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Cover: A female Black-bellied Seedeater (*Sporophila melanogaster*) coupled with male (background). Repenning & Fontana, in this issue, studied how distinguishing capuchino females in field, based on vocalizations. Photo author: Márcio Repenning.

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ARTICLE

Breeding biology of the Cipo Cinclodes *Cinclodes espinhacensis*, a micro-endemic furnariid of the southeastern Brazilian mountains

Lílian Mariana Costa[1,4], Guilherme Henrique Silva de Freitas[1], Pedro Henrique Vieira Braga Pereira da Silva[1], Leonardo Cotta Ribeiro[2], Marcelo Ferreira de Vasconcelos[3] & Marcos Rodrigues[1]

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ABSTRACT: The Cipo Cinclodes *Cinclodes espinhacensis* is a recently described furnariid endemic to the *campos rupestres* of Serra do Cipó, southern Espinhaço Range, southeastern Brazil. It is an "Endangered" species and its natural history is poorly known. We studied the Cipo Cinclodes breeding biology at Serra do Breu, where we found six nests on rock outcrops in 2009 and 2012. At least one nest was reused in different years. Breeding season was from September (nest building) to January (dependent juveniles). Nests were shallow cups or beds placed in chambers at the end of earthen and/or rocky tunnels or crevices on rock outcrops. Clutch size was 2–3 eggs. It exhibited biparental care during all nest stages. We demonstrated that the nesting habits of Cipo Cinclodes agree with those reported for other species of the genus, although some details differ from what is known for the closely related species, the Long-tailed Cinclodes *Cinclodes pabsti*.

KEY-WORDS: cavity nest, *campos rupestres*, egg, fledgling, Furnariidae, nest, nestling, reproduction.

INTRODUCTION

The Cipo Cinclodes *Cinclodes espinhacensis* is a recently described furnariid endemic to *campo rupestre* vegetation mosaic from the highest mountaintops of Serra do Cipó, southern Espinhaço Range, Brazil (Freitas *et al.* 2012 & 2019). The species is isolated by more than 1000 km from its closest relative, the Long-tailed Cinclodes *Cinclodes pabsti* from the Serra Geral, southern Brazil (Freitas *et al.* 2008 & 2012, Chaves *et al.* 2015). Cipo Cinclodes is included in the Brazilian Red List as "Endangered" (MMA 2014), and the Long-tailed Cinclodes as "Near-Threatened" (ICMBio 2014). The global Red List considers the Long-tailed Cinclodes, including the Cipo Cinclodes as subspecies, as "Near-Threatened" (BirdLife International 2019).

A recent study investigated the population and spatial ecology of Cipo Cinclodes, improving our understanding of their basic biology and distribution and supporting the designation as "Endangered" on the Brazilian Red List (Freitas *et al.* 2019). Beyond that, nothing else has been published about the natural history of Cipo Cinclodes since its description (Freitas *et al.* 2012). About its breeding biology, it is only known that it nests in cavities (Freitas *et al.* 2012), which is a common pattern within the genus (Zyskowski & Prum 1999, Remsen-Jr. 2019). However, a variety of cavity types are used by members of the genus, existing some evidence of species-specificity and also intra-specific differentiation (Hahn *et al.* 2005, Ojeda 2016).

Recognizing the importance of breeding data not only to species conservation, but also to investigate ecological and evolutionary hypotheses (Zyskowski & Prum 1999, Hahn *et al.* 2011), we present information about the breeding biology of Cipo Cinclodes, including data on its nest, nest site, clutch size, egg, nestling, fledgling, breeding season and parental care.

METHODS

We studied a Cipo Cinclodes population at Serra do Breu, Santana do Riacho municipally, state of Minas Gerais, from 2009 to 2017. The study area comprises

~295 ha of *campo rupestre* – a high altitude complex mosaic of vegetation (see Alves *et al.* 2014, Silveira *et al.* 2016) – where quartzite outcrops predominate within grasslands, traversed by several streams bordered by low riparian vegetation. We marked birds and searched for nests by following the adults during nine visits (4–7 days each): two in 2009 (November and December), six in 2012–2013 (July, September, October, December, January and February), and one in 2017 (January). Birds were captured with mist nets and marked with color and metallic numbered leg bands, and with radio transmitters (Biotrack Pip Ag393; details in Freitas *et al.* 2019).

We measured with a metric tape (to the nearest 0.5 cm) the following nest and nest site attributes: height of the entrance above ground, distance of the entrance to the top of the bank/hillside, width and height of the entrance, length of the tunnel or crevice (distance from the entrance to nest cup) and total length of the cavity (distance from the entrance to the end of the chamber; "burrow depth" *sensu* Hansell 2000), inclination (angle of inclination of the tunnel or crevice, measured with a protractor); width and height of the chamber containing the nest; nest external and internal diameter and depth ("nest diameter", "cup diameter", and "cup depth", respectively, *sensu* Hansell 2000). We weighted (*Pesola*© spring scales to the nearest 0.1 g) and measured (with a Mitutoyo© caliper to the nearest 0.1 mm) eggs (width and height), nestlings (tarsus, total culmen, bill width at gape, total body length and total head length – from the tip of the bill to the occiput) and fledglings (body length) (Baldwin *et al.* 1931).

Some nests and its contents were not reachable (neither visible) inside their cavities to be measured, and the nest stage was inferred from the adults' behavior (*e.g.*, staying long periods inside the nest or taking food). For nest shape, site and attachment descriptions we follow the terminology of Simon & Pacheco (2005) and Hansell (2000).

RESULTS

We found six nests, four in the breeding season of 2009 and two in 2012. One of those nests found in 2009 was active again in 2012. Nesting period extended from September, when we observed nest building activity, through November and December, when eggs and nestlings were found. Juveniles dependent on parental were observed in December and January.

All nests were found within cavities on rocky outcrops (Fig. 1) and consisted of a shallow cup made of fragments of thin and pliable material, with some soil among them (Figs. 2A & B). Nest materials were mostly from plants, such as dry grass-like narrow leaves, inflorescences of small Eriocaulaceae, and green mosses, but also from animals, like mammals' hair and feathers from other bird species. The nests were placed inside chambers that were preceded by narrower entrances that frequently had a small amount of the same nest materials, notably large flight feathers. The entrances were mainly tunnels in soil among the rocks ($n = 4$) or rocky crevices or gallery ($n = 2$). The chambers with nests were always positioned above the opening of the entrances, so tunnels were inclined upwardly. The narrow entrances communicated with the exterior directly (*i.e.*, the openings were visible to an external observer; $n = 2$), or, most frequently, it opened inside a rocky shelter or cave (*i.e.*, the openings were hidden to an external observer; $n = 4$). The substrates delimiting the chambers and entrances (*i.e.*, their walls, ceilings, and floors) were the quartzitic rock itself and the dark, moist, peat soil with some fine roots of the above plants emerging. The nest shape and site of Cipo Cinclodes can be described as cups or beds placed in ground hole/cavity (*sensu* Hansell 2000), and classified as cavity/with-tunnel/low cup (or cavity/with-tunnel/simple/platform) with an inclined tunnel (*sensu* Simon & Pacheco 2005). Nests are individually described below (see Fig. 1 & Table 1).

The clutch size was three ($n = 2$ nests) or two ($n = 1$ nest) eggs. Eggs were white with overall (varying) oval shape (Fig. 2C, Table 1). At hatching, nestlings had closed eyes, pinkish skin and tarsus, gray natal down feathers (neossoptiles), brown nails with whitish tips, orange bill with brownish tip and an egg-tooth, vivid orange inner mouth and light yellow enlarged gape flanges (Fig. 2D). At fledging, the black-colored bill and the overall plumage appearance were similar to the adults, but the enlarged yellow gape and some neossoptiles at the tips of some feathers were retained, the flight feathers (still growing) were shorter, and the breast had a scaled appearance (Fig. 2E). Those features were still observed in the post-fledgling period but were gradually being lost, being the scaled breast the most persistent feature (Fig. 2F). Both parents were seeing entering into the nest cavity during all nest phases, carrying nest material during nest building and incubation, and taking food to nestlings. In some occasions, both parents were observed inside the nest cavity simultaneously.

The nest one was found on 18 November 2009 with three eggs. It was built inside a chamber at the end of a tunnel at the ceiling of a rocky cave (Fig. 1A), *c.* 2.6 m from the cave entrance, that was 1.4 m wide. The tunnel had its superior part composed of rock and the inferior of soil (Fig. 1B). The chamber containing the nest was entirely composed of soil, with fine roots emerging. There were many worn feathers from other bird species and other nest materials lining the tunnel and loosely placed at the ground of the cave below the tunnel entrance,

Table 1. Attributes of the Cipo Cinclodes *Cinclodes espinhacensis* nests, eggs, nestling and fledglings found from 2009 to 2012 at Serra do Breu, Serra do Cipó, Brazil. Entrance type: tunnel on soil (T), rocky crevice or gallery (S); entrance opening: hidden (H), visible (V). Eggs 1–3 and all nestlings were from nest one; eggs 3–6 from nest 3 (egg 6 was rotten); eggs 7–8 and all fledglings from nest 4.

	Identification numbers of measured unities												
Nest Sites Entrance	**1**	**2**	**3**	**4**	**5**	**6**			***n***	**Mean**	**SD**	**Min**	**Max**
Type/opening	T/H	T/V	T/H	T/V	S/H	S/H							
Height above ground (cm)	90.0	210.0	292.0	133.0	239.5	195.0			6	193.3	72.8	90.0	292.0
Distance to top (cm)	-	34.0	40.0	28.0	-	-			3	34.0	6.0	28.0	40.0
Opening width (cm)	16.0	18.0	5.0	13.0	44.0	-			5	19.2	14.7	5.0	44.0
Opening height (cm)	7.0	20.5	13.0	11.0	56.0	19.5			6	21.2	17.8	7.0	56.0
Length of the tunnel or crevice (until nest; cm)	48.0	70.0	12.0	17.0	84.5	114.0			6	57.6	39.7	12.0	114.0
Total length of the cavity (including chamber; cm)	63.5	90.0	36.0	87.0	101.5	-			5	75.6	26.1	36.0	101.5
Inclination (°)	43.0	20.0	55.0	-	45.0	-			4	40.8	14.8	20.0	55.0
Chamber with nest													
Width (cm)	19.0	-	21.0	-	-	-			2	20.0	1.4	19.0	21.0
Height (cm)	14.0	-	20.0	-	-	-			2	17.0	4.2	14.0	20.0
Nests	**1**	**2**	**3**	**4**	**5**	**6**							
External diameter (cm)	-	-	15.0	24.0	-	-			2	19.5	6.4	15.0	24.0
Internal diameter (cm)	-	-	10.0	12.0	-	-			2	11.0	1.4	10.0	12.0
Depth (cm)	-	-	4.0	2.5	-	-			2	3.3	1.1	2.5	4.0
Eggs	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**					
Width (mm)	21.6	21.5	21.6	21.1	20.9	-	20.5	19.4	7	20.9	0.8	19.4	21.6
Height (mm)	27.2	28.0	27.0	28.4	27.6	-	26.4	27.5	7	27.4	0.7	26.4	28.4
Mass (g)	6.1	5.9	6.0	6.0	5.6	5.3	5.2	5.1	8	5.7	0.4	5.1	6.1
Nestlings (0–1 day)	**1**	**2**	**3**										
Body mass (g)	6.7	4.8	9.1						3	6.8	2.2	4.8	9.1
Body length (mm)	53.0	47.0	53.5						3	51.2	3.6	47.0	53.5
Tarsus length (mm)	11.4	10.5	12.0						3	11.3	0.8	10.5	12.0
Total culmen length (mm)	9.8	8.7	9.8						3	9.4	0.6	8.7	9.8
Bill width (mm)	12.0	9.7	12.1						3	11.3	1.4	9.7	12.1
Total head length (mm)		19.1	21.3						2	20.2	1.6	19.1	21.3
Fledglings (0 day)	**1**	**2**											
Body mass (g)	51.2	52.2							2	51.7	0.7	51.2	52.2
Body length (mm)	150.0	165.0							2	157.5	10.6	150.0	165.0

apparently dropped from it. One of the birds attending this nest was observed energetically shaking and mashing a flight feather from other species with the mandibles before taking it to the nest. On 22 November 2009, three nestlings were born (Fig. 2B) and on 16 December 2009, the nest was empty.

Three years later, on 09 September 2012, this nest was active again. Two birds were carrying narrow straws and gray mammal hairs to the nest, one non-marked and another banded in July 2012. Given that just one of the paired birds was banded in 2009 (and disappeared in 2012), it is possible that at least one member of the pair was the same at both breeding attempts. On 10 December 2012, the marked bird was feeding a juvenile outside the nest. After four years, on 04 January 2017, the nest was not active, but the pile of nest materials below the tunnel entrance was still there, where we found white eggshell fragments.

The nest two was discovered on 20 November 2009, apparently with eggs. It was inside a long tunnel – so deep

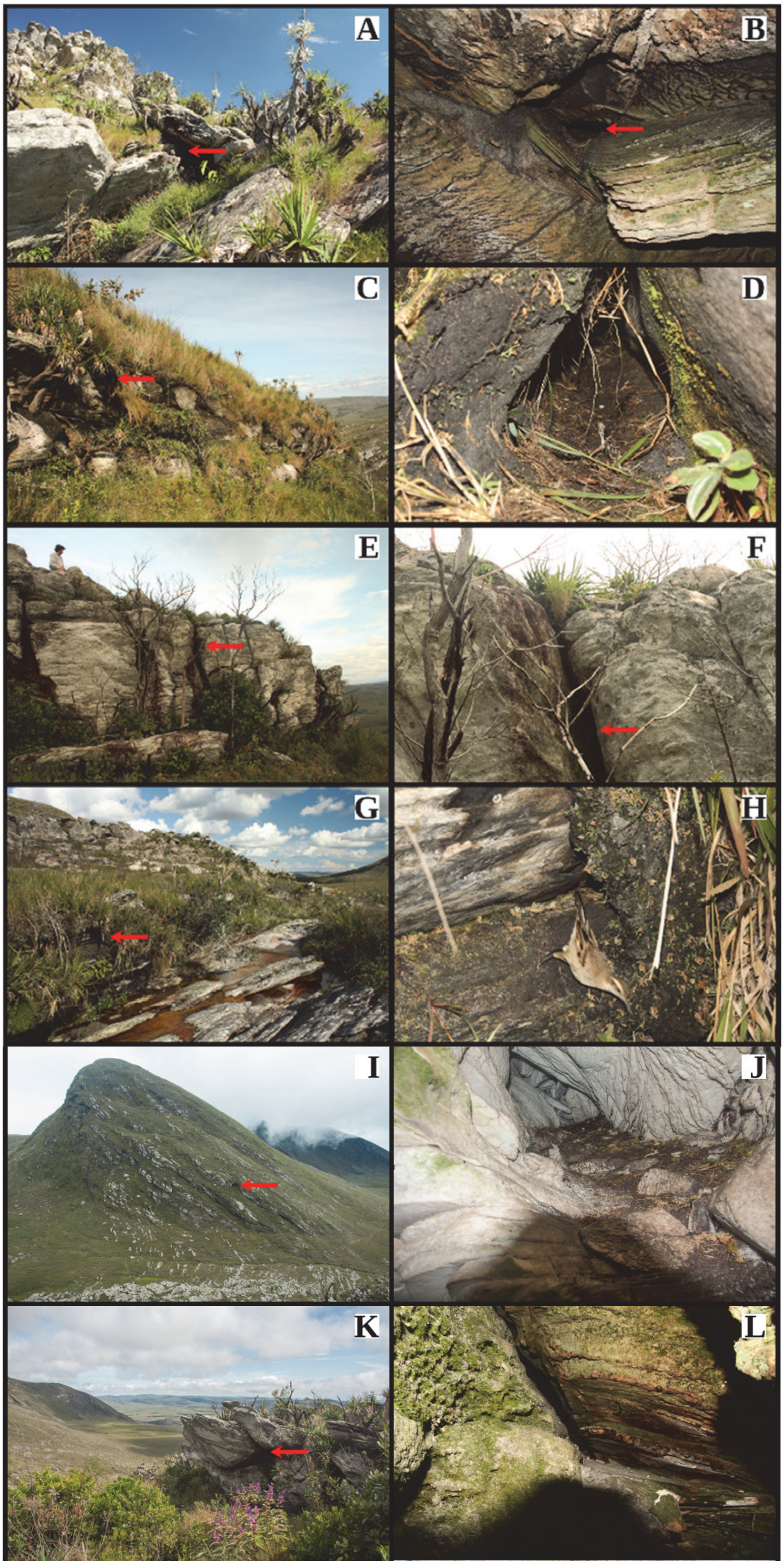

Figure 1. Nest sites of the Cipo Cinclodes *Cinclodes espinhacensis* at Serra do Breu, southern Espinhaço Range, Brazil. For each nest two pictures show the overall (left) and close-up (right) location of the nest cavities (red arrows indicate entrances). Nest 1 (**A** & **B**), nest 2 (**C** & **D**), nest 3 (**E** & **F**), nest 4 (**G** & **H**), nest 5 (**I** & **J**), and nest 6 (**K** & **L**). Photo author: G.H.S. Freitas.

