

BETA-DIVERSITY ANALYSIS OF A BIRD ASSEMBLAGE OF A BIODIVERSITY HOT-SPOT WITHIN THE ATLANTIC FOREST

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Abstract · The Atlantic Forest, a biodiversity hotspot, is the second largest tropical rainforest in South America. It harbors the greatest number of threatened and endemic bird species in Brazil. Serra de Paranapiacaba is one of the best-preserved and largest forest remnants, inserted within the Serra do Mar massif. Despite its undoubted importance for bird conservation, ornithological knowledge in the region is still scattered across different studies. The aim of this article is to report bird species richness in the Serra de Paranapiacaba and to compare it with 19 other well-preserved and well-sampled Atlantic Forest localities via multivariate analysis to synthesize ornithological knowledge in the region. We compiled bird records from the literature and provide our own records based on surveys and non-systematic observations at three localities between 2010 and 2017. We performed a Hierarchical Cluster and a Principal Coordinate analysis with bird communities to infer avifauna affinities of Serra de Paranapiacaba and other Atlantic Forest regions with different vegetation types. Overall, we compiled records for 479 species, 144 of which are endemic to Atlantic Forest and 15 which are threatened at global level. The Serra de Paranapiacaba bird community is more similar to that of localities where vegetation is montane ombrophilous dense forest and mixed ombrophilous forest and, to a lesser extent, to semi-deciduous and restinga forest. Our study corroborates a division of southern and northern counterparts of some bird species along Serra do Mar as proposed by other authors. We suggest the Guapiara Plateau and Paranapiacaba Ridge, in São Paulo state, as barriers of these assemblages. Finally, we confirm the importance of the region for the conservation of Atlantic Forest birds and updated the data used to classify it as an Important Bird Area (IBA).

Resumo · Análise de diversidade beta de uma assembléia de aves em um hotspot de biodiversidade na Mata Atlântica

A Mata Atlântica, um hotspot de biodiversidade, é a segunda maior floresta tropical na América do Sul. Nela se encontra o maior número de espécies de aves endêmicas e ameaçadas no Brasil. A Serra de Paranapiacaba é um dos maiores e mais bem preservados remanescentes florestais inseridos na Serra do Mar. Apesar de sua incostável importância para a conservação das aves, o conhecimento ornitológico da região ainda se encontra disperso por diferentes estudos. O objetivo deste artigo é reportar a riqueza de aves da Serra de Paranapiacaba e compará-la com outras 19 localidades bem preservadas e bem amostradas na Mata Atlântica por meio de análises multivariadas com o objetivo de sintetizar o conhecimento ornitológico na região. Nós compilamos registros de aves da literatura e fornecemos registros pessoais e observações não sistemáticas em três localidades entre 2010 e 2017. Nós realizamos análise de cluster e análise de coordenadas principais com a comunidade de aves para inferir a afinidade de avifauna entre a Serra de Paranapiacaba e outras localidades na Mata Atlântica com diferentes tipos de vegetação. Ao todo, nós compilamos 479 registros de espécies de aves, 144 das quais são endêmicas da Mata Atlântica e 15 ameaçadas de extinção em nível global. A comunidade de aves da Serra de Paranapiacaba é mais relacionada com localidades onde a vegetação é formada por floresta ombrófila densa montana e floresta ombrófila mista e, em menor medida, com localidades de florestas estacionais semidecíduais e restinga. O nosso estudo corrobora ainda uma divisão entre as partes norte e sul de algumas espécies ao longo da Serra do Mar como proposto por outros autores. Nós sugerimos o platô de Guapiara e a Serra de Paranapiacaba, no estado de São Paulo, como barreiras para essas assembleias. Por último, nós corroboramos a importância da região para a conservação das aves da Mata Atlântica e atualizamos os dados utilizados para classificá-la como uma Área Importante para as Aves (IBA).

Key words: Aves · Brazil · Conservation · Habitat fragmentation · Hierarchical Cluster Analysis · Multivariate Analysis · Principal Coordinate Analysis · Serra de Paranapiacaba

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INTRODUCTION

The Atlantic Forest (AF) is the second largest tropical rainforest in South America. It is mainly distributed near the Brazilian coast, originally stretching south from the state of Rio Grande do Sul far north as the state of Rio Grande do Norte, NE Brazil, reaching inner South America to parts of Paraguay and Argentina (Galindo-Leal & Câmara 2005). The region holds one of the highest levels of bird richness in the world (~ 900 species), with many (~ 24%) endemic taxa (Bencke et al. 2006, Lima unpub. data). Despite the high levels of biodiversity, its conservation status is currently imperiled, as only 12% of its forests persist and most (> 80%) of the remaining vegetation is fragmented and composed of weakly connected small (< 50 ha) patches. Moreover, nature reserves protect only 9% of remaining forests and only 1% of original vegetation (Ribeiro et al. 2009). This scenario of high bird diversity, endemism, and devastation makes AF a priority area for avian conservation worldwide (Bencke et al. 2006). Despite this, ornithological knowledge in the region is still scarce, with the discovery of new species even near large urban centers (Buzzetti et al. 2013), and forest remnants remain poorly studied even near the largest universities and research centers in Brazil (Tonetti et al. 2017).

