	98(93)	99(92)	44(29)	58(27)		91(91)

biotas in protected areas. We found that the percentage of potential species actually recorded in reserves varied among subregions but could be as low as 14%. On the other hand, representation increased with elevation, reflecting the fact that most protected areas are concentrated at upper elevations.

Some low representation values found in this study could simply reflect lack of knowledge, as vast areas within many of these protected areas have not been explored. In addition, few studies have been published. Only six of the references included in this study were published in national or international journals, with all other studies mostly in reports. Another source of error is that many studies were limited in time and spatial extent and may therefore underestimate species richness because of seasonal variation in species presence or detectability (G. Kattan *et al.*, unpubl. data). Some species may only be detected after continued and intense sampling effort, even though they may be locally abundant (e.g. brown-banded antpitta *Grallaria milleri*; Kattan & Beltrán, 1997, 1999). The disadvantages of short-term sampling are particularly relevant for transcontinental migratory species, which may be completely missed.

If all potential species actually occur in these protected areas then representation levels are high but this is unlikely as even well surveyed Parks (e.g. PNN Farallones de Cali) do not include all potential species. This reflects the fact that not all species are uniformly distributed over the entire subregion (Kattan *et al.*, 2006). Some species are endemic to part of the subregion (e.g. Magdalena tinamou *Crypturellus saltuarius*) or have discontinuous distributions (e.g. chestnut-bellied flower-piercer *Diglossa gloriosissima* or red-ruffed fruit-crow *Pyroderus scutatus*, Hilty & Brown, 1986; Renjifo *et al.*, 2002; G. Kattan, pers. obs.). In physiographically complex regions such as the Andes differences in species composition may occur between neighbouring river drainages (Kattan *et al.*, 2006).

In addition, the turnover in species composition among elevational zones means that protected areas that do not cover the entire altitudinal gradient will not adequately represent the slope's species diversity (Kattan & Franco, 2004). In particular, the slopes of the inter-Andean valleys of the Cauca and Magdalena rivers have no protected areas at lower elevations. Some of the Critically Endangered and Endangered bird species in Colombia that do not occur in protected areas occur in the inter-Andean valleys and adjacent slopes (e.g. Magdalena tinamou, cinnamon teal *Anas cyanoptera*, Niceforo's wren *Thryothorus nicefori* and Tolima dove *Leptotila conoveri*; Appendix 2). The situation for these species is particularly critical because most of the original vegetation cover in this region has been

destroyed (Etter, 1998). The high number of threatened species in the Andean region of Colombia reflects the degree of landscape transformation that this region has undergone, combined with an abundance of restricted range species (Bibby *et al.*, 1992; Etter & van Wyngaarden, 2000; Etter & Villa, 2000). Other threatened species occur in areas entirely lacking official protection, such as the Serranía de San Lucas and adjacent lowlands on the northern tip of the central Cordillera (white-mantled barbet *Capito hypoleucus*, subtropical doradito *Pseudocolopteryx acutipennis* and Antioquia bristle-tyrant *Phylloscartes lanyoni*), northern end of the eastern Cordillera (Perijá metaltail *Metallura iracunda*), and the wetlands and dry enclaves of the Departments of Cundinamarca and Boyacá (yellow-billed pintail *Anas georgica*, spot-flanked gallinule *Gallinula melanops* and horned lark *Eremophila alpestris*).

Another aspect that needs to be considered in an evaluation of systems of protected areas is the viability of populations. There are two aspects to this problem: the number of populations and population size (determined by size of protected area). An important criterion in protected area planning is redundancy of populations, used as an insurance policy in case of catastrophic loss of one area (Groves, 2003). This is particularly relevant for threatened species, especially if populations are small and isolated. The mean area of National Parks in Andean Colombia is 178,176 ha and the largest is 629,280 ha (excluding Flora and Fauna Sanctuaries, which are all <10,500 ha). Although this may be sufficient for small-bodied and relatively sedentary species, many species require much larger areas and usually range beyond protected area boundaries, as is the case for large raptors (e.g. black-and-chestnut eagle *Oroaetus isidori*). Many parks may not have sufficient area to sustain viable populations of these species (Thiollay, 1989). On the other hand, many species (e.g. parrots, quetzals) carry out regional or altitudinal migrations, and seasonal habitat and resources of critical importance may lack protection.

This study reveals that representation of bird species diversity in the Andean protected areas of Colombia is relatively high, but important gaps still exist, in particular relating to lower elevations and threatened species. Our findings suggest that representation of most species does not translate into coverage of threatened species, a result that complements other studies that have demonstrated that reserve selection based on threatened species does not guarantee coverage of all other species (Bonn *et al.*, 2002, Tognelli, 2005). In addition, many protected areas are small and may not be sufficient for sustaining viable populations of many species. Even if the existing network of protected areas contains most bird species, not all bird species may be



represented within their peak abundance locations (Bonn & Gaston, 2005). Although in some cases representation levels exhibited by one taxa may reflect that of other groups (Warman *et al.*, 2004), in other cases representation is expected to be much lower, in particular for less vagile taxonomic groups, and therefore the case of birds represents an optimistic scenario. More detailed analyses at the level of each protected area and subregion are required, taking into account regional and altitudinal distributions of species, to ensure that beta diversity within subregions is accounted for (Kattan *et al.*, 2006). This is important because beta diversity not only represents differences in species composition, but also evolutionary phenomena.

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## Appendices 1–2

The appendices for this article are available online at <http://journals.cambridge.org>

### Biographical sketches

Padu Franco and Carlos A. Saavedra are researchers at the Colombia Program of the Wildlife Conservation Society (WCS). Their work focuses on macroecology and behavioural ecology of tropical birds, and the ecology and conservation of mammals, respectively.

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