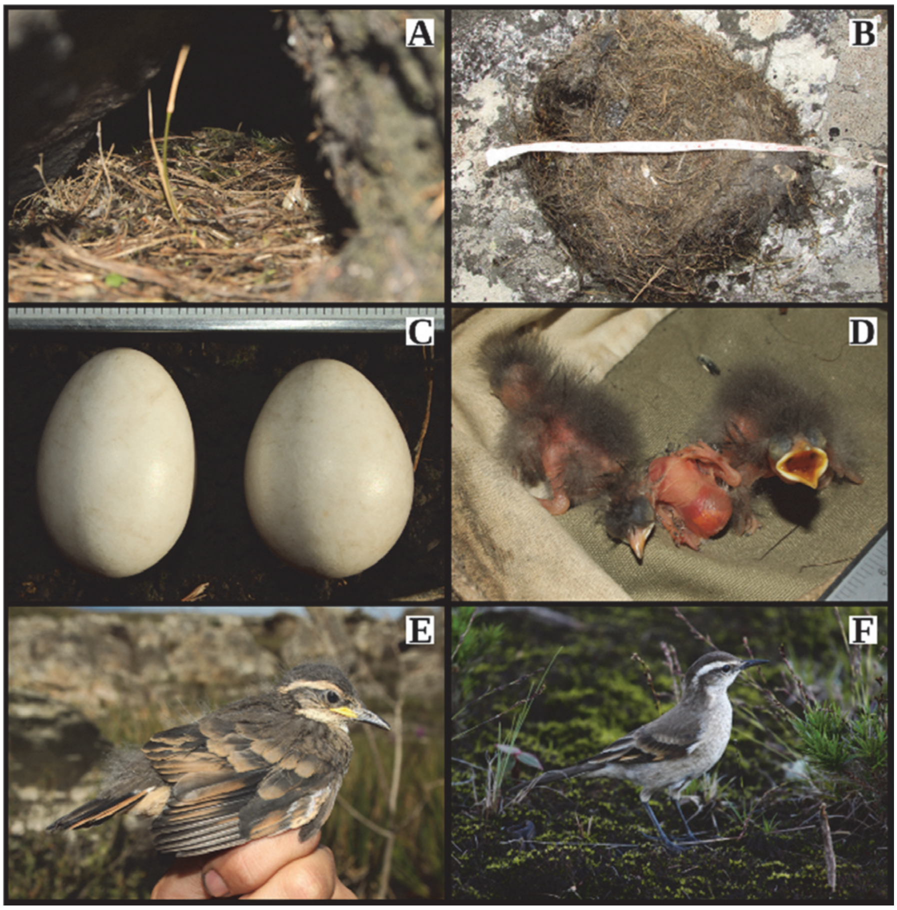

Figure 2. Shallow cupped nests inside (**A**) and removed from the cavity (**B**), eggs (**C**), hatchlings (**D**), fledglings (**E**), and a dependent juvenile (**F**) of the Cipo Cinclodes *Cinclodes espinhacensis* at Serra do Breu, southern Espinhaço Range, Brazil. At (**B**), approximately 30 cm of a metric tape is apparent; at (**C**) and (**D**), part of a caliper with 1 mm graduation is apparent. Photo author: G.H.S. Freitas (**A** & **C**–**F**) and L.M. Costa (**B**).

that the content was not accessible – at the border of a rocky outcrop (Fig. 1C). The cross section of the tunnel was triangular, with one rocky wall and the remaining sides of soil with rootlets (Fig. 1D). The floor was lined with feathers and thin dry grass-like leaves. Both adults were observed entering the tunnel. On 17 December 2009, we witnessed an adult carrying food to the nest that apparently contained at least one well-developed nestling.

The nest three was found on 19 November 2009 with three eggs, being one of them rotten. The nest was within a chamber of soil, after a tunnel with rock and soil that opened inside a rocky crevice, *c.* 45 cm of the outside (Figs. 1E & F). In the tunnel, we found feathers and thin grass leaves near the nest. We observed one adult taking nest material into the nest cavity. On 16 December 2009, the nest was empty.

The nest four was first observed on 21 November 2009 with two eggs. It was located in a rocky outcrop bordering a stream (Fig. 1G). The entrance was a short, not inclined, roughly triangular tunnel, with one rocky wall and the other sides were soil (Fig. 1H). There was a small hole on the opposite side of the cavity containing the nest. Twenty-five days later, on 16 December, two juveniles fledged when we approached the nest. Those were captured and collected (paratypes described in Freitas *et al.* 2012; Fig. 2C). One was a male and the other a female, both heavier than adults (*c.* 45 g).

The nest five was detected on 09 December 2012, with nestlings. Adults were seen taking food to the nest and nestlings begging calls were heard. The nest was placed at the end of a long rocky gallery (Fig. 1J) that opened inside a small cave located in the middle of a mountain slope (Fig. 1I).

The nest six was found on 13 December 2012, probably with eggs. The nest was unreachable inside a rocky crevice at the end of an extensive and narrow crevice between two large boulders (Figs. 1K & L). Two adults visited the nest, sometimes carrying nest material in the beak.

DISCUSSION

The Cipo Cinclodes is socially monogamous with biparental care during all nest stages. The breeding season length was at least four to five months, from early September (nest building) to January (dependent juveniles). The habitat used for nesting was rock outcrops, the typical environment of the *campos rupestres* landscape that occurs among grasslands, in slopes or bordering streams. Although Cipo Cinclodes uses all habitat types available in our study area, including rocky outcrops, grasslands, and riparian areas, a recent habitat selection analyses revealed the importance of riparian areas for foraging (Freitas *et al.* 2019), while the present study evidenced the importance of the rocky outcrops to complete the Cipo Cinclodes life cycle.

The breeding biology of the Cipo Cinclodes is overall similar to that reported (observed or presumed) for its congeners. There are at least minimal information about the breeding of all of the ~16 species recognized in the genus (Cawkell & Hamilton 1961, Sick 1973, Narosky *et al.* 1983, Belton 1984, de la Peña 1987 & 2019, Graves & Arango 1988, Bertolero & Zavalaga 2003, Greeney *et al.* 2011, Salvador & Salvador 2012, Avalos & Gómez 2014, Salvador 2015, Ojeda 2016, Vizcarra *et al.* 2018, Remsen-Jr. 2019). The Cipo Cinclodes' sister species, the Long-tailed Cinclodes, nests at end of tunnel excavated in soil banks (some with rocks), frequently at roadcuts, or in roof beam within farm-house attics (Sick 1973, Belton 1984). While for some species there are records of nest only in earthen banks (the Chestnut-winged Cinclodes *C. albidiventris*, the Cream-winged Cinclodes *C. albiventris*, and the Stout-billed Cinclodes *C. excelsior*; Graves & Arango 1988, Greeney *et al.* 2011, Salvador 2015), others seem to breed exclusively in natural rocky crevices (the Royal Cinclodes *C. aricomae*, the Surf Cinclodes *C. taczanowskii*, and the White-bellied Cinclodes *C. palliatus*; Bertolero & Zavalaga 2003, Avalos & Gómez 2014, Vizcarra *et al.* 2018, Remsen-Jr. 2019). However, this differentiation can be due to a lack of adequate sampling, since for the remaining species of the genus there are records for both types of cavities, with some species nesting also in other kinds of burrows, such as tree holes (Cawkell & Hamilton 1961, Narosky *et al.* 1983, de la Peña 1987 & 2019, Salvador & Salvador 2012, Ojeda 2016). Cipo Cinclodes lies within that third group since the nests can be placed in natural holes among the rocks or at the end of tunnels in an earthen substrate, although the tunnels were always bordering a rock. Although we did not observe the birds actively excavating tunnels as others did for congeneric species (*e.g.*, Sick 1973, Graves & Arango 1988, Greeney *et al.* 2011), we suspect that this occurred in some nests, since the burrows seemed to be recently made, with rootlets visible.

The nest architecture of the Cipo Cinclodes was a shallow, flattened cup, composed of very fragmented and pliable material. The nests of the Long-tailed Cinclodes also differ by having some sticks within the soft cushion (Sick 1973). When classifying the nest shape and site of Cipo Cinclodes following the standardized classification schemes (Hansell 2000, Simon & Pacheco 2005) we found some difficulties. One of them was to classify the nests without typical tunnels preceding it as cavity/without-tunnel, because their entrances did not open directly to the exterior (like the Fig. 4A in Simon & Pacheco 2005), but were always preceded by narrowing rock entrances; so we kept it as cavity/with-tunnel. A further doubt we have was about the elementary nest standard. Due to the imprecision of the terms, we think that the nests could be classified both as low cups and as simple/platforms (*sensu* Simon & Pacheco 2005), or its equivalents cups and beds (*sensu* Hansell 2000). Cups were suggested as the *Cinclodes* nest type by Simon & Pacheco (2005) and Zyskowski & Prum (1999). Those last authors, in their nest-based phylogenetic analysis of the Furnariidae, hypothesize that platforms and cups are two ordered derived states of nests built in cavities, showing the putative importance in distinguishing between these nest types. We observed a thick platform with a prominent depression in the middle, which is dissimilar to those nests of Olrog's Cinclodes (*C. olrogi*) and Cordoba Cinclodes (*C. comechingonus*) as can be seen on photographs in Salvador & Salvador (2012) that are distinctly cup-like and composed of less fragmented material, mostly by broader straw-like grasses.

Here, we provide the first detailed information on many aspects of the breeding biology of Cipo Cinclodes. However, more information is required for a complete understanding of the breeding ecology of Cipo Cinclodes, such as the duration of the nest stages, nestling and fledgling development, and reproductive success. We demonstrated that it agrees with those reported for other species of the genus, although some details differ from what is known for the closely related species, the Long-tailed Cinclodes. The rock outcrop habitat of the *campos rupestres* could be key to the breeding of Cipo Cinclodes, as also documented for the other furnariid endemic to the *campos rupestres*, and sympatric at our study area, the Cipo Canastero *Asthenes luizae*, despite their distinct nesting habits (Costa *et al.* 2019). Investigating the availability of suitable nesting sites for Cipo Cinclodes may elucidate possible restrictions on their occupancy. Detailed studies on the breeding biology of other Cinclodes are needed, allowing to detect intra-generic and intra-specific differentiation, and to better understand the evolution of the breeding strategies in Furnariidae.

ACKNOWLEDGEMENTS

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ARTICLE

Distinguishing females of capuchino seedeaters: call repertoires provide evidence for species-level diagnosis

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ABSTRACT: Reliable identification of cryptic Neotropical capuchino seedeater females remains as a recurrent and non-trivial issue in field ornithology. Even in the hand, capuchino females cannot be accurately diagnosed to the species level based solely on visual plumage examination, which may present a problem for future research on this group. During 10 years of field research on this group, we observed subtle vocal differences. We studied females of two parapatric species that may breed in syntopic upland grassland areas in southern Brazil: Tawny-bellied Seedeater *Sporophila hypoxantha* and Black-bellied Seedeater *Sporophila melanogaster*. Our main aim was to measure dissimilarities between inter-specific and intersexual repertory calls. We found unequivocal inter-specific divergences in call type repertoires revealed by cluster analysis, and no intersexual differences in the co-specific repertoire calls. These combined results enhance the understanding about the role of repertoire calls on species-specific recognition and interbreeding isolation processes (assortative mating), and provide a way to overcome the problem of field identification of female capuchinos at the species level.

KEY-WORDS: acoustic communication, assortative mating, bioacoustic, songbirds, *Sporophila*, vocal repertory.

INTRODUCTION

Females of the Neotropical genus *Sporophila* are very cryptic, which has limited field research in this group. The absence of morphological divergence and a uniform dull brownish plumage, which is common among females in this genus, make the study of this group very challenging (Meyer de Schauensee 1952, Ridgely & Tudor 1989, Ouellet 1992, Sick 1997, Areta *et al.* 2011, Rising *et al.* 2011).

Currently, there are ten *Sporophila* (*i.e.*, capuchino) seedeater species, all derived from a common ancestor (Campagna *et al.* 2015, Di Giacomo & Kopuchian 2016). Species within this clade vary little in morphology and size and are notably sexually dimorphic in the coloration of their plumage, with males typically being colorful while females are brownish (Ridgely & Tudor 1989). Despite inter-specific differences based on adult male plumage and song, genomic variation between capuchino seedeaters is minimal (Campagna *et al.* 2017), exemplifying the recent radiation of this Neotropical passerines (*e.g.*, Campagna *et al.* 2010, Burns *et al.* 2014). As incipient species, some inconsistencies exist in the identification of the capuchinos: hybridization, aberrant plumages, color morphs, individual and seasonal variation of plumage color, and lack of diagnosis of the female by visual observation (Sick 1963 & 1967, Short-Jr. 1969, Ouellet 1992, Areta 2008, Repenning *et al.* 2010b, Areta *et al.* 2011, Areta & Repenning 2011).

Despite improvements in our knowledge of the taxonomy and ecology of *Sporophila* species in the last decade, the diagnosis of females remains uncertain. A single attempt to find a differentiation among females of capuchino species was based on the wavelength reflected from their plumage, which did not refute the hypothesis of simply the limitation of human vision (Benites *et al.* 2010). However, researcher has yet to resolve the subject of species-level diagnosis of female capuchino. As a result, there is still no detailed analysis to objectively determine female capuchino, perhaps because of our sensorial limitations in detecting and assimilating the slight differences in their voices. Conversely, based on previous experience, we suspect that female call types differ among species. We believe that the ability to successfully identify capuchino female's voice would open a new window into research on the behavioral ecology, evolution and taxonomy of Neotropical seedeaters (Odom & Benedict 2018). Additionally, it could have positive implications for the conservation of threatened species of capuchinos, helping authorities identify specimens in female plumage that are confiscated from the illegal pet trade (*e.g.*, females, first year males and males in complete "eclipse" plumage).

Besides the importance of making the correct diagnosis of *Sporophila* females at the species level in the field, mapping their sex-specific voice repertoires would provide a new approach to study species-specific recognition and assortative mating (Paterson 1985, Slabbekoorn & Smith 2002). Sexual selection that operates on traits used to transmit information to rivals and potential mates is an important driver in the evolution of passerines (Irwin *et al.* 2000). *Sporophila* capuchinos, besides using visual signals, may use simple vocal signals as premating barriers, thus maintaining differences between incipient species (Price 2008).