The largest remaining AF patch in Brazil is located in the Serra do Mar massif along the coastal mountains of the state of São Paulo, in the southeast of the country. This remnant contains more than 1,000,000 ha of continuous forests, or 7% of all AF remaining at national level (Ribeiro et al. 2009). In northern São Paulo, these mountains run parallel to the coast. As they approach the lower Ribeira Valley, to the southeast, the Serra do Mar retreats to the interior dividing the Ribeira and Paranapanema water sheds (Figure 1). There, it is known as Serra de Paranapiacaba (hereafter SdP). SdP, with more than 200,000 ha one of the best-preserved continuous AF remnants. It harbors several globally threatened species and is a stronghold for populations of some of the most AF endangered bird species, such as the Black-fronted Piping-Guan (*Aburria jacutinga*) (Galetti et al. 1997). Due to the amount of threatened and endemic bird species, SdP is an Important Bird Area (IBA SP10, Bencke et al. 2006). Endemic and threatened species from other taxonomic groups, such as mammals, reptiles, amphibians, and plants also occur in the region (IARBMA 2014), including the discovery of a population of the endangered black lion tamarin (*Leontopithecus chrysopygus*) (Röhe et al. 2003). Several reserves lie within SdP, among which the largest ones are the Intervalles, Carlos Botelho, Turístico do Alto Ribeira and Nascentes do Paranapanema State Parks as well as the Xitué Ecological Station. Together they encompass ~ 75% of SdP area and form an important mosaic of protected areas (Figure 1, IARBMA 2014). Given their importance to biodiversity conservation and human welfare, these reserves are part of the AF

Biosphere Reserve according to UNESCO (Mateos et al. 2002).

Despite its undoubted importance for bird conservation, SdP ornithological knowledge is still scattered. It comprises studies on bird communities (Aleixo & Galetti 1997, Antunes & Eston 2007, 2010; Costa 2008, Antunes et al. 2011), inventories (Willis & Oniki 1981, 2003; Figueiredo & Filho 2003; Antunes et al. 2008, 2013b; Antunes 2009, Martensen et al. 2012), species records (Antunes et al. 2006, 2007; Jesus et al. 2014), behavior (Paccagnella et al. 1994), diet (Pizo 2007), conservation (Galetti et al. 1997, Gussoni 2007) breeding biology (Beisiegel 2006, Perrella et al. 2015, Biagolini-Jr et al. 2016), taxonomy (Cavarzere et al. 2014), seeding predation (Cestari & Bernardi 2011), plant-bird interaction (Machado & Semir 2006), inter-specific associations (Machado 1999), landscape ecology (Martensen 2008, Martensen et al. 2012b), and population censuses (Mateos et al. 2002, Meirelles 2009).

In this article, we present an updated compilation of bird species recorded within SdP. We collected field records, records from literature and online databases. We also compare its bird community to other AF localities in south and southeast Brazil by using multivariate analysis to infer SdP beta diversity. We synthesize the ornithological knowledge on SdP and discuss some implications of our results for bird conservation.

METHODS

Study area. The mountainous relief of SdP is truncated (does not include sea level forests), ranging from 60 to 1100 m a.s.l. It comprises mostly lowland and montane ombrophilous dense forest in advanced stages of regeneration in most of its areas. It also comprises small portions of mixed ombrophilous forest in its southern parts at 1000 m a.s.l. (Pisciotta 2002). In this habitat type, the Paraná pine (*Araucaria angustifolia*, Araucariaceae), globally critically endangered (Thomas 2017), is predominant. Annual rainfall is high (ranging from 1,800 mm in higher parts, above 1000 m a.s.l., to 4000 mm in lowlands) and average annual temperature is 24° C (Bencke et al. 2006). Tree in lowland forests reach up to 40 m in height and forests are lower on the slopes (15 m), with some parts covered by clouds throughout the year, forming cloud forests (Pisciotta 2002, Bencke et al. 2006). The main threats to the SdP biodiversity are hunting, extraction of non-timber forest products, especially the jussara palm-heart (*Euterpe edulis*, Palmaceae; Aleixo & Galetti 1997), and mining in areas adjacent to reserves (Bencke et al. 2006). A project to build a large hydroelectric plant in the Ribeira River endangers extensive forested areas (Bencke et al. 2006).