Here, we present a new way to diagnose visually indistinguishable capuchino females. We studied two migratory capuchino species, Tawny-bellied Seedeater and Black-bellied Seedeater, which breed mostly in allopatry and also in narrow contact zones in southern Brazilian grasslands (Repenning *et al.* 2010a). Our main aim was to evaluate whether capuchino females that are members of closely-related species differ vocally when breeding in contact zones. To address that question, we aimed to (1) provide an objective method for species-level diagnosis of *Sporophila* females, testing for differences in the repertories of calls; and (2) tested whether there is intra-specific, sex-based variation in contact call repertoires. Finally, we discuss the role of calls in assortative mating in the genus *Sporophila*.

METHODS

Study species and site

We studied two long-distance migratory species of the capuchino group: Tawny-bellied Seedeater *Sporophila hypoxantha*, and Black-bellied Seedeater *Sporophila melanogaster*. These species segregate spatially from each other throughout an environmental gradient (altitude and habitat) in the inner *Planalto Meridional Brasileiro* (Repenning *et al.* 2010a; Fig. 1). *Sporophila melanogaster* is common in the highest eastern grasslands (average 1000 m a.s.l.) and *S. hypoxantha* occurs in western valleys or at lower altitudes. They are the smallest among the *Sporophila* seedeaters species with total length of ~98.0 mm and a body mass of ~8.8 g (Franz & Fontana 2013, Fontana & Repenning 2014). The distinguishable plumage color of the adult male in breeding season was the primary criteria for the selection of these two species, because the unequivocal diagnosis of males was an assumption for this study.

Current knowledge about the pattern of the breeding ranges of both species was secondarily relevant. We carried out 10 years (2008–2018) of fieldwork in broad upland grassland localities in southern Brazil, including breeding areas of complete allopatry and areas of syntopy of both species, across five contact zone areas (Fig. 1, Table S1).

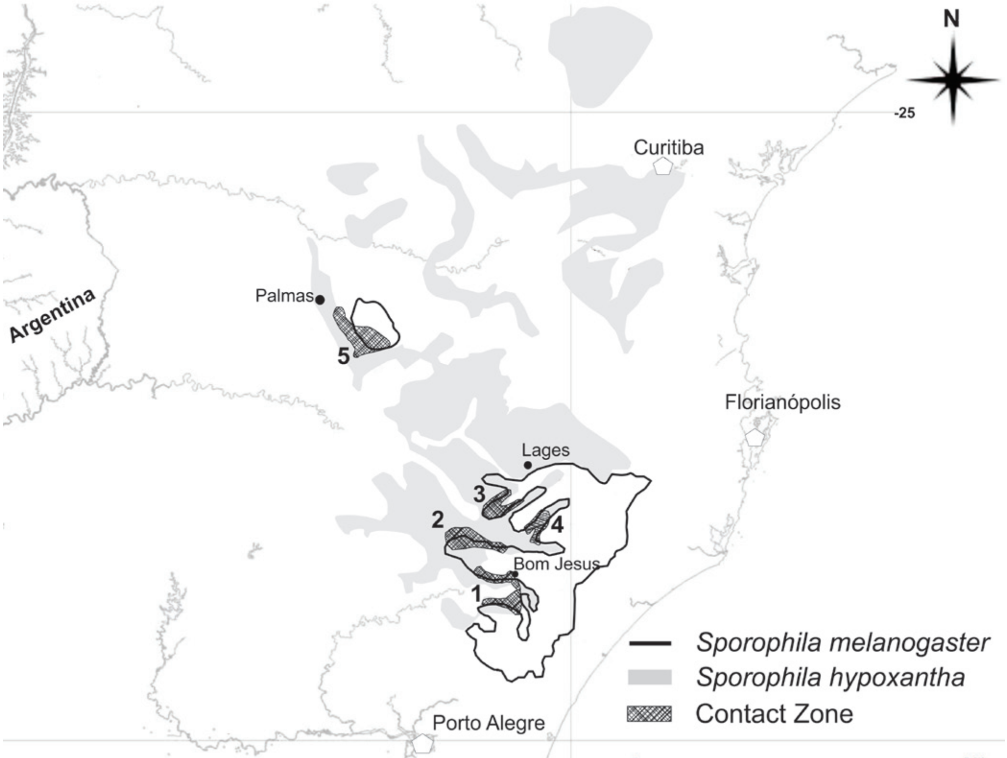

Figure 1. Breeding range of *Sporophila melanogaster* (solid black line) and *S. hypoxantha* (grey polygons) in the southern Brazilian highlands. Hachured polygons are five areas identified *in situ* as contact (hybrid) zones. Distributional limits were inferred based on a potential distribution estimates model, using the author's bird nesting records (Fig. S1 & S2).

Definitions

Allopatric areas are the localities where only males of pure phenotype (plumage and song) of each species were recorded breeding. The contact (hybridization or introgression) zones are the areas in which we recorded nesting activity of coupled males of both species with a breeding territory in contiguous areas, and breeding simultaneously, *i.e.*, in syntopy. Males with a non-pure phenotype were also documented in these syntopic areas, suggesting some level of introgression of plumage characteristics. We recorded some of these males, but we did not include them in the sound analysis.

Field recording and alarm call behavior

The recording of capuchino female songs occurred after a rigorous identification of the social mate of each female, by observing mate-guarding behavior. Only recordings of females that were associated with evidence of breeding (*e.g.*, incubating, taking care of nestlings or newly fledglings) were considered. We recorded vocalizations under a standardized close range to the focal bird (~10–15 m) using Sony TC-D5M recorder and Nagra LB, Tascam DR-680 or Sony PCM-D50 digital recorders, with Sennheiser ME66 or ME62 external microphones associated with a Telinga parabola (21.5in/6.1in). All sounds recorded will be archived at the Macaulay Library of Natural Sounds (*e.g.*, ML111751281), Cornell Lab. of Ornithology (Ithaca, NY). Territorial males and females were captured with an Ecotone mist net (16/20 mm) for color and metal banding. We banded all birds caught for individual identification and to prevent sample replication (Roos 2010).

Sound processing and call definitions

We consider a call type the unity of sounds that can be constituted by a single long note, a short note or syllables, *i.e.* a building block of songs or a regularly grouped combination of multiple whistled notes produced as a common unit (Baptista 1996, Hagemeyer *et al.* 2012). The very fast (shorter) calls we named chirps. We first classified each call type based on visual inspection of discrete categories under the temporal-spectral shape of the spectrogram. Calls were assumed as the same type when they were consistently equivalent in duration and frequency range, in their starting and ending frequencies, and in their frequencies at inflection points (Hagemeyer *et al.* 2012). Secondly, we built a reference collection with labeled sequential call types. For calls that were more difficult to discriminate, the Cross-Correlation analysis was also used, and slow-speed playback was used to help solving specific doubts. Such an analytical tool is an efficient way to measure similarities between short vocal elements over time and recorded sound quality with regard to signal-to-noise contrast (Bioacoustic Research Program 2004). We assumed that pairs of call types had the same sound element or note correlation when they had values higher than 0.7. Definition of sound units may be difficult due to the characteristic of continuity or discontinuity of each typical vocal element in oscine passerines (Lynch 1996). Therefore, we used analytical tools in a complementary way, aiming to reduce subjectivity regarding the discrete limits of each vocal element (Horn & Falls 1996). Classic experiments have shown that the shape note or syllable within the repertoire in passerines can be a functional signal, with a more important role in species-specific recognition than syntax or the structural characteristics of the voices (Bremond 1976, Catchpole & Slater 2008). Hence, understanding the extension of the similarity of call repertoires would allow us to assess the role of acoustic communication on assortative mating among closely-related capuchino species.

An evaluation of the scanned recordings was based on an analysis of the spectrogram, using a frequency resolution of 172 Hz and a time resolution of 2.3 ms, generated with RAVEN Pro 1.5 software. We selected individual call types automatically (Band Limiter Energy Detector - BLED) using the following configuration: minimum frequency of 1076 Hz, maximum of 6696 Hz, minimum duration of 0.0243 s, maximum of 0.855 s and a minimum separation of 0.0087 s in Target Signal Parameters. Other parameters followed the default configuration. After the detector interaction, another visual review was carried out to certify that heterospecific notes were not selected. This procedure was applied for each recorded individual. Lastly, each call type was labeled directly in a BLEDs interaction result table.

Statistical analysis

The recording sample available for analyses comprised a total of 1021 and 527 selected call types recorded in allopatry and syntopy, respectively, for *S. hypoxantha* (n = 32 females, n = 24 males), and 946 and 481 selected call types recorded in allopatry and syntopy, respectively, of *S. melanogaster* (n = 25 females, n = 16 males). Frequency contour measurements were designed through spectrogram pitch tracking, which uses the dominant frequency value of a sound over time. The chosen tool to do this was the Frequency Contour Percentile 50% (Hz) which selects the frequency values (Y axis) through time (X axis), and amplitude (Z axis = grayscale in the spectrogram).

A distance matrix was built using aligned call types, in which each column represents a set of calls from a unique specimen. Each call type represents a sequential pitch frequency (shape note) set of values, *i.e.*, frequency contour measurements (Hz). We ran Bray-Curtis Cluster Analysis (Single Link) in BioDiversity Pro (McAleece 1997). Only specimens with a bias to stabilize the repertoire were analyzed. For each individual we used an average of three calls of each call type, aiming to understand the extent of intra-individual variation in calls. After assessing this variation in calls and realizing that it was smaller than that of the inter-individual calls, we selected only one call type to describe the individual repertoire that was used in the final similarity analysis.

RESULTS

Repertoire accumulation

The time over which the call types were revealed in successive voice recordings for each female is illustrated in Fig. 2. Female call type accumulation curves reached an asymptote in approximately 12 to 25 of the recorded calls. There was also variation in the rate in which females produced different call types, with some females exhibiting the full repertoire within the first eight recorded calls, whereas others required more than 30 calls to present and equivalent-sized call type repertoire (Fig. 2).

Female call type repertoire

The size of call type repertoires was similar between both species, with each female of *S. melanogaster* and *S. hypoxantha* having an average of 6 (4–9) and 7 (3–8) call types, respectively. Also, females of *S. melanogaster* and *S. hypoxantha* often issued fast calls, with two and three chirps, respectively. Some calls were produced by almost every female (*e.g.*, calls 4, 6 and 8 of *S. hypoxantha*, and calls 14 and 16 of *S. melanogaster*). Some call types (*e.g.*, 1 and 18; Fig. 3) were rarely produced by females of either species. Female call types corresponded to male call type repertoire in both species. Nevertheless, male *S. melanogaster* calls have two notes that are absent in the repertoires of co-specific females (*e.g.*, call types 19 and 20) (Fig. 3).

Intra and inter-specific repertoire variation

The cluster analysis of male and female *S. melanogaster* and *S. hypoxantha* repertoires revealed a dichotomy of species-level call repertoires (Fig. 4). We did not find any shared calls in the repertories of either species, even in the syntopic population. Additionally, no female coupled with a *S. melanogaster* male presented a repertoire of pure call types exhibited by *S. hypoxantha*, or vice versa. We found no intersexual divergence in call types because males and females did not present a clear intra-specific sub-cluster within the two larger clusters observed for *S. melanogaster* and *S. hypoxantha* (Fig. 4). Finally, we found that note types used by males in advertising songs were also used as contact/alarm calls by their co-specific females (*S. melanogaster* males [songs] and females [call repertory] shared 50% of note types and *S. hypoxantha* males [songs] and females [call repertory] shared 43%; Fig. 3).

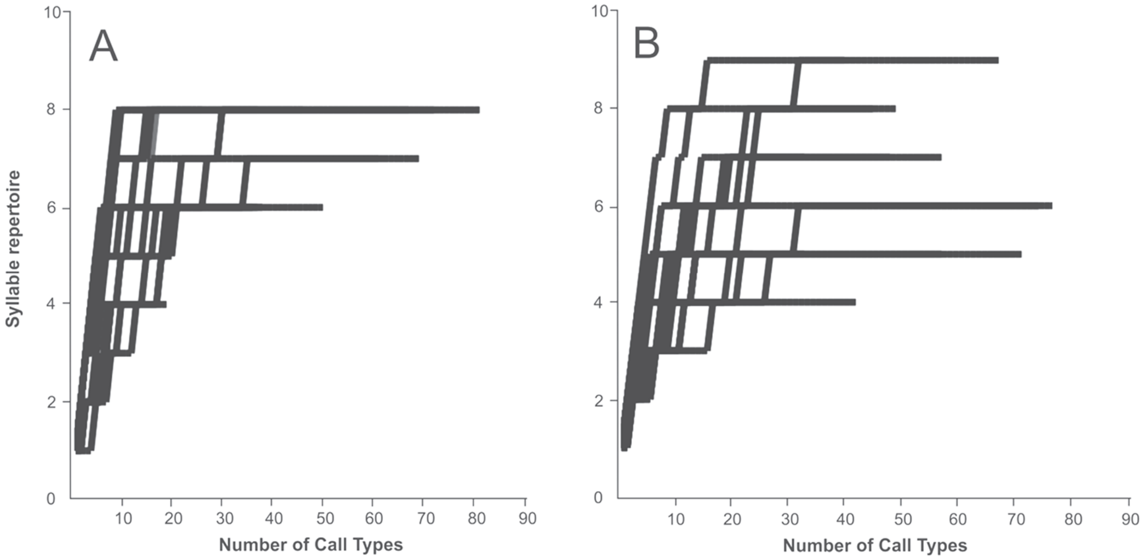

Figure 2. Call type repertoire size and accumulation functions for each individual in the sample of female *Sporophila hypoxantha* (*n* = 35, **A**) and *S. melanogaster* (*n* = 26, **B**) from allopatric and syntopic breeding areas in the southern Brazilian highlands. Each line represents a different female.

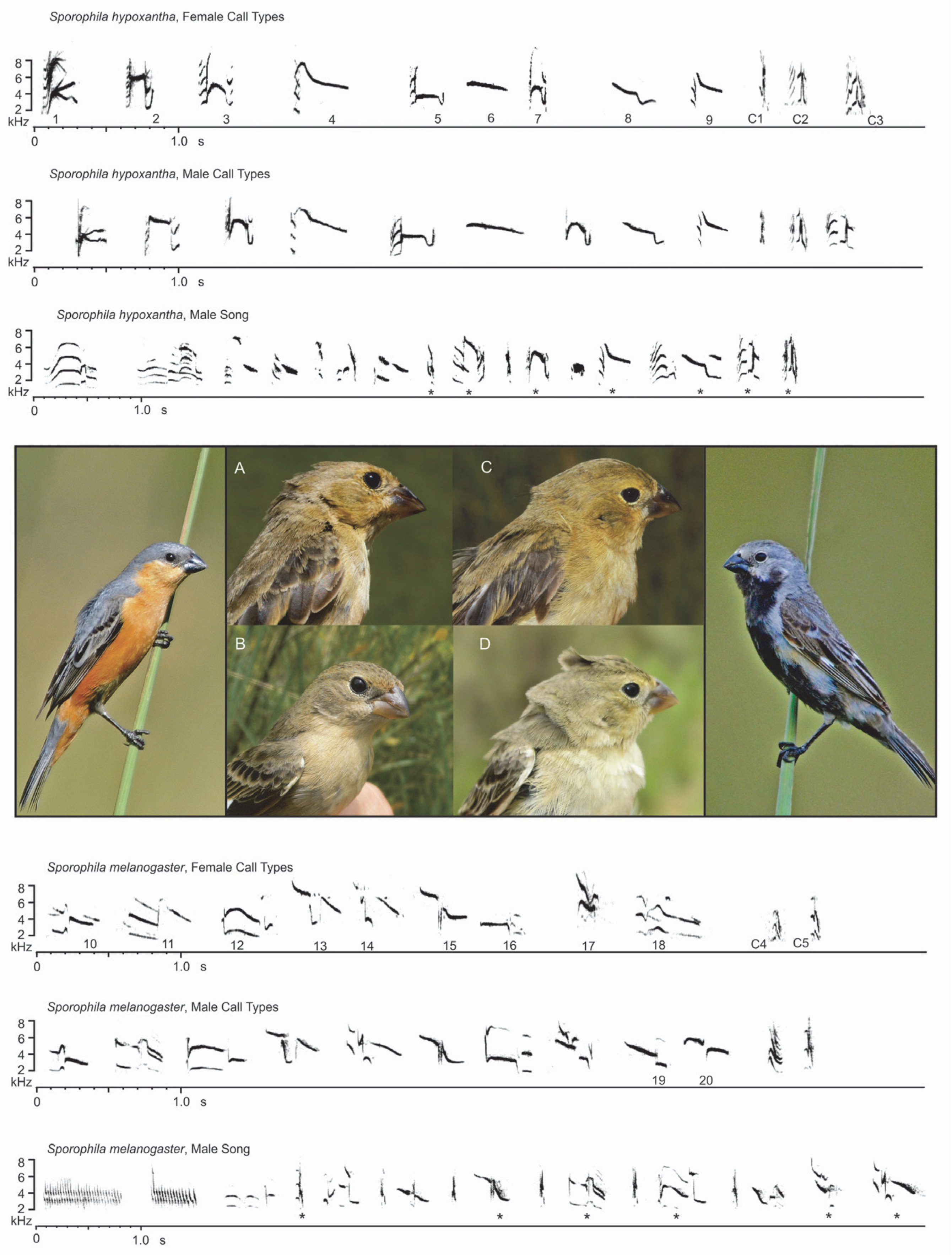

Figure 3. Call type repertoires for *Sporophila melanogaster* and *S. hypoxantha* in breeding areas in the southern Brazilian highlands. Call types are labeled by ordinal numerals and chirps with a "C" associated with a numeral (see mp3 files in supporting information). (**A**) Breeding females of *S. hypoxantha* in formative plumage and (**B**) definitive plumage; (**C**) *S. melanogaster* in formative plumage and (**D**) definitive plumage. Definitive plumage: typical adult male *S. hypoxantha* (left) and *S. melanogaster* (right).

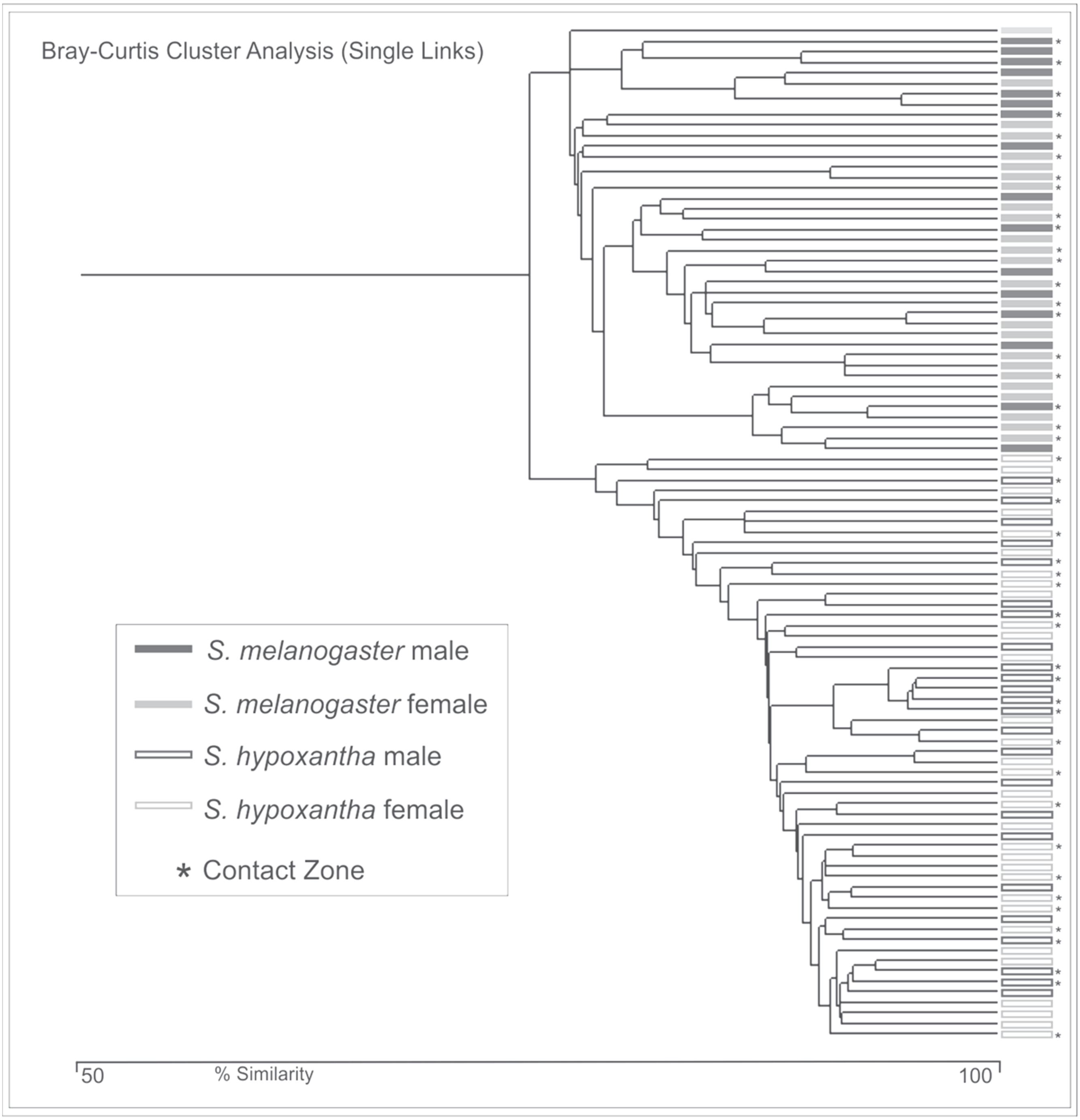

Figure 4. Similarities between the call type repertoires of *Sporophila melanogaster* and *S. hypoxantha* females and males of breeding populations in southern Brazil, based on Bray-Curtis Cluster Analysis.

DISCUSSION

We provide the first substantial evidence that voices are useful for species-level determination of female capuchino seedeaters in the field, as supported by several lines of evidence. First, we found no sharing (introgression) in call type repertoires of females of *S. melanogaster* and *S. hypoxantha*. Second, males and females of both species use the same call type repertoire as contact voices. Finally, call type repertoires seem to be a more stable signal than color plumage patterns in females and males of these two species (pers. obs.).

We observed few changes in the shape of notes, but found no cogent cluster that suggest sexual differentiation. The sound degradation hypothesis can explain the subtle variations in calls between the sexes in passerines (Searcy & Brenowitz 1988, Ratcliffe & Otter 1996, Collins 1999). This phenomenon has been reported for songs of *S. melanogaster* and *S. hypoxantha* when temporal variation was documented in note types (Repenning *et al.* 2010b, Areta & Repenning 2011). Conservatively, it makes sense that sound degradation in capuchino calls should occur in parallel in both sexes, especially because of the preserved homology in their note shapes over time.

We highlight that results presented in this study are a more reliable and less complex way to discriminate between species of capuchino females than previous attempts, which involved visually modeling UV-wavelength separation (Benites *et al.* 2010), and which is operationally complex. Additionally, we observed evidence of variation in the extent of female plumage coloration (primarily by age) within these capuchino species. When comparing first-year females (formative plumage) of *S. melanogaster* and *S. hypoxantha*, they look more similar to each other than when comparing a first-year female with a co-specific female in a different plumage cycle (*e.g.*, formative *vs.* definitive plumage) (Fig. 3). This observation illustrates the complexity of relying on the use of plumage parameters for identification of capuchino females. Concerning plumage similarities, we also highlight that there is evidence showing that the measurement of plumage color reflectance in the laboratory/museum may be less reliable as compared to that on live birds captured in the field (Doucet & Hill 2009, Hubbard *et al.* 2017).

In comparison, with some experience (*i.e.*, an ability to distinguish between capuchino calls), one can widely improve their ability to detect and identify visually identical females in the field. However, unlike the relatively pure, long and very distinctive capuchino male songs, female contact calls across species are very short and may sound extremely similar to the human ear. Hence, the sonogram is a valuable tool for seeing and, in turn, hearing the complexities of these short vocalizations. In addition, using slow-speed playback appeared effective to learn how to listen to the very fast pitch changes of the vocalizations. By following such steps in the process of sound analysis, we will enhance our understanding of the extension of co-specific communication of the studied species, and even that of other capuchino species that are difficult to identify.

We found that females of each species have fully distinct contact call types, and as do males, females of different species sing different songs (Repenning *et al.* 2010b). Although we initially suspected there was a certain degree of introgression in the *S. hypoxantha* and *S. melanogaster* voice elements, it was not confirmed even in syntopic populations. Additionally, we did not find females with a repertoire of *S. melanogaster* coupled with *S. hypoxantha* males or vice versa, revealing there is nonrandom mating (Servedio 2004). This observation suggests that capuchinos present positive assortative mating with concordant intra-specific, sex-based call type repertoires and no mixed pairing (Randler 2002). In this scenario, social calls should play an important role in specific mate recognition between recently diverged taxa (Searby & Jouventin 2004).

The relationships between songs and calls and how song is derived from calls varies among songbirds (Baptista 1996). Capuchino call types could be innate elements (begging calls that develop into social calls) of their vocalization or inherently learnt from their co-specific calls (Groth 1993, Hughes *et al.* 1998, Riebel 2003). In addition, a considerable number of female call types (half) are composed of advertising male song. These traits may be favorable to transmit species-specific sound signals long distances, when the breeding season starts (Riebel 2003, Catchpole & Slater 2008). These vocal systems seem to contribute to a favorable co-specific acoustic environment in the process of assortative mating (Béguin *et al.* 1998, Baptista & Kroodsma 2001). This scenario would induce birds to breed near their natal areas because oscine female sexual imprinting occurs on familiar songs of her natal population (Irwin & Price 1999, Nelson 2000, MacDougall-Shackleton *et al.* 2001).

Which signals would be more important in isolating populations or species? This is a recurrent question in studies on the evolution of prezygotic isolation (Brelsford & Irwin 2009). For capuchino seedeaters, contact calls are likely to play a key role in the isolation process, since they are more concordant and stable signals for communication between them. Vocal communication appears to be the first signal during the species-specific mate recognition process among capuchino seedeaters, since concordance in voice might influence females to select males that sing dialects of the female's birthplace. Moreover, the quality or differences of male plumage coloration could be a secondary visual signal, more associated with male-male competition (Searcy & Nowicki 2000, Byers & Kroodsma 2009) in the process of intra-specific sexual selection. Paradoxically, we highlight that vocal and male plumage divergences did not completely prevent interbreeding between these two species, because putative hybrid males have been recorded in contact zones. Nevertheless, we attribute rape behavior as the primary cause of interbreeding between these two species, which has been occasionally observed in areas of syntopy (pers. obs.).

Finally, based on strong evidence of differentiation among closely-related capuchino females, we suggest rigorous field song-call recording followed by spectrogram analyses of the call type repertoires for species-level diagnosis and to solve the cryptic female discrimination problem. Our analysis, in addition to visual modeling for reflectance quantification of female plumage (Benites *et al.* 2010), reinforces the human sensorial limitation bias for accurately distinguishing capuchino females. We encourage a similar evaluation for other species or populations of capuchino seedeaters with independent trajectories and ongoing speciation across a wide geographic area as possible. Populations also can be identified by their call notes, as in other oscine passerines (Groth 1993), even when they are in their wintering areas (Areta 2012).

The improvement of this kind of research would have positive implications for taxonomy, evolutionary and behavioral ecology studies in Neotropical seedeaters. From a conservation perspective, the identification of species-specific calls and songs can be a useful tool for conservation of threatened capuchino species, since it can help in the identification of specimens illegally captured in nature and in female-like plumage.

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ARTICLE

The avifauna of the Catimbau National Park, an important protected area in the Brazilian semiarid

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ABSTRACT: The Catimbau National Park is a protected area, located within the Caatinga Dry Forest, in the central region of the Brazilian state of Pernambuco. This protected area encompasses ~60,000 ha of an exceptional diversity of habitats, resulting in a high avian diversity, including several rare and endemic species. The park is considered an area of high biological importance and of conservation priority. Despite its relevance for conservation, human degradation due to chronic anthropogenic disturbances (hunting, birds trapping, selective logging, and livestock grazing) has modified the park's natural environments. In 2014, we initiated avian inventories within the park, as part of a long-term ecological research (LTER). Although the avifauna of the park has been described before, our systematic surveys allowed us to have a better understating of the park's avifauna and resulted in several additions to the species list. Here, we update and reevaluate the park's avifauna, discuss the presence of resident and migratory species, and include comments on endemic and rare species that occur within the park's boundaries. We sampled the avifauna through systematic surveys (point counts) and opportunistic observations between 2014 and 2017, including both dry and rainy seasons. We recorded a total of 192 species, including 25 species new to the park's list. During our point counts, we detected 117 species in the dry season, whereas 34 were recorded exclusively during the rainy season. Nearly 10% of the park's avifauna (19 species) is represented by migratory species, such as *Elaenia chilensis* and *Turdus amaurochalinus*. Catimbau National Park is important for the conservation of the Caatinga avifauna, since it harbors endemic, range-restricted, migratory, and globally threatened species. Therefore, we emphasize that environmental education and ecological restoration projects, allied to enforcing environmental laws are urgent for the maintenance of biodiversity and ecosystem services in the Catimbau National Park.

KEY-WORDS: Caatinga, long-term ecological research, migratory birds, Neotropical Dry Forests, ornithological inventory.

INTRODUCTION

The Caatinga Domain (hereafter, Caatinga) represents the largest patch of Seasonally Dry Tropical Forest in the Neotropics (Pennington *et al.* 2000). Far from representing a single vegetational type, the Caatinga is highly heterogeneous, presenting a wide diversity of ecosystems and habitats. Different combinations of soil, relief, topography and rainfall regimes create a wide variety of habitats (Egler 1951, Sarmiento 1975, Andrade-Lima 1981, Leal *et al.* 2003). Much of this variation can be found at one particular protected area in the Caatinga: the Catimbau National Park (hereafter, CNP). This exceptional diversity of habitats results in a high diversity of bird species, including several rare and endemic, which is one of the reasons the park is considered an area of high biological importance and of conservation priority (Devenish *et al.* 2009, Menezes *et al.* 2012).

Unfortunately, much of the degradation observed within the Caatinga, where over 63% of its area has already been modified by human activities (Pennington *et al.* 2009, Araújo & Silva 2017, Silva & Barbosa 2017) is also evident at the CNP. The park faces many chronic anthropogenic disturbance pressures as a result of the nearly 300 families that live within the park and depend on livestock grazing and logging to survive (Rito *et al.* 2017, Arnan *et al.* 2018). Also, the absence of a well-designed management plan, mandatory by Brazilian law (SNUC 2002), reflects negatively on the overall conservation of the National Park. At present, CNP presents many degraded areas with different histories of human land use (Cruz *et al.* 2017, MMA 2018a).