Data collection and analysis. We searched for indexed articles and gray literature (such as technical reports and theses) with bird records in the citation databases Scielo, Web of Science, Google Scholar,

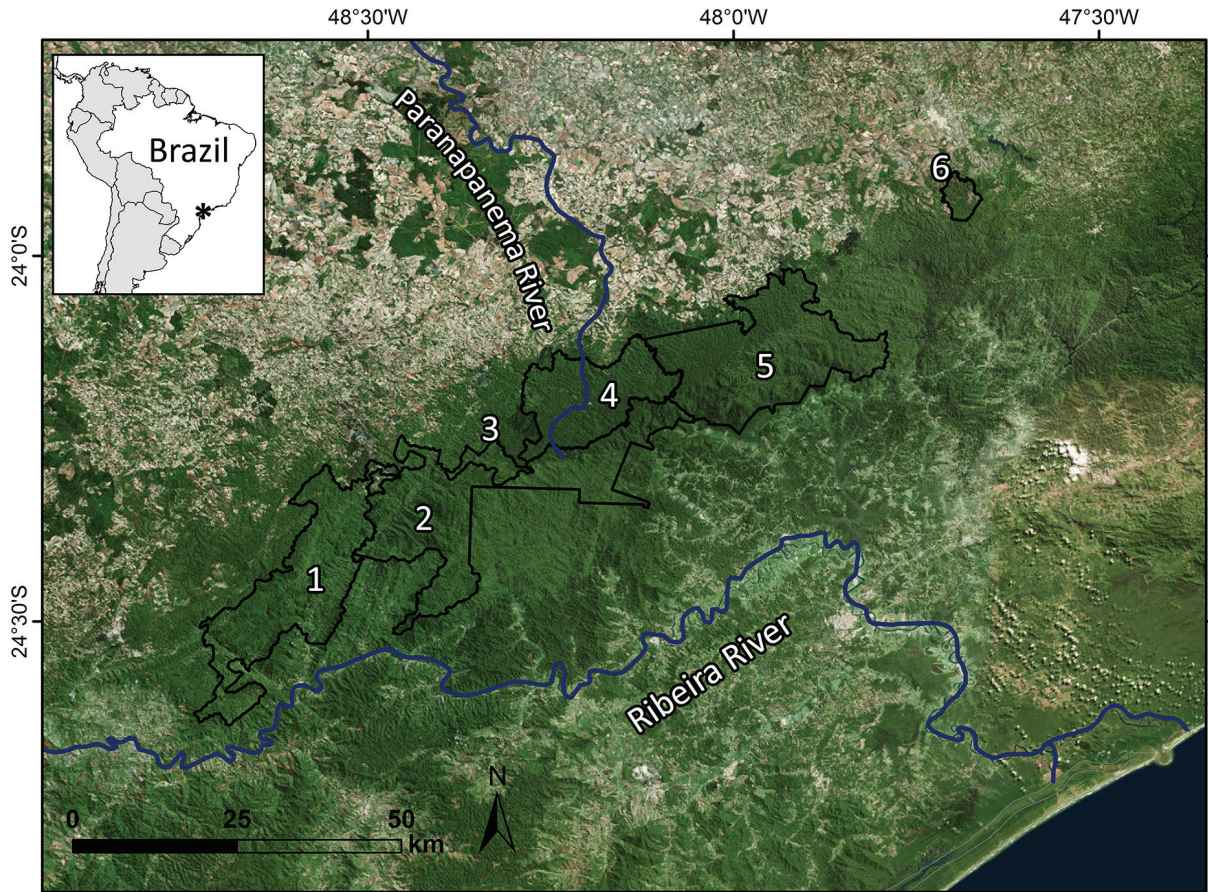


Figure 1. Serra de Paranapiacaba, São Paulo state, Brazil with localities included in this study: 1 = Turístico do Alto Ribeira State Park, 2 = Intervalos State Park, 3 = Xitué Ecological Station, 4 = Nascentes do Paranapanema State Park, 5 = Carlos Botelho State Park and 6 = João XXIII Farm.

and Google using the terms “Paranapiacaba,” “Intervalos,” “Carlos Botelho,” “Turístico do Alto Ribeira,” “PETAR,” “Xitué,” and “Nascentes do Paranapanema” associated with the terms “avifauna” and/or “birds”. We also compiled bird records from WikiAves (www.wikiaves.com) and Xeno-Canto (www.xeno-canto.org) databases until 12 January 2017. We considered records performed within these reserves as well as their surroundings within SdP massif. We carefully examined photographs and recordings and discarded doubtful or erroneous identifications. We followed taxonomic nomenclature according to the most recent classification of the Brazilian Committee of Ornithological Records (Piacentini et al. 2015).

We also surveyed birds at João XXIII Farm between September 2013 and February 2015. João XXIII Farm is a mosaic of *Eucalyptus* plantations (totaling ~ 1300 ha) and patches of AF (~ 1000 ha). The farm also comprises smaller pastures areas (Röhe et al. 2003). We surveyed birds in different months comprising all seasons. We used mist-netting, an adequate method to capture secretive understory birds (Roos 2010), transects using MacKinnon lists, and non-systematic observations (Ribon 2010). We established 13 nets (12 m each) on the forest ground and concentrated opening in the mornings and late afternoons, totaling 10,000 hours·m². We banded and released some

captures and collected a few voucher specimens that were deposited at Museu de Zoologia da Universidade de São Paulo. In addition to mist-netting, we accumulated 250 10-species MacKinnon lists (Ribon 2010) as systematic surveys. We further surveyed several environments within the study area (e.g., forest edges, degraded areas, mature forests, and marshes). Observers walked randomly while recording all birds observed (with the aid of binoculars) or heard (Ribon 2010). In addition to visiting João XXIII Farm, we performed non-systematic observations between 2010–2017 at Intervalos and Carlos Botelho State Parks by recording all birds detected (visually/auditively) while walking on trails, totaling ~ 200 h of sample efforts.