Given the remarkable habitat heterogeneity found at the park, the relatively large topographic variation (500–1100 m), and the rainfall gradient within such a small area (650–1100 mm/yr), Catimbau National Park was selected to establish a Long-term Ecological Research (LTER) Program (http://www.peldcatimbau.org). The main purpose of Catimbau's LTER site is to evaluate how chronic anthropogenic disturbances and changes in rainfall regime affect the biota. A total of 20 permanent plots were established, covering most of the topographical, environmental, and anthropogenic disturbance gradient, offering a unique opportunity to understand patterns of diversity in many different biological groups (Rito *et al.* 2017). Each biological group studied relied on a different sample scheme, depending on the spatial scale desired. To study the avifauna, we established 2 km transects around each one of the 20 permanent plots, sampled by 10 point counts, systematically established every 200 m.

The avifauna of the CNP is relatively well known due to past surveys (Farias 2009, Sousa *et al.* 2012). The first ornithologist to present a species list of the park's avifauna, based on non-systematic inventories and opportunistic observations, included 139 species (Farias 2009). A few years later, Sousa *et al.* (2012) presented a more complete list of the park's avifauna, updating the park's list to 202 species, including important endemic and threatened species, such as *Penelope jacucaca* and *Spinus yarrellii.*

In this study, we present the results of three years (2014–2017) of systematic surveys conducted around 20 sites distributed throughout the park, and opportunistic observations conducted elsewhere within the park. We also present a new updated list of the avifauna of the CNP, with relevant information about the avian community, with important records of threatened, migratory, and endemic species. We also provide ecological aspects of species richness and patterns of species composition, highlighting the potential threats found in this protected area and its importance for the conservation of Caatinga birds.

METHODS

Study area

The Catimbau National Park (~60,000 ha), created by a federal decree on 13 December 2002, is a protected area located within three municipalities (Buíque, Tupanatinga and Ibimirim) in the central region of the Brazilian state of Pernambuco (between 8°24'00'' and 8°36'35''S; 37°0'30'' and 37°1'40''W) (Fig. 1). Climate is classified as tropical semiarid, according to Koeppen's classification; showing a mean annual temperature of 23°C, with a great inter-annually irregularity in rainfall regimes, which vary from 650 to 1100 mm/year (SNE 2002).

This protected area is located within the Caatinga Domain, a Seasonally Dry Tropical Forest. Most of the park (70%) is composed of old-growth vegetation in sandy soils, with five main phytophysiognomies with distinct vegetation structure and floras, including *i*) shrubby-arboreal Caatinga generally located on the leeward slopes and at altitudes between 600 and 800 m a.s.l., *ii*) shrubby Caatinga with Cerrado elements can be found in many sites of the Chapada São José, both in lower and surrounding areas of the hills and slopes, *iii*) shrubby Caatinga with elements of rocky fields (*campos rupestres*) occur in the plateaus and mountain ranges (800 and 1100 m a.s.l.), *iv*) evergreen arboreal vegetation (*brejos de altitude*) at the foothills, and *v*) evergreen shrubby Caatinga located on windward slopes between 600 and 800 m a.s.l. (Rodal *et al.* 1998, SNE 2002). Systematic and opportunistic methodologies were conducted in these phytophysiognomies, as well as in aquatic environments (lagoons, ponds and temporary pools) found at the CNP (Fig. 2).

Bird survey and analyses

We conducted avian surveys at the CNP between August 2014 and August 2017, including both the dry and the rainy seasons. We surveyed the avifauna using point counts with unlimited detection radius (Ralph *et al.* 1996, Bibby *et al.* 2000, Sutherland *et al.* 2004). CNP hosts 20 LTER permanent sites (plots), spatially established to remain independent from one another and to account for the climatic and land use variation found at the park (Table 1, Fig. 1). Around each of these 20 sites, we established 2 km-long transects, which we sampled conducting point counts, which were systematically distributed every 200 m, totaling 10 point counts per site and 200 in the park. All localities and point-counts were geo-referenced using a Garmin GPS unit (GPSMAP64). We sampled each point count during 10 min, when all birds detected by sight or sound were recorded. Each site was sampled three times, once during the dry season and twice during the rainy season, totaling 600 point counts. Besides our systematic surveys, we conducted opportunistic observations between point counts and throughout the park's entire area.

Birds were identified by sight and sound by an experienced observer (FMGLC). We used binoculars and digital recorders to observe and document species presence in the area. Taxonomy and nomenclature follow the Brazilian Committee of Ornithological Records (Piacentini *et al.* 2015). Species were classified according to their conservation and distribution status. Patterns of endemism (Caatinga and northeast Brazil endemics) were based on Pacheco (2004) and Araújo & Silva (2017). Threatened species were defined according to Brazilian (MMA 2018b) and international red lists (IUCN 2019). Migration status follows Somenzari *et al.* (2018), who revised migratory patterns for Brazilian birds.

For habitat we used the five types as described by

Table 1. Permanent plots from the Long-Term Ecological Research (LTER) PELD Catimbau, Brazil.

LTER Sites	Geographic coordinates		Annual mean precipitation (mm)	Altitude (m a.s.l.)
	Long (W)	Lat (S)		
P02	-37.1968	-8.5313	647	703.0
P04	-37.3551	-8.5072	591	692.2
P07	-37.3973	-8.5554	516	559.8
P08	-37.2993	-8.4496	578	665.9
P10	-37.2301	-8.5354	647	705.4
P11	-37.2248	-8.5167	673	719.8
P14	-37.3046	-8.4278	540	623.3
P15	-37.3174	-8.4133	510	577.8
P16	-37.3259	-8.4658	555	650.6
P17	-37.2329	-8.5581	940	836.8
P20	-37.3222	-8.4854	653	733.3
P21	-37.2963	-8.5209	843	876.2
P22	-37.3428	-8.4831	552	660.8
P23	-37.3118	-8.5178	785	842.1
P25	-37.238	-8.4757	588	655.2
P26	-37.2346	-8.4942	645	698.5
P27	-37.277	-8.5113	903	965.5
P28	-37.3096	-8.5372	787	829.4
P29	-37.2475	-8.5708	762	772.6
P30	-37.2449	-8.5166	913	960.6

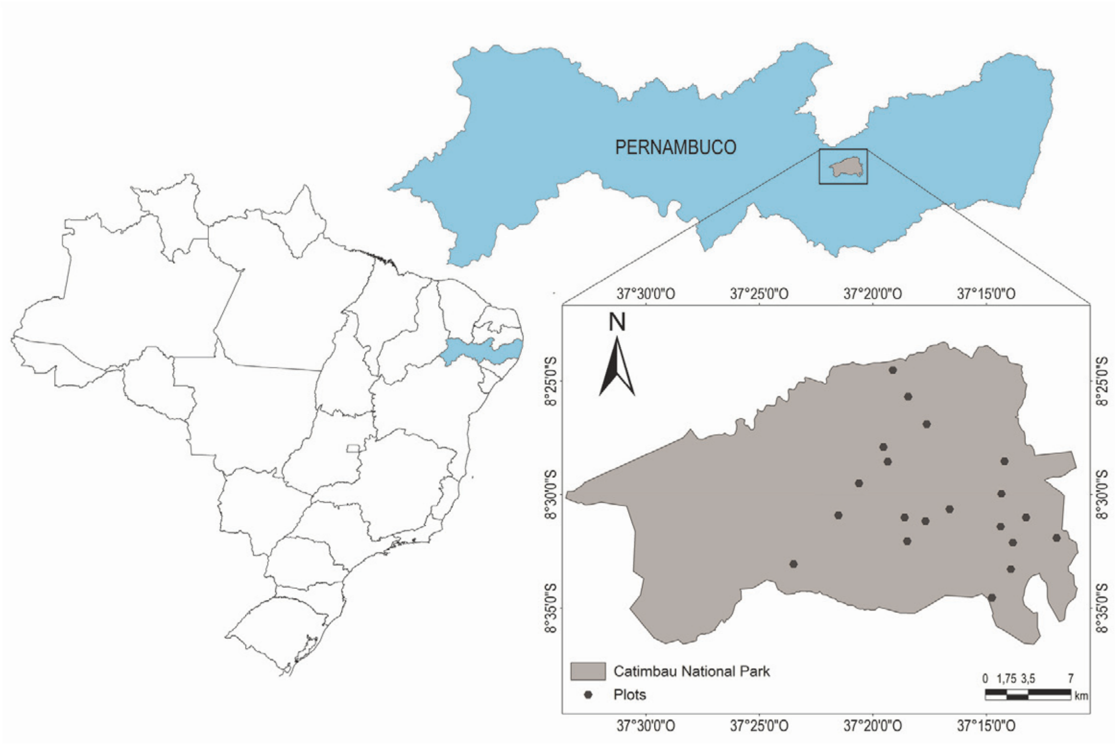

Figure 1. Location of Catimbau National Park, Pernambuco, Brazil. Distribution of the 20 plots used for bird sampling with point counts in PELD Catimbau.

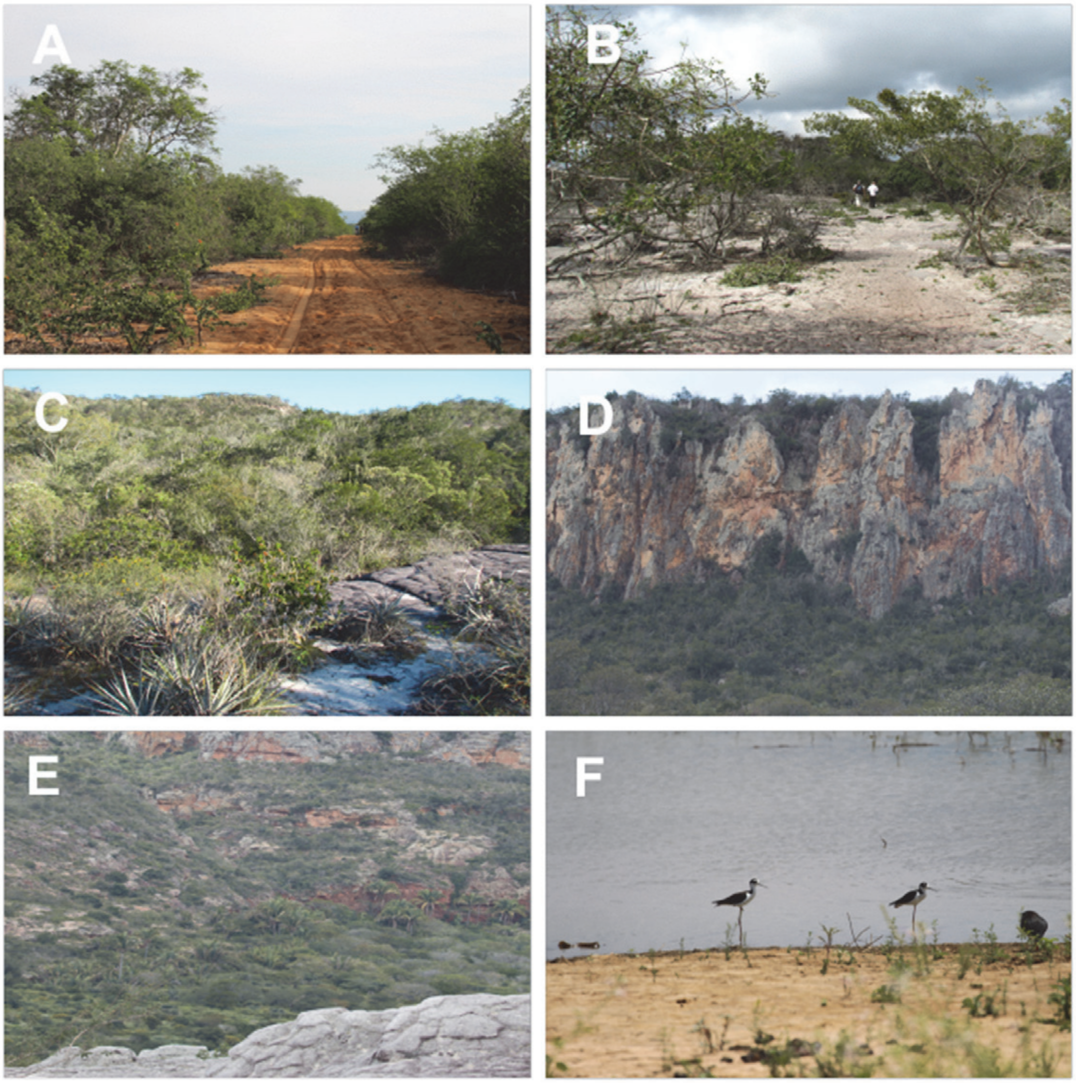

Figure 2. General view of phytophysiognomies and landscapes found at Catimbau National Park, Pernambuco, Brazil. (**A**) shrubby-arboreal Caatinga; (**B**) shrubby Caatinga with Cerrado elements; (**C**) shrubby Caatinga with rocky fields elements (Campos Rupestres); (**D**) evergreen arboreal vegetation; (**E**) evergreen shrubby Caatinga; (**F**) aquatic environment available during the rainy season. Photo author: F.M.G. Las-Casas.

Rodal *et al.* (1998) and SNE (2002): shrubby-arboreal Caatinga, Caatinga with Cerrado elements, Caatinga with rocky outcrops elements (*campos rupestres*), evergreen arboreal vegetation and evergreen shrubby Caatinga. The evergreen arboreal vegetation (*brejos de altitude*) is largely disturbed, especially by agriculture. It presents a typical vegetational composition and can be found in the foothills of the scarpment (~800 m a.s.l.). Habitat categorization for birds was based on our own records, and is applied exclusively for birds detected during this study. Photographs and/or digital recordings were archived at www.wikiaves.com and can be assessed online using the provided voucher numbers (Table 2).

To evaluate sampling effectiveness, we used Chao 1 and Jackknife 1 richness estimators (Magurran 2004), which are based on quantitative data and are known to overcome other estimators in terms of bias and precision (Gotelli & Colwell 2010). The total number of species observed at the point counts was represented by a rarefaction curve. These analyses were performed using the software EstimateS 9.1.0 (Colwell 2011). Opportunistic data were excluded from these analyses.

RESULTS

Our surveys detected 192 species of birds, 25 of which were recorded at the CNP for the first time (Table 2). Point counts resulted in the detection of 155 species (~70% of all species). Opportunistic observations added another 37 species. Bird species detected represented 48 avian families. More than half of the species (*n* = 106 or 55.2%) were passerines, and 86 species (44.8%) were non-passerines (Table 2). Sampling around the 20 LTER

Table 2. List of bird species recorded at the Catimbau National Park, Pernambuco, Brazil. Species recorded by Sousa *et al.* (2012), and not by us (#). New records for the park during the present study (*). Migratory species (MG) and partially migratory (PM). Undefined endemic (End): Caatinga endemic (EC), endemic northeast (EN). Threatened (Thr): "Near Threatened" (NT; IUCN 2019), "Vulnerable" (VU; MMA 2018). Habitat: aquatic environment (AE), shrubby arboreal Caatinga (SA), shrubby Caatinga with Cerrado elements (SC), shrubby Caatinga and rocky fields (RC), evergreen arboreal Caatinga (EA), evergreen shrubby Caatinga (ES).

Family and species	English names	End/Thr	Habitats	Documentation
TINAMIDAE				
Crypturellus noctivagus zabele#	Yellow-legged Tinamou	EN/VU,NT		
Crypturellus parvirostris	Small-billed Tinamou		SA/SC/EA/ES	
Crypturellus tataupa	Tataupa Tinamou		SA/SC/EA/ES	
Nothura boraquira	White-bellied Nothura		SA/ES	
Nothura maculosa	Spotted Nothura		SA	
Rhynchotus rufescens#	Red-winged Tinamou			
ANATIDAE				
Dendrocygna viduata	White-faced Whistling-Duck		AE	WA2919491
Cairina moschata#	Muscovy Duck			
Amazonetta brasiliensis#	Brazilian Teal			
CRACIDAE				
*Penelope superciliaris ochromitra**	Rusty-margined Guan	EN	EA/ES	
Penelope jacucaca#	White-browed Guan	EC/VU		
Ortalis araucuan	East Brazilian Chachalaca		AE	
PODICIPEDIDAE				
*Tachybaptus dominicus**	Least Grebe		AE	
Podilymbus podiceps#	Pied-billed Grebe			
PHALACROCORACIDAE				
Nannopterum brasilianus#	Neotropic Cormorant			
ARDEIDAE				
Tigrisoma lineatum#	Rufescent Tiger-Heron			
Nycticorax nycticorax#	Black-crowned Night-Heron			
Butorides striata#	Striated Heron			
Bubulcus ibis	Cattle Egret		SA	
Ardea alba	Great Egret		AE	
Egretta thula	Snowy Egret		AE	
CATHARTIDAE				
Cathartes aura	Turkey Vulture		SA/SC/RC/EA/ES	
Cathartes burrovianus	Lesser Yellow-headed Vulture		SA/SC/RC/EA/ES	WA2104773
Coragyps atratus	Black Vulture		SA/SC/RC/EA/ES	WA2104774
*Sarcoramphus papa**	King Vulture		SA/SC/RC/EA/ES	WA1467218
ACCIPITRIDAE				
Gampsonyx swainsonii	Pearl Kite		SA/ES	WA1874623
Elanus leucurus	White-tailed Kite		SA	
Ictinia plumbea#	Plumbeous Kite			
Geranospiza caerulescens	Crane Hawk		SA	

Family and species	English names	End/Thr	Habitats	Documentation
*Heterospizias meridionalis**	Savanna Hawk		SA	
*Urubitinga urubitinga**	Great Black Hawk		SA	
Rupornis magnirostris	Roadside Hawk		SA/SC/RC/EA/ES	WA2427047
*Parabuteo unicinctus**	Harris's Hawk		SA	WA2560060
Geranoaetus albicaudatus	White-tailed Hawk		SA	
Geranoaetus melanoleucus	Black-chested Buzzard-Eagle		SA/RC	WA2101247
Buteo nitidus[#]	Gray-lined Hawk			
Buteo brachyurus	Short-tailed Hawk		SA/EA	
Buteo albonotatus[#]	Zone-tailed Hawk			
RALLIDAE				
Aramides mangle[#]	Little Wood-Rail			
Aramides cajaneus[#]	Gray-necked Wood-Rail			
Pardirallus nigricans[#]	Blackish Rail			
Gallinula galeata	Common Gallinule		AE	
Porphyriops melanops	Spot-flanked Gallinule		AE	
Porphyrio martinicus[PM]	Purple Gallinule		AE	WA2951832
CHARADRIIDAE				
Vanellus chilensis	Southern Lapwing		SA	
RECURVIROSTRIDAE				
*Himantopus mexicanus**	Black-necked Stilt			WA2490975
JACANIDAE				
Jacana jacana	Wattled Jacana		AE	
COLUMBIDAE				
Columbina minuta	Plain-breasted Ground-Dove		SA/EA/ES/SC	
Columbina talpacoti	Ruddy Ground-Dove		EA/ES	
Columbina squammata	Scaled Dove		SA/EA/ES/SC	
Columbina picui	Picui Ground-Dove		SA/EA/ES/SC	WA1471673
*Claravis pretiosa**	Blue Ground-Dove		SA	
*Columba livia**	Rock Pigeon			
Patagioenas picazuro	Picazuro Pigeon		SA/EA/ES	
Zenaida auriculata	Eared Dove		SA	WA2723505
Leptotila verreauxi	White-tipped Dove		SA/EA/ES/SC	
Leptotila rufaxilla	Gray-fronted Dove		EA	
CUCULIDAE				
Micrococcyx cinereus[*MG]	Ash-colored Cuckoo		SA	
Piaya cayana	Squirrel Cuckoo		SA/EA/ES/SC	WA2106950
Coccyzus melacoryphus[MG]	Dark-billed Cuckoo		SA/EA/ES/SC	WA2850701
Crotophaga major[#]	Greater Ani			
Crotophaga ani	Smooth-billed Ani		SA	
Guira guira	Guira Cuckoo		SA	WA2049012
Tapera naevia	Striped Cuckoo		SA	
TYTONIDAE				
Tyto furcata	American Barn Owl		SA	

Family and species	English names	End/Thr	Habitats	Documentation
STRIGIDAE				
Megascops choliba	Tropical Screech-Owl		SA	
Glaucidium brasilianum	Ferruginous Pygmy-Owl		SA/EA/ES	WA2677373
Athene cunicularia	Burrowing Owl		SA	WA2290250
NYCTIBIIDAE				
Nyctibius griseus	Common Potoo		SA	
CAPRIMULGIDAE				
Antrostomus rufus$^{\#}$	Rufous Nightjar			
Nyctidromus albicollis	Common Pauraque		SA	
Nyctidromus hirundinaceus	Pygmy Nightjar	EC	SA	
Hydropsalis parvula^{*PM}	Little Nightjar		SA	WA2723643
Hydropsalis longirostris *	Band-winged Nightjar		SA	
Hydropsalis torquata	Scissor-tailed Nightjar		SA	
Nannochordeiles pusillus novaesi	Least Nighthawk	EN	SA	
Chordeiles acutipennis$^{\#}$	Lesser Nighthawk			
APODIDADE				
Tachornis squamata	Fork-tailed Palm-Swift		SA/EA	
TROCHILIDAE				
Anopetia gounellei	Broad-tipped Hermit	EC	SA/ES	
Phaethornis pretrei	Planalto Hermit		SA/EA/ES	
Eupetomena macroura	Swallow-tailed Hummingbird		SA	WA1989371
Anthracothorax nigricollis$^{\#}$	Black-throated Mango			
Chrysolampis mosquitus	Ruby-topaz Hummingbird		SA	WA1874630
Chlorostilbon lucidus	Glittering-bellied Emerald		SA/SC/RC/EA/ES	WA2918587
Polytmus guainumbi$^{\#}$	White-tailed Goldenthroat			
Amazilia fimbriata *	Glittering-throated Emerald		SA	WA2490872
Amazilia lactea *	Sapphire-spangled Emerald		SA	
Heliomaster squamosus	Stripe-breasted Starthroat		SA/SC	WA2918598
TROGONIDAE				
Trogon curucui	Blue-crowned Trogon		SA/EA/ES	WA3273333
ALCEDINIDAE				
Chloroceryle americana	Green Kingfisher			
BUCCONIDAE				
Nystalus maculatus	Spot-backed Puffbird		SA/SC/RC/EA/ES	WA2346838
PICIDAE				
Picumnus fulvescens	Tawny Piculet	EN/NT	SA/SC/RC/EA/ES	WA2687064
Veniliornis passerinus	Little Woodpecker		SA/SC/RC/EA/ES	
Piculus chrysochloros	Golden-green Woodpecker		SA	
Colaptes melanochloros	Green-barred Woodpecker		SA/SC/RC/EA/ES	
CARIAMIDAE				
Cariama cristata	Red-legged Seriema		SA/SC	
FALCONIDAE				
Caracara plancus	Southern Caracara		SA/SC	
Milvago chimachima	Yellow-headed Caracara		SA/SC	

Family and species	English names	End/Thr	Habitats	Documentation
Herpetotheres cachinnans	Laughing Falcon		SA/SC/EA/ES	WA1635330
Micrastur ruficollis	Barred Forest-Falcon		SA/SC/EA/ES	
Falco sparverius	American Kestrel		SA/SC/EA/ES	
Falco rufigularis	Bat Falcon		RC	
Falco femoralis	Aplomado Falcon		SA/SC/EA/ES	
_Falco peregrinus_*MG	Peregrine Falcon		SA/ES	
PSITTACIDAE				
Primolius maracana#	Blue-winged Macaw			
Thectocercus acuticaudatus haemorrhous	Blue-crowned Parakeet	EN	SA/ES	
Eupsittula cactorum	Cactus Parakeet	EC	SA/SC/RC/EA/ES	WA2106953
Forpus xanthopterygius	Blue-winged Parrotlet		SA/SC/EA/ES	WA1989370
Amazona aestiva	Turquoise-fronted Parrot		SA/EA/ES	
THAMNOPHILIDAE				
Myrmorchilus strigilatus strigilatus	Stripe-backed Antbird	EN	SA/SC/RC	
Formicivora melanogaster bahiae	Black-bellied Antwren	EN	SA/SC/RC/EA/ES	WA1467784
_Herpsilochmus sellowi_*	Caatinga Antwren	EN	SA/RC	WA2113554
Herpsilochmus atricapillus#	Black-capped Antwren			
Sakesphorus cristatus	Silvery-cheeked Antshrike	EC	SA/SC/RC	WA2850912
Thamnophilus capistratus	Caatinga Antshrike	EC	SA/SC/RC	WA2851005
Thamnophilus torquatus	Rufous-winged Antshrike		SA	
Thamnophilus pelzelni	Planalto Slaty-Antshrike		SA/SC/EA/ES	
Taraba major	Great Antshrike		SA/SC/RC/ES	
GRALLARIIDAE				
Hylopezus ochroleucus	White-browed Antpitta	EC/NT	SA/SC/RC/EA/ES	WA2308551
DENDROCOLAPTIDAE				
Sittasomus griseicapillus#	Olivaceous Woodcreeper			
Campylorhamphus trochilirostris	Red-billed Scythebill		SA	
_Dendroplex picus_*	Straight-billed Woodcreeper		SA	
Lepidocolaptes angustirostris	Narrow-billed Woodcreeper		SA/SC/RC/EA/ES	WA2490963
FURNARIIDAE				
Furnarius figulus	Wing-banded Hornero		SA	
Furnarius leucopus	Pale-legged Hornero		SA/ES	
Pseudoseisura cristata	Caatinga Cacholote	EN	SA	
Phacellodomus rufifrons rufifrons/ specularis	Rufous-fronted Thornbird	EN	SA/SC/EA/ES	
Certhiaxis cinnamomeus	Yellow-chinned Spinetail		SA/SC/RC	
Synallaxis hellmayri	Red-shouldered Spinetail	EC	SA/SC/RC	
Synallaxis frontalis	Sooty-fronted Spinetail		SA/SC/RC	
Synallaxis albescens	Pale-breasted Spinetail		SA	
Synallaxis hypospodia#	Cinereous-breasted Spinetail			
Synallaxis scutata#	Ochre-cheeked Spinetail			
Cranioleuca semicinerea	Gray-headed Spinetail		SA/EA/ES	

Family and species	English names	End/Thr	Habitats	Documentation
TITYRIDAE				
Pachyramphus viridis	Green-backed Becard		SA/SC	
Pachyramphus polychopterus^{PM}	White-winged Becard		SA/SC/ES	WA2918602
Pachyramphus validus$^{\#PM}$	Crested Becard			
Xenopsaris albinucha	White-naped Xenopsaris		SA	WA2491020
RHYNCHOCYCLIDAE				
Tolmomyias flaviventris	Yellow-breasted Flycatcher		SA/SC/EA/ES	
Todirostrum cinereum	Common Tody-Flycatcher		SA/SC/RC/ES	
Hemitriccus margaritaceiventer	Pearly-vented Tody-tyrant		SA/SC/RC	WA2101248
TYRANNIDAE				
Hirundinea ferruginea	Cliff Flycatcher		SA/RC	WA2288299
Stigmatura napensis bahiae	Lesser Wagtail-Tyrant	EN	SA/SC	WA2678822
Euscarthmus meloryphus	Tawny-crowned Pygmy-Tyrant		SA/SC/RC	
Camptostoma obsoletum	Southern Beardless-Tyrannulet		SA/SC/RC/EA/ES	WA2347009
Elaenia flavogaster	Yellow-bellied Elaenia		EA/ES	
Elaenia spectabilis^{PM}	Large Elaenia		SA/SC/RC/ES	
Elaenia chilensis^{MG}	Chilean Elaenia		SA/SC/RC/ES	WA2677969
_Suiriri suiriri bahiae_*	Suiriri Flycatcher	EN	SA	WA1874629
Myiopagis viridicata^{PM}	Greenish Elaenia		SA/SC/ES	
Phaeomyias murinaND	Mouse-colored Tyrannulet		SA/SC/RC/ES	WA2850711
Phyllomyias fasciatus cearae	Planalto Tyrannulet	EN	SA/SC/ES	
_Serpophaga subcristata_*	White-crested Tyrannulet		SA/ES	WA2678868
Myiarchus swainsoni *^{PM}	Swainson's Flycatcher		SA	
Myiarchus ferox	Short-crested Flycatcher		EA/ES	
Myiarchus tyrannulus	Brown-crested Flycatcher		SA/SC/RC/EA/ES	WA1989368
Casiornis fuscus^{PM}	Ash-throated Casiornis		SA/ES	WA2490796
Pitangus sulphuratus	Great Kiskadee		SA/SC/ES	
Machetornis rixosa	Cattle Tyrant		SA/ES	
Myiodynastes maculatus^{PM}	Streaked Flycatcher		SA/ES	WA2490928
Megarynchus pitangua	Boat-billed Flycatcher		SC/EA/ES	
Myiozetetes similis	Social Flycatcher		SA/SC/EA	
Tyrannus melancholicus	Tropical Kingbird		SA/SC/RC/EA/ES	
Tyrannus savana *^{PM}	Fork-tailed Flycatcher		SA	
Empidonomus varius^{PM}	Variegated Flycatcher		SA/SC/RC/EA/ES	WA2851003
Myiophobus fasciatus^{PM}	colored Flycatcher		SA/SC/RC/ES	
Sublegatus modestus^{PM}	Southern Scrub-Flycatcher		SA/ES	
Fluvicola albiventer	Black-backed Water-Tyrant		AE	WA2918597
Fluvicola nengeta	Masked Water-Tyrant		SA/ES	
Arundinicola leucocephala	White-headed Marsh Tyrant		AE	WA2288334
Cnemotriccus fuscatus	Fuscous Flycatcher		SA/SC/EA/ES	WA1635342
Knipolegus nigerrimus hoflingi	Velvety Black-Tyrant	EN	SA/RC	WA2918592
Xolmis irupero niveus	White Monjita	EN	SA	