To infer community affinities among SdP and other AF localities in southern and southeastern Brazil, we compared bird communities from another 19 well-preserved and well-surveyed forest remnants by using multivariate analysis. These localities lie in areas of different forest types, i.e., ombrophilous dense forests: Boraceia Biological Station (Cavarzere et al. 2010), Serra da Cantareira (Tonetti et al. 2017), Morro Grande Reserve (Develey & Martensen 2006), Salto Morato Private Reserve (Straube & Urben-Filho 2005), Serra do Itajaí National Park (ICMbio 2009), and Ubatuba municipality (Simpson et al. 2012); mixed ombrophilous forests: Campos do Jordão

(composed by the Mananciais de Campos de Jordão and Campos do Jordão State Parks, Willis & Oniki 1981), Irati National Forest (Volpato et al. 2010, Urben-Filho & Straube 2013), Itatiaia National Park (ICMbio 2013), and Três Barras National Forest (Corrêa et al. 2008); semi-deciduous forests: Barreiro Rico Ecological Station (Antunes 2007), Caetetus Ecological Station (Cavarzere et al. 2009), Fazenda Rio Claro (Donatelli et al. 2004), Mata dos Godoy State Park (dos Anjos 2001), Morro do Diabo State Park (Uezu & Metzger 2016), Porto Ferreira (composed by Porto Ferreira and Vassununga State Parks, Uezu & Gaban-Lima 2003), and Vila Rica do Espírito Santo State Park (Neto & Bispo 2011). In addition, we included one *restinga* forest: Ilha Comprida municipality (Gussoni 2010). We also considered WikiAves and Xeno-Canto databases to compose bird lists of those localities. Although the efforts samples and methods are different, we assume that sampling effort is sufficiently adequate (including SdP) because all studies conducted exhaustive sampling, allowing comparison among bird communities. For comparisons, we excluded exotic species (such as Rock Pigeon *Columba livia*) and seabirds (e.g., Magnificent Frigatebird *Fregata magnificens*).

We performed multivariate analyses following Tonetti et al. (2017). We used Mountford's dissimilarity index (Wolda 1981) to perform a hierarchical cluster analysis (HCA) and a Principal Coordinate Analysis (PCoA) to compare bird communities considering species presence or absence only. After calculating the Mountford's index within the R package *vegan* (Oksanen et al. 2017, we performed a HCA and a PCoA using the Ward's minimum variance criterion as the objective function, the results of which define which clusters merge at each step (Ward Jr 1963). We performed HCA and PCoA using the *hclust* and *ordiplot* functions (Oksanen et al. 2016).

RESULTS

Overall, we compiled records for 479 species in SdP. Non-passerines accounted for 199 species in 34 families and passerines accounted for most records, represented by 280 species distributed in 35 families. AF endemic species accounted for 30% of the records (under the classification proposed by Bencke et al. 2006). Fifteen species are globally threatened (Bird-Life 2016), 12 are considered threatened in Brazil (MMA 2014), and 34 are threatened within the state of São Paulo (São Paulo 2014).

HCA indicated three major groups of AF areas according to their bird community. One of these includes dense or mixed ombrophilous forests, another comprises areas of semi-deciduous forests and *restinga* forest defined an out-group (Figures 2, 3). Although the groups that comprise areas of ombrophilous dense or mixed forests are clustered within the same root, it is possible to separate them (Figure 3). According to HCA, the SdP bird community

is more similar to that of Salto Morato Private Reserve, an AF dense ombrophilous forest remnant some ~ 80 km from SdP, and less similar to Ilha Comprida, composed by *restinga* forest and ~ 50 km from SdP (Figure 2). On the other hand, PCoA suggested SdP bird community is more similar to that of Serra do Itajaí (dense ombrophilous forest) and Itatia (mixed ombrophilous forest) National Parks and less similar than that at Iguaçu National Park (semi-deciduous forest) and other localities composed by semi-deciduous and ombrophilous mixed forest (Figure 4).

DISCUSSION

To our knowledge, this is the most comprehensive analysis on the SdP avifauna. SdP comprises 25% of all species recorded in Brazil (Piacentini et al. 2015) and 53% within AF (Lima unpub. data). Other bird counts in well preserved AF localities of ombrophilous forests in southeast Brazil that used similar methods employed by us reported less bird species: these include Serra da Cantareira (326 spp., Tonetti et al. 2017) and Boraceia Biological Station (323 spp., Cavarzere et al. 2010). On the other hand, a compilation of records from Ubatuba reported bird richness similar to this study (417 spp., Simpson et al. 2012). These differences are probably due to the fact that both SdP and Ubatuba encompass an almost complete elevational gradient. In AF, bird communities in lowlands and highlands in the Serra do Mar massif show slightly different compositions (Cavarzere & Silveira 2012). Some endemic and globally threatened birds found in SdP occur most predominantly in lowlands, such as Salvadori's Antwren (*Myrmotherula minor*) and Black-headed Berryeater (*Carpornis me-lanocephala*). On the other hand, threatened birds like the White-bearded Antshrike (*Biatas nigropectus*) are locally only found in forests above 500 m a.s.l. (Ridgely & Tudor 2004). Moreover, species like the Black-fronted Piping-Guan (*Aburria jacutinga*) are known to perform altitudinal migration in search of fruits that follow alternated phenological cycles at different elevations, e.g., jussara palm-heart (Galetti et al. 1997, Sick 1997). This highlights the importance of conserving areas in AF that comprise continua of both lowland and montane forests, a condition currently rare in this region, especially in protected areas (Bencke et al. 2006, Ribeiro et al. 2009, Simpson et al. 2011, Cavarzere & Silveira 2012).

WikiAves and Xeno-Canto databases comprised 88% of our records, highlighting the importance of citizen science in ornithology (Dickinson et al. 2010). Some species, such as the Southern Antpipit (*Corythopsis delalandi*), were recorded in the region only recently (last five years), indicating that the number of species in SdP can still increase in the future. Although some species are no longer recorded in our study area, such as the Purple-winged Ground-Dove (*Claravis geoffroyi*), we cannot assume local extinctions as there are examples of rediscovered bird spe-