Family and species	English names	End/Thr	Habitats	Documentation
VIREONIDAE				
Cyclarhis gujanensis	Rufous-browed Peppershrike		SA/SC/RC/ES	
Hylophilus amaurocephalus	Gray-eyed Greenlet		SA/SC/RC/ES	
Vireo chivi^{PM}	Chivi Vireo		SA/SC/RC/ES	
CORVIDAE				
Cyanocorax cyanopogon	White-naped Jay		SA/SC/RC/ES	
HIRUNDINIDAE				
Stelgidopteryx ruficollis$^{\#PM}$	Southern Rough-winged Swallow			
Progne chalybea^{PM}	Gray-breasted Martin		SA	
TROGLODYTIDAE				
Troglodytes musculus	Southern House Wren		SA/SC/RC/EA/ES	WA2683268
Pheugopedius genibarbis$^{\#}$	Moustached Wren			
Cantorchilus longirostris bahiae	Long-billed Wren	EN	SA/SC/RC	
POLIOPTILIDAE				
Polioptila plumbea	Tropical Gnatcatcher		SA/SC/RC/EA/ES	WA2101250
TURDIDAE				
Turdus leucomelas	Pale-breasted Thrush		EA/ES	
Turdus rufiventris	Rufous-bellied Thrush		SA/SC/RC/EA/ES	
Turdus amaurochalinus^{PM}	Creamy-bellied Thrush		SA/SC	
MIMIDAE				
Mimus saturninus arenaceus	Chalk-browed Mockingbird	EN	SA/SC/RC/ES	WA2723585
MOTACILLIDAE				
Anthus lutescens	Yellowish Pipit		ES	
PASSERELLIDAE				
Zonotrichia capensis	Rufous-collared Sparrow		SA/SC/RC	WA1467779
Ammodramus humeralis	Grassland Sparrow		SA	
PARULIDAE				
Setophaga pitiayumi	Tropical Parula		SA/ES	
Myiothlypis flaveola	Flavescent Warbler		SA/EA/ES	
ICTERIDAE				
Icterus pyrrhopterus	Variable Oriole		SA/SC/RC	WA2918615
Icterus jamacaii	Campo Troupial	EN	SA/SC/RC	WA2106592
Chrysomus ruficapillus	Chestnut-capped Blackbird		SA	
Agelaioides fringillarius	Pale Baywing	EN	SA	
Molothrus bonariensis	Shiny Cowbird		SA	
Sturnella superciliaris	White-browed Meadowlark		SA	
THRAUPIDAE				
*Schistochlamys ruficapillus**	Cinnamon Tanager		RC	WA2113557
Paroaria dominicana	Red-cowled Cardinal	EC	SA/SC	WA2918606
Tangara sayaca	Sayaca Tanager		SA/SC/RC/EA/ES	
Tangara palmarum	Palm Tanager		EA/ES	
Tangara cayana	Burnished-buff Tanager		SA/SC/RC/EA/ES	
Nemosia pileata	Hooded Tanager		SA/SC/RC/EA/ES	

Family and species	English names	End/Thr	Habitats	Documentation
Compsothraupis loricata	Scarlet-throated Tanager	EN	SA/SC/RC	WA1635323
Conirostrum speciosum	Chestnut-vented Conebill		SC/EA/ES	
Sicalis flaveola	Saffron Finch		SA	
Sicalis luteola	Grassland Yellow-Finch		SA	
Volatinia jacarina	Blue-black Grassquit		SA/RC	WA2105977
Coryphospingus pileatus	Pileated Finch		SA/SC/RC	WA2850094
Tachyphonus rufus	White-lined Tanager		SA/SC/RC/ES	WA2105976
*Dacnis cayana**	Blue Dacnis		ES	
Coereba flaveola	Bananaquit		SA/SC/RC/EA/ES	
Sporophila lineola$^{\#PM}$	Lined Seedeater			
Sporophila nigricollis	Yellow-bellied Seedeater		SA	
Sporophila leucoptera$^{\#}$	White-bellied Seedeater			
Sporophila bouvreuil$^{\#PM}$	Copper Seedeater			
Sporophila albogularis	White-throated Seedeater	EC	SA/SC/RC	WA2918631
Saltator similis	Green-winged Saltator		SA	
Thlypopsis sordida	Orange-headed Tanager		SA/ES	WA2687083
CARDINALIDAE				
*Piranga flava**	Hepatic Tanager		EA/ES	
Cyanoloxia brissonii	Ultramarine Grosbeak		SA/SC/RC	
FRINGILLIDAE				
Spinus yarrellii$^{\#}$	Yellow-faced Siskin	VU		
Euphonia chlorotica	Purple-throated Euphonia		SA/SC/RC/EA/ES	
ESTRILDIDAE				
*Estrilda astrild**	Common Waxbill		SA	
PASSERIDAE				
Passer domesticus	House Sparrow		SA	

sites was fairly complete. Based on our point counts, estimated species richness was 158 (Chao 1) and 167 species (Jackknife 1). Thus, observed richness by point counts corresponds to 95.6% and 90.4%, respectively, of the estimated richness (Fig. 3).

During point counts, we made 18,272 avian contacts. The 10 most detected species during these censuses were *Zonotrichia capensis* (*n* = 926), *Eupsittula cactorum* (*n* = 850), *Zenaida auriculata* (*n* = 675), *Sakesphorus cristatus* (*n* = 626), *Stigmatura napensis* (*n* = 620), *Hemitriccus margaritaceiventer* (*n* = 592), *Columbina picui* (*n* = 559), *Polioptila plumbea* (*n* = 547), *Coryphospingus pileatus* (*n* = 545), and *Thamnophilus capistratus* (*n* = 539). On the other hand, 26 species were only recorded once (singletons) or twice (doubletons).

During the dry season we detected 117 species and 4,521 individuals. During the wet season (which we sampled twice) we detected 146 species and had a mean abundance of 6,875.2 individuals (*n* = 13,751). The five most abundant species during the dry season were *Eupsittula cactorum* (*n* = 283 individuals detected), *Chlorostilbon lucidus* (*n* = 276), *H. margaritaceiventer* (*n* = 239), *P. plumbea* (*n* = 212), and *Formicivora melanogaster* (*n* = 174). Whereas, during the wet season the five most abundant species were *Z. capensis* (*n* = 394), *Z. auriculata* (*n* = 337), *E. cactorum* (*n* = 283), *S. cristatus* (*n* = 243) and *S. napensis* (*n* = 223).

From our inventory (systematic and opportunistic) most of the species detected are considered residents. Nineteen species recorded at the CNP are considered migratory or partially migratory (Table 2). For example, *Elaenia chilensis* is an austral migrant, *Tyrannus savana* and *Turdus amaurochalinus* are considered partial austral migrants. We observed a single individual of *T. savana* flying over a disturbed open area in the CNP on March 2017. *Elaenia chilensis* and *T. amaurochalinus* were commonly recorded only during the rainy season. Similarly, two species of migratory cuckoos (*Coccyzus melacoryphus* and *Micrococcyx cinereus*) were only recorded during the rainy season. Whereas *C. melacoryphus* was

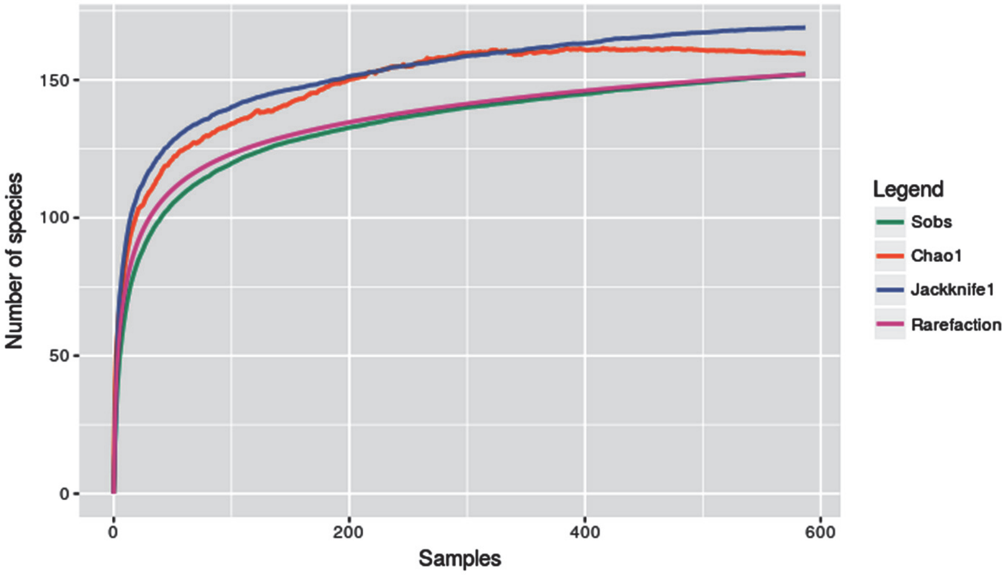

Figure 3. Observed richness (green line), rarefaction (pink line) and richness estimators Chao 1 (orange line) and Jackknife 1 (blue line) curves for the bird assemblage recorded in the Catimbau National Park, Pernambuco, Brazil.

relatively common, *M. cinereus* was recorded once on June 2017, during an opportunistic observation in a disturbed area. Some partial migrant species (*Myiophobus fasciatus*, *Casiornis fuscus*, *Myiodinastes maculatus*, *Empidonomus varius*, *Hydropsalis parvula*, *Vireo chivi*, *Pachyramphus polychopterus*, *Elaenia spectabilis*, *Myiarchus swainsoni* and *Progne chalybea*) were regularly detected during the rainy season in the park. Finally, species like *Bubulcus ibis, Xenopsaris albinucha*, *Columbina minuta*, *Columbina talpacoti*, *Patagioenas picazuro*, *Z. auriculata*, *Chrysomus ruficapillus*, *Agelaioides fringillarius*, *Molothrus bonariensis*, *Sicalis luteola*, *Volatinia jacarina*, and aquatic species such as *Dendrocygna viduata*, *Himantopus mexicanus*, as well as species from the families Podicipedidae, Ardeidae and Rallidae (Table 2) were recorded exclusively during the rainy season and are likely to carry out seasonal displacements within the Caatinga.

During our surveys most species were detected in more than one habitat. Most of the species recorded during our studies were detected in shrubby-arboreal Caatinga (162 species), followed by shrubby Caatinga with Cerrado elements (n = 85 spp.), shrubby Caatinga with elements of rocky fields (n = 59 spp.), evergreen arboreal vegetation (n = 56 spp.), evergreen shrubby Caatinga (n = 89), and 12 species related to aquatic environments.

A total of 28 taxa detected in our surveys are considered range-restricted. Nine species are endemic to the Caatinga, whereas 19 taxa are restricted to the Brazilian northeast (Table 2). *Picumnus fulvescens* a northeastern endemic and *Hylopezus ochroleucus* a Caatinga endemic are considered "Near Threatened", with decreasing trends in their populations (IUCN 2019). None of the species is considered threatened by extinction according to the Brazilian MMA (2018b). Three exotic species were recorded (*Columba livia*, *Estrilda astrild* and *Passer domesticus*), mostly in urban and peri-urban areas, but there is no evidence that they represent any threat to autoctonous species.

DISCUSSION

In this study we presented newly quantitative data on the avian assemblage found at the Catimbau National Park. During our quantitave surveys, restricted to 20 sites, we detected ~70% (155 species) of the 192 species. In addition, opportunistic observations included another 37 species of birds, mostly waterbirds that do not occur at or near our sampled sites. In fact, according to species richness estimators, our quantitative surveys detected the vast majority of the species present in our sites, showing the importance of conducting systematic surveys. The CNP avian assemblage (192 species) represented ~35% of bird species registered for the Caatinga Domain (*sensu* Araújo & Silva 2017; n = 548) and 35.8% of the 535 bird species recorded for the state of Pernambuco (Farias & Pereira 2009).

Despite our systematic surveys, we failed to find 34 bird species previously reported for the CNP by Sousa *et al.* (2012). Among the species we failed to record, 11 are linked to aquatic environments, including three species of herons (*Tigrisoma lineatum*, *Nycticorax nycticorax*, and *Butorides striata*), two of ducks (*Cairina moschata* and *Amazonetta brasiliensis*), two common inhabitants of ponds and pools (*Podilymbus podiceps* and *Nannopterum brasilianus*), two species of raptors likely occurring in low densities (*Buteo nitidus* and *Buteo albonotatus*), two species of hummingbirds (*Anthracothorax nigricollis* and *Polytmus guainumbi*), two species of nightbirds (*Antrostomus rufus* and *Chordeiles acutipennis*), four species of birds often linked to more humid forests (*Herpsilochmus atricapillus*, *Sittasomus griseicapillus*, *Synallaxis hypospodia*, and *Pheugopedius genibarbis*), and three species of seedeaters known to have erratic populations elsewhere in the Caatinga (*Sporophila lineola*, *Sporophila leucoptera*, and *Sporophila bouvreuil*).

More important, however, were the apparent absences of three species of conservation concern, including three endemic and threatened species (*Crypturellus noctivagus zabele*, *P. jacucaca*, and *S. yarrellii*) previously reported by Sousa *et al.* (2012). These species are known to be widely hunted by poachers and for the illegal trade, and their absences may indicate local extinctions. The CNP suffers strong pressure from hunting and illegal trade, particulalry for birds. During the study period hunters and local residents were observed trapping birds within the CNP boundaries, an illegal activity outside and even inside the protected area. We found many endemic avian taxa in captivity, including *E. cactorum*, *Paroaria dominicana*, *Sporophila albogularis* and *Icterus jamacaii*, but also more widespread species, such as *Amazona aestiva* and *Cyanoloxia brissonii*, widely appreciated by the illegal trade. We are afraid that if the scenario of hunting activities, illegal logging, overgrazing by goats and cattle, hunting of wild animals (mainly mammals and birds), and bird trapping continue to occur within the park, other species may also become locally extinct. Species whose populations are locally and regionally small are more susceptible to local extinction (*e.g.*, Pereira & Brito 2005, Pereira & Azevedo-Jr. 2011, Fernandes-Ferreira *et al.* 2012, Las-Casas *et al.* 2012, Albuquerque *et al.* 2017).

On the other hand, we recorded 25 species that were not previously recorded at the CNP (Table 2), including two aquatic species (*Tachybaptus dominicus* and *Himantopus mexicanus*), three species of raptors (*Heterospizias meridionalis*, *Urubitinga urubitinga*, *Parabuteo unicinctus*); some austral and intratropical migrants (*M. cinereus*, *Serpophaga subcristata*, *T. savana*, and *Piranga flava*), whose movements are poorly known; a boreal unreported fron the park; migrant (*Falco peregrinus*); two species of exotic birds (*Columba livia* and *Estrilda astrild*), previously unreported from the park; and one endemism that likely went undersampled in the past (*Herpsilochmus sellowi*). These results suggest that the core avian assemblage of the CNP is likely very well established by now, and that future records will likely result from more nomadic aquatic species, austral and northern migrants, and possibly some widespread species that have not yet been recorded in the park. Species richness and avian composition may also vary according to differences in the methods applied, sampling effort, nocturnal observations (Vizentin-Bugoni *et al.* 2015), as well as the conservation status of the areas (Sayer *et al.* 2017, Bovo *et al.* 2018).

These results also suggest that the Caatinga bird assemblage composition presents some clear interannual variation, particularly for aquatic and low density species (Araújo & Silva 2017). During the rainy season at the CNP, there was an increment in bird species richness, with the presence of migratory birds, including both long-distance and intratropical migrants (*e.g.*, Ruiz-Esparza *et al.* 2011, Las-Casas *et al.* 2012, Lyra-Neves *et al.* 2012, Araújo *et al.* 2017).

Most of the bird species found at the CNP occured in shrubby arboreal Caatinga, which is the main phytophisiognomy found within the park boundaries. On the other hand, many species of birds can be found in more than one habitat (Table 2), a pattern that is common among birds in the Caatinga. Most of the species included in the park's list are not forest dependent, being able to explore different habitats (Araújo & Silva 2017). However, some species may be considered forest specialists. In the CNP species such as *Leptotila rufaxilla* and *Ortalis araucuan* were restricted to more humid habitats such as evegreen forests, a type of vegetation nowadays very uncommon within the park. This type of vegetation was transformed in areas of plantations and pastures (*e.g.*, Pedra do Cachorro) and the remaining tracts of evergreen forests is very fragmented and present different levels of disturbances.

We also noticed that some bird species at the CNP prefer well-conserved and/or forested habitats and rarely occur in disturbed environments (Pereira & Azevedo-Jr. 2011, Las-Casas *et al.* 2012, Lyra-Neves *et al.* 2012). This was the case of *P. superciliaris*, *Trogon curucui*, *Piculus chrysochloros*, *Micrastur ruficollis, H. sellowi*, *H. ochroleucus*, *C. trochilirostris*, *Dendroplex picus* and *S. ruficapillus.* In contrast, other species were only observed in disturbed and open areas, such as *Athene cunicularia*, *Suiriri suiriri bahiae* and *Xolmis irupero niveus*. Species such as *Sarcoramphus papa*, *Geranoaetus melanoleucus*, *Hydropsalis longirostris*, *Hirundinea ferruginea* and *Knipolgeus nigerrimus* were associated to the CNP's rocky walls. Some of those rare species were those more dependent on forested habitats and more sensitive to disturbance, preferring isolated sites with very low human interference such as *P. superciliaris*, *Claravis pretiosa*, *M. ruficollis*, *C. trochilirostris* and *S. ruficapillus*.

The Caatinga is the largest block of tropical Dry forests found within South America (Silva & Souza 2018) and is one of the most threatened in the Neotropics, with less than 10% of its original extent (Banda *et al.* 2016). In Brazil, habitat conservation is uneven among biomes (Jenkins & Joppa 2009, Oliveira & Bernard 2017) and the Caatinga represents the least protected one, with only

1.3% of the total area officially included in protected areas that receive full protection (MMA 2017).

Besides the anthropogenic pressures found within this protected area, such as bird hunting, trapping and cattle grazing, our results demonstrate that the CNP still harbors a valuable Caatinga avian diversity with the presence of range-restricted, endemic, threatened, and migratory species, highlighting its importance for bird conservation. But we emphasize the need of effective management inside and outside the park's boundaries, since pressures inside the reserve may usually reflect those occurring around (Laurance *et al.* 2012). Despite being fragmented, patches of Caatinga remain well-connected, which may facilitate recolonizations and community regeneration (Antongiovanni *et al.* 2018). Thus, the maintenance, management and expansion of protected area networks continue to be one of the most important tools for biodiversity conservation (Las-Casas *et al.* 2012, Oliveira & Bernard 2017, Antongiovanni *et al.* 2018).

The exceptional natural features of the park, allied to a rich avifauna could provide an economic opportunity through the development of birdwatching, offering new job opportunities. We emphasize that actions such as environmental education and ecological restoration projects, allied to inspection are urgent for the maintenance of the biodiversity and ecosystem services at the CNP.

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ARTICLE

Temperate forest bird communities associated with a historic mining impact area: do tailing remnant effects modify their structure?

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ABSTRACT: Birds contribute to the stability of ecosystems and represent a tool used to evaluate a variety of anthropogenic impacts. The area known as El Oro-Tlalpujahua Mining District in central Mexico was subjected to significant environmental impacts as a result of ore extraction, including profound habitat transformations, landscape changes, and the accumulation of potentially toxic elements in their tailings (favoring its bioavailability and dispersion). After more than 60 years without extractive activities, there is no knowledge on extant remaining impacts on biological communities. Assuming the presence of negative impacts on birds, we compared the composition and abundance of bird communities in two locations, representing a site without exposure to tailings (S_1) and another one with tailings deposition (S_2). From June 2014 to June 2015, we recorded 2828 individuals of 108 avian species in 369 point counts ($S_1 = 91$, $S_2 = 95$). The Chao1 indicator suggested we recorded 96% of the species present. We found a high similarity in the general composition and abundance of bird species between communities (> 85%). However, there were significant differences in the abundances of 18 species (9 of them higher in the control site); these differences might result from differential effects of potentially toxic elements on functional groups (such as feeding guilds), resource availability, as well as other factors not accounted for. Historically, mining activities in the area generated significant changes in the structure and composition of the forest, and disrupted ecological processes. Despite the fact that current conditions appear favorable to the relative stability of the bird community, specific physiological effects on some species of birds sixty years after the cessation of mineral extraction could occur. Further studies on physiological performance and the effects of potentially toxic elements on local birds could unveil unknown effects at the individual level.

KEY-WORDS: avian communities, diversity, El Oro-Tlalpujahua Mining District, mining tailings, remnant effects.

INTRODUCTION

Information on the diversity and abundance of species in communities represent the basis for assessing the quality of their environment. Through monitoring it is possible to evaluate changes associated with different causal factors; comparisons on the occurrence of species in different environments, and the characterization of their relative abundance is often presented as supporting evidence (Balmer 2002).

Disturbance processes generated by human activities involve habitat changes through the modification of land use for productive activities (*e.g.*, agriculture and livestock), urban development, and mining activities, with the resulting effects on soil and water (Manson & Jardel-Peláez 2009). These events at the landscape level modify the structure of vegetation and generate successional processes that promote changes in the structure and composition of animal communities (Pickett & White 1985). In birds, these types of changes have been described previously by Ugalde-Lezama *et al.* (2012) and Manson & Jardel-Peláez (2009), who found the simplification of forest structure related to the decrease in the composition of bird communities.

To evaluate anthropogenic impacts on wildlife, it is desirable to have an indicator of the intensity and extent of the impacts; if significant, they might be reflected in changes in the composition and/or abundance of species at the community level. At the population level, impacts may be reflected in changes in survival rates or reproductive success of species, or changes in their distribution (Altaf *et al.* 2018, Mahmoud & Gan 2018, Xu *et al.* 2018). Responses at the individual level are the most sensitive and usually have been assessed through changes in physical and physiological conditions (*e.g.*, height, weight, condition index, quantity of fat reserves)

(Pérez-Tris 1999). Few studies have explored the response of birds to anthropogenic impacts resulting from mining at the community level; most have focused on particular species (*e.g.*, Garitano-Zavala *et al.* 2010, Rubio *et al.* 2016), or ecological settings (*e.g.*, Ouboter *et al.* 1999, Eagles-Smith *et al.* 2016).

Several authors recognize the need for environmental monitoring from geological, ecological, and public health perspectives (Boulet & Larocque 1988, Perotti *et al.* 2017). Reclamation mining sites have sometimes been perceived as sites potentially important for biodiversity (Batty 2005). Mines that have operated for centuries are the source of pollutants that remain stored in tailings or the bottom of reservoirs, and their ecological effects in most cases have not been determined (Kossoff *et al.* 2014). Globally, estimations of mercury released to the environment as a byproduct of the amalgamation for recovery of gold and silver indicate that there has been over 260,000 tons released between 1550 and 1930 (Lacerda 1997). Furthermore, for mining sites that historically ceased production and left a legacy of ecological impact, little is known about the span and intensity of their impacts (Balistrieri *et al.* 2002, Eisler 2004, Cristol *et al.* 2008, Ventakeswarlu *et al.* 2016). Some studies have addressed aspects of geodynamics, bioavailability and transfer of elements in mine tailings, which are potentially toxic elements derived from mining runoff and water currents (*e.g.*, Rösner 1988, Perotti *et al.* 2017), as well as on soil and vegetation (O'Sullivan *et al.* 1999, Jacob & Otte 2004, Struckhoff *et al.* 2013), aquatic and terrestrial animals (such as benthic invertebrates, springtail insects, fish, amphibians, reptiles and birds), remediation, and ecological restoration (Lefcort *et al.* 1988, Gonçalves-Rodriguez & Shraft 2001, Lock *et al.* 2003, Cristol *et al.* 2008, Márquez-Ferrando 2008). Data from historically important mining areas in the world is scarce, and there is no documented information on possible remnant effects in reference to wildlife.

The Oro-Tlalpujahua Mining District (OTMD) in central Mexico has been the site of ecological changes associated with the settlement of a very important center of gold and silver ore extraction, from the middle 19th to early 20th century (Corona-Chávez & Uribe-Salas 2009). Mina Dos Estrellas was an exceptional settlement in its time, whose establishment and operation with major infrastructure caused the almost complete deforestation of the original forests, and led to the creation of roads, landscape alteration, and the accumulation of waste materials from ore extraction, among others. As a result of continued activities, the area gradually accumulated tailings of momentous volume. These elements have defined the environmental history of the region, and have stimulated interest in understanding the long term consequences of disturbance in the area (Corona-Chávez *et al.* 2010).

During the 65 years after cessation of activities in Mina Dos Estrellas, the region has experienced ecological succession that led to the reestablishment of secondary temperate forest made up of tolerant and pioneer tree species that survived the disturbance period on impoverished soil conditions (Muñiz-Castro 2008).

Because of the demands of wood and other materials for the construction and maintenance of mine galleries, the surrounding areas, and even those far away were also overexploited (Corona-Chávez & Uribe-Salas 2009). While the area was subjected to a strong mining impact, at the end of the mine's active life some nearby areas remained free from the effects of ore wastes, deforestation, agriculture and cattle grazing. These areas offer the possibility of investigating if some remnant effects derived from mining in the past are maintained and affect bird communities. Considering the possibilities of extant impacts, we analyzed and compared the richness and abundance of forest bird communities inhabiting tailings sites (abandoned approximately 65 years ago) and sites free from mine wastes, in order to determine differences that might be indicative of remnant impacts on the avifauna. Facing a possible scenario of intense and prolonged impact induced by the bioavailability of potentially toxic elements in tailings, we expected bird communities away from tailings to be more diverse and have higher abundance at least for the most common species, in comparison to the polluted area.

METHODS

Study area

The OTMD is situated in the limits of the states of Michoacan and Mexico (19°18'N; 100°09'W; Fig. 1) (Nieto-Monroy 2007), as part of the Trans-Mexican Volcanic Belt. At an elevation ranging from 2600 to 2850 m a.s.l., 45% of its surface is covered by secondary forest of Cedars (*Cupressus lusitanica*), Junipers (*Juniperus deppeana*), oaks (*Quercus* spp.), and pines (*Pinus* spp.). Its climate is temperate sub-humid with rainfall in summer (800–1100 mm per year), and the soils are mainly represented by andosols and luvisols (INEGI 2009). The OTMD area is adjacent to the polygons of the Monarch Butterfly Biosphere Reserve (MBBR) (Coronado-Martínez 2016). Although OTDM is not part of the reserve, it has had influences within the protected area because of historical extraction of materials in the past and tourism activities in the present (Ramírez-Ramírez 2001, SEMARNAT 2001, Coronado-Martínez 2016). Due to the limited and specific features of the area, the study sites are included only in one site, without replicates.

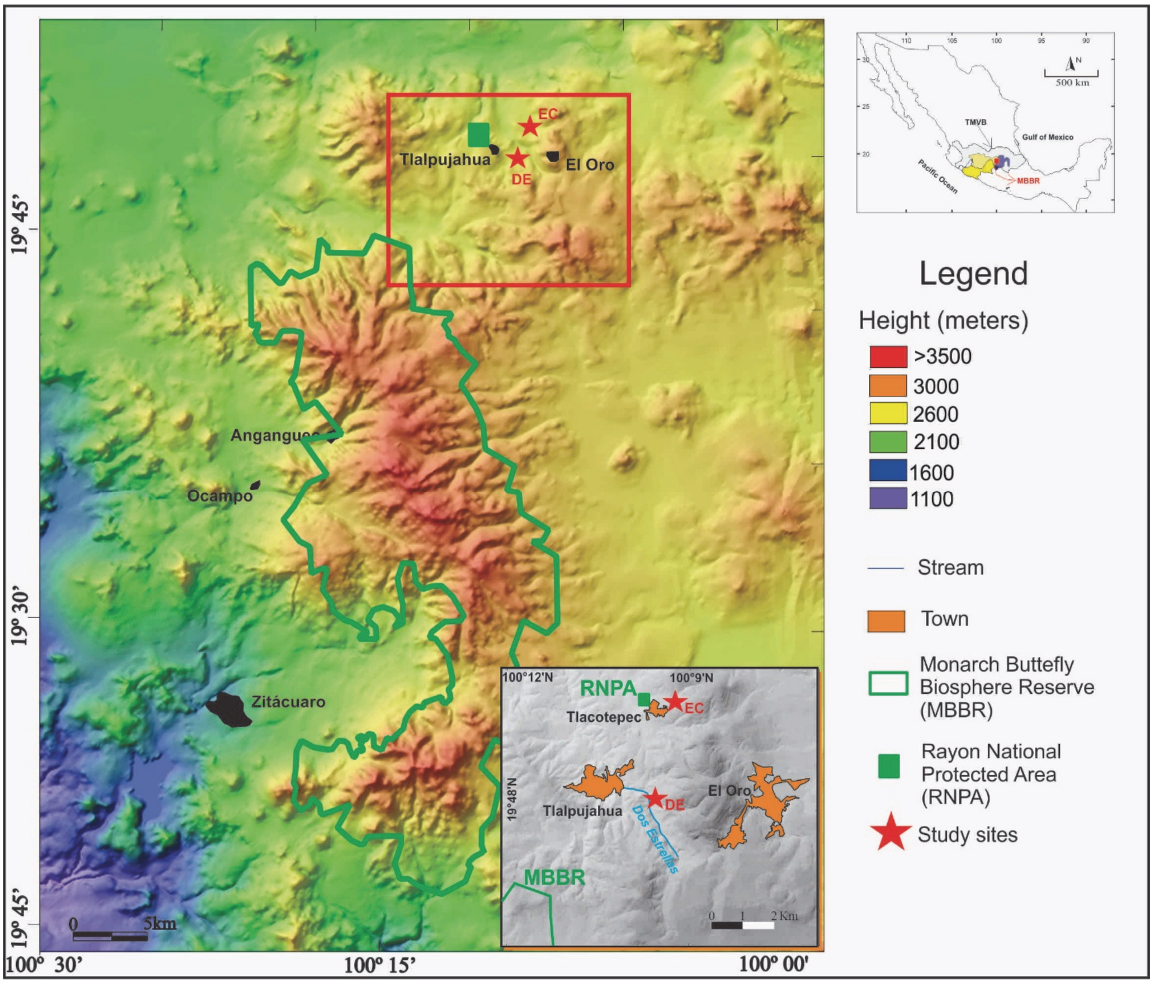

Figure 1. The Oro-Tlalpujahua Mining District study area in central Mexico (EC = El Castillo, S_1; DE = Mina Dos Estrellas, S_2).

Bird sampling

Bird sampling was carried out in two study sites: a) a control site far from tailings (El Castillo, Tlacotepec, S_1; 19.822°N; -100.145°W, 2750 m a.s.l.; Fig. 2A) and b) a tailings site (Mina Dos Estrellas, Tlalpujahua, S_2; 19.793°N; 100.156°W, 2648 m a.s.l.; Fig. 2B), both within the municipality of Tlalpujahua, Michoacan. Vegetation in both sites resulted from a natural secondary succession process and have similar structure and composition (Osuna-Vallejo *et al.* 2016). To determine the composition and abundance of bird communities, every month from June 2014 to June 2015, we conducted a total of 369 point counts (10 min) (169 in the control site S_1 and 200 in the tailings site S_2), located randomly every 200 m along independent paths, in which we registered individuals detected visually and acoustically (by songs or calls) within a fixed 50 m radius (to avoid bias due to detectability) (Hutto *et al.* 1986, Buskirk & McDonald 1995). The taxonomic arrangement adopted here was that proposed by the American Ornithological Society (AOS 2017), while the assignment of species to seasonality categories was based on our own experience and Howell & Webb (2005). Species considered in any concern category were defined according to *Norma Oficial Mexicana* NOM-059-SEMARNAT-2010, where native species of wild flora and fauna in Mexico considered in any conservation risk are listed (SEMARNAT 2010).

Data analysis

We estimated the relative abundance and frequency of occurrence of bird species by site. The former was expressed by the number of individuals in 100 point counts, and the latter was evaluated through the percentage of counts where the species was recorded, which can reflect the detection probability of the species (Hutto *et al.* 1986).

We used the Completeness Index (Chao 1 estimator) to make a prediction of the expected species in the community based on our sampling (Chao *et al.* 2005). For each site we generated species accumulation curves to ensure sampling effort was adequate and to compare richness among sites (Colwell & Coddington 1994). These analyses were performed in EstimateS 9.1.0 (Colwell 2013).

In order to compare the similarity of communities