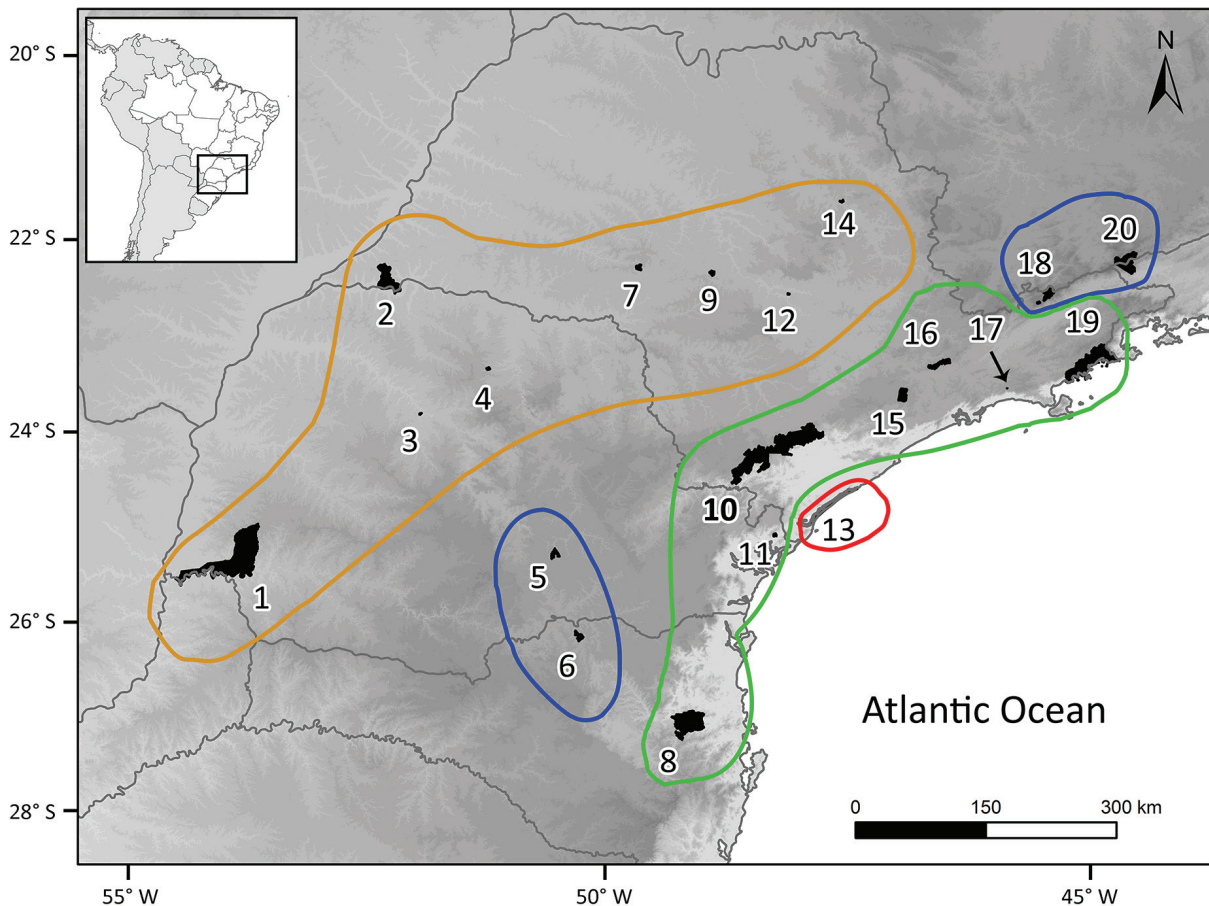


Figure 2. Localities of Atlantic Forest in Brazil whose bird communities were compared via multivariate analysis. Regions where vegetation is ombrophilous dense forest are surrounded by green line, mixed ombrophilous in blue, semideciduous in orange and restinga in red. 1 = Iguaçu National Park, 2 = Morro do Diabo State Park, 3 = Vila Rica do Espírito Santo State Park, 4 = Mata dos Godoy State Park, 5 = Irati National Forest, 6 = Três Barras National Forest, 7 = Caetetus Ecological Station, 8 = Itajaí National Park, 9 = Fazenda Rio Claro, 10 = Serra de Paranapiacaba, 11 = Salto Morato Private Reserve, 12 = Barreiro Rico Ecological Station, 13 = Ilha Comprida, 14 = Porto Ferreira State Park, 15 = Morro Grande Reserve, 16 = Serra da Cantareira, 17 = Boracéia Biological Station, 18 = Campos do Jordão, 19 = Ubatuba, 20 = Itatiaia National Park.

cies after centuries of disappearing (Scheffers et al. 2011).

Community affinities. This study is the most comprehensive comparison of bird communities in AF using multivariate analysis (20 localities surveyed). Although Hierarchical Cluster Analysis and Principal Coordinate Analysis do not consider species abundance, we used an adequate similarity index for presence/absence data not suffering from effects of sample size (Wolda 1981). Based on bird (Tonetti et al. in 2017) and anuran (Lucas & Fortes 2008) communities, our results suggest SdP avifauna is more similar to regions with ombrophilous dense and mixed forest and less similar to seasonal semi-deciduous and *restinga* forests (Figures 3, 4). Such areas of ombrophilous dense forest are inserted in a well-known center of endemism for passerines in AF, the Serra do Mar area of endemism, which includes coastal southern and southeastern Brazil (Silva et al. 2004).

Differences among areas may reflect proximity with coastal forests. For instance, according to HCA SdP avifauna is less similar to Ilha Comprida than to Serra do Itajaí National Park (Figure 3), even though the first is ~ 50 km distant and the latter is ~ 300 km (Figure 2). The three types of forests used in this comparison (*restinga*, ombrophilous dense, and semideciduous forests) are characterized according to differences in climate, mostly precipitation, temperature, and type of soil. Climate in semideciduous forests is seasonal, with dry and cold winters and a well-delimited rainy season during summer and spring. On the other hand, precipitation and temperature in ombrophilous forest are higher and more homogeneous throughout the year, resulting in taller forests with higher species richness and abundance of epiphytes. The main difference between ombrophilous dense forest and *restinga* is due to the soil: the second is composed by nutrient poor sandy soil and forests are lower (~ 10 m), sometimes composed by shrubs (IBGE 2012).

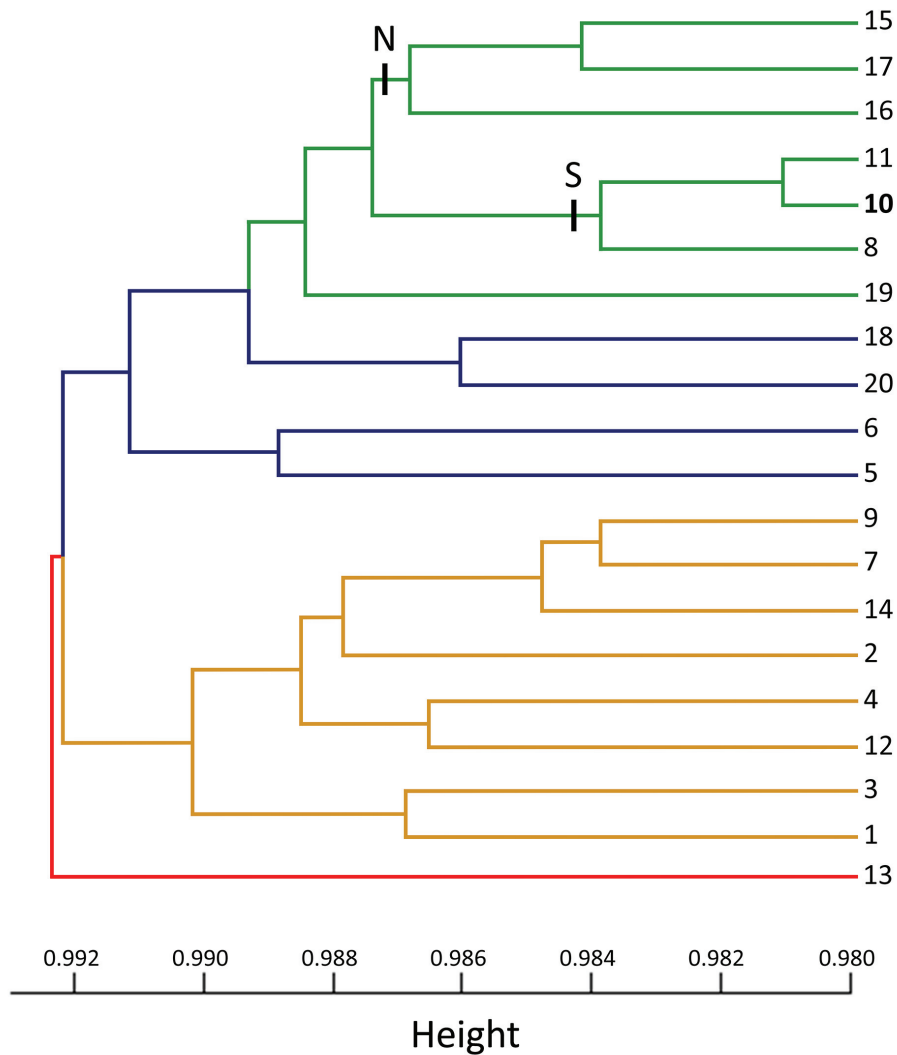


Figure 3. Hierarchical cluster analysis comparing bird communities of Atlantic Forest localities in south and southeast Brazil. The green branches correspond to localities where vegetation is ombrophilous dense forest, blue branches as ombrophilous mixed forest, orange branches are semi-deciduous forest and red corresponds to a single branch of *restinga* forest. N = north Serra do Mar, S = south Serra do Mar, 1 = Iguaçu National Park, 2 = Morro do Diabo State Park, 3 = Vila Rica do Espírito Santo State Park, 4 = Mata dos Godoy State Park, 5 = Irati National Forest, 6 = Três Barras National Forest, 7 = Caetetus Ecological Station, 8 = Itajaí National Park, 9 = Fazenda Rio Claro, 10 = Serra de Paranapiacaba, 11 = Salto Morato Private Reserve, 12 = Barreiro Rico Ecological Station, 13 = Ilha Comprida, 14 = Porto Ferreira State Park, 15 = Morro Grande Reserve, 16 = Serra da Cantareira, 17 = Boraceia Biological Station, 18 = Campos do Jordão, 19 = Ubatuba, 20 = Itatiaia National Park.

Although the presence of few species with predominant occurrence in semi-deciduous forest, such as the Southern Antpipit (*Corythopsis delalandi*), there are several species typical of ombrophilous dense forest in SdP. These include Buff-throated Purpletuft (*Iodopleura pipra*) and others that are more common in mixed ombrophilous forest, e.g., the Araucaria Tit-Spinetail (*Leptasthenura setaria*), highly associated with the Paraná pine (Ridgely & Tudor 2004, IBGE 2012). This is due to the geographic location of SdP in AF. The southern section of SdP, especially parts of the Turístico do Alto Ribeira State Park, have forest remnants in high altitudes composed by ombrophilous mixed forests and, to a lesser extent there are areas where vegetation is semi-deciduous forest (Ivanauskas et al. 2011).

Cavarzere et al. (2014) suggested a kilometric gap (~ 100 km) in the middle of São Paulo state based on lack of records of several montane bird taxa which occur only in the north and south of the state. For instance, Plovercrests (*Stephanoxis* spp.) and Serra do Mar Tyrannulet (*Phylloscartes difficilis*) only inhabit higher terrains in São Paulo, being absent on lower grounds of the Ribeira do Sul valley. The Violet-crowned Plovercrest (*Stephanoxis loddigesii*) is present in semideciduous forests in Paraná state (to the south), but at lower (colder) latitudes. The Ribeira do Sul valley, a large lowland patch of forests, is situated on the Paranapiacaba Ridge, just south of the Guapirara plateau, exhibiting karstic terrains quite different from northern geologic formations (Lenhare & Sallun-Filho 2014).

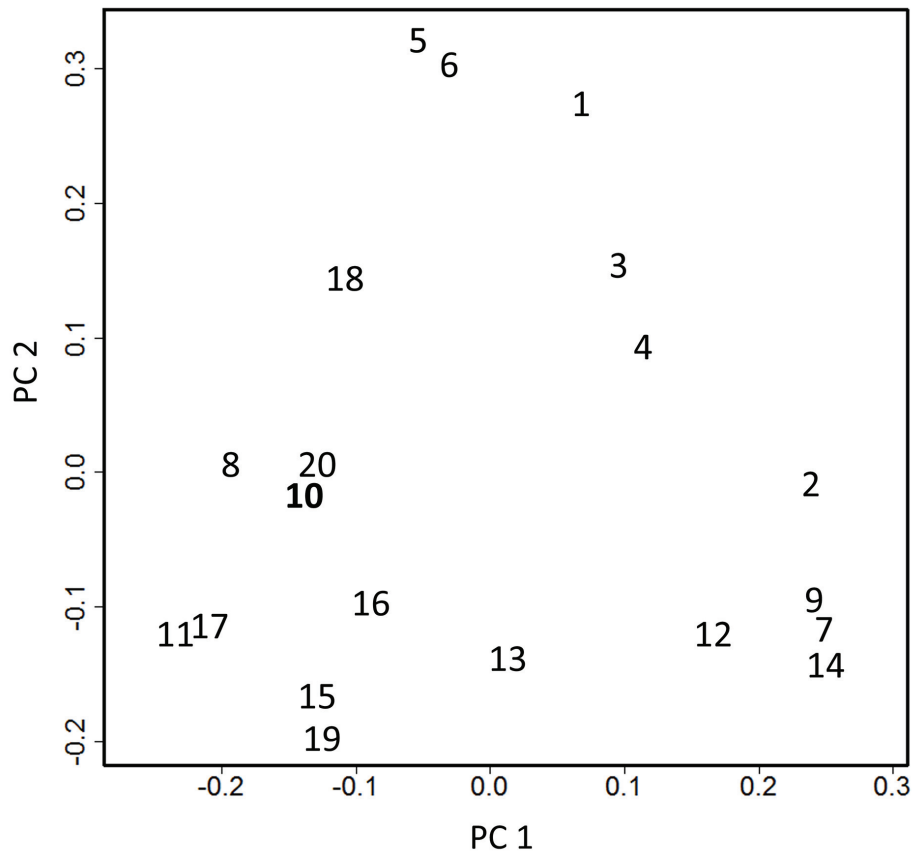


Figure 4. Principal Coordinate Analysis comparing bird communities of Atlantic Forest localities in south and southeast Brazil. 1 = Iguaçu National Park, 2 = Morro do Diabo State Park, 3 = Vila Rica do Espírito Santo State Park, 4 = Mata dos Godoy State Park, 5 = Irati National Forest, 6 = Três Barras National Forest, 7 = Caetetus Ecological Station, 8 = Serra do Itajaí National Park, 9 = Fazenda Rio Claro, 10 = Serra de Paranapiacaba, 11 = Salto Morato Reserve, 12 = Barreiro Rico Ecological Station, 13 = Ilha Comprida, 14 = Porto Ferreira State Park, 15 = Morro Grande Reserve, 16 = Serra da Cantareira, 17 = Boracéia Biological Station, 18 = Campos do Jordão, 19 = Ubatuba, 20 = Itatiaia National Park.

Silva et al. (2004) suggested the entire Serra do Mar as a center of endemism. However, it is likely that this large forested block may include a few smaller areas of endemism. Although we did not intend to identify such areas, our similarity analyses suggest distinct bird communities, i.e., northern and southern counterparts, corroborating the division of Serra do Mar proposed by Cavarzere et al. (2014). Not surprisingly, SdP is found within the southern cluster, along with Salto Morato Private Reserve and Serra do Itajaí National Park on the Guapiara Plateau whose bird community is more similar to southern AF. On the other hand, northern forest regions form a distinct group (formed by Morro Grande, Boracéia Biological Station, and Serra da Cantareira, Figure 3). There are phylogeographic studies that demonstrate genetic breaks in bird lineages from both clusters (Cabanne et al. 2007). Thus, similarities in bird communities do not seem connected with vegetation type. Instead, latitudinal range may play an important role, in which case southern and northern bird communities would be segregated by the Guapiara Plateau and Paranapiacaba Ridge.

Conservation. In addition to reporting high species richness for a single locality, our study corroborates the importance of SdP for bird conservation and its inclusion as an Important Bird Area according to BirdLife International. Bencke et al. (2006) estimated bird richness of ~ 400 species and asserted that 14 globally threatened species occur in SdP. Our results update these numbers. We reported an overall number 479 species in SdP, of which 15 are globally threatened (Supplementary Material online).

SdP is in the best-preserved area of endemism for passerines in AF (Serra do Mar, 36.5% of native forest cover; da Silva et al. 2004, Ribeiro et al. 2009) when compared to others, such as the Pernambuco area of endemism (12.1% of forest cover; Ribeiro et al. 2009, Pereira et al. 2014). Unlike almost all AF areas, where habitat fragmentation is a major threat, SdP forests are continuous and well preserved (Ribeiro et al. 2009). In addition, protected areas in SdP represent ~ 150,000 ha. However, there are large amounts of mature forests that are not protected in SdP (Figure 1; Bencke et al. 2006). These non-protected areas are more vulnerable to illegal hunting, extraction of non-timber forest products, and

logging, representing serious threats for the long-term conservation of their biodiversity (Bencke et al. 2006, pers. obs.). To increase protection of SdP forests, similarly to what has recently occurred with the creation of the Nascentes do Paranapanema State Park (Martensen et al. 2012), we suggest the establishment of new reserves, especially in those areas adjacent to the Intervalos State Park (Figure 1).

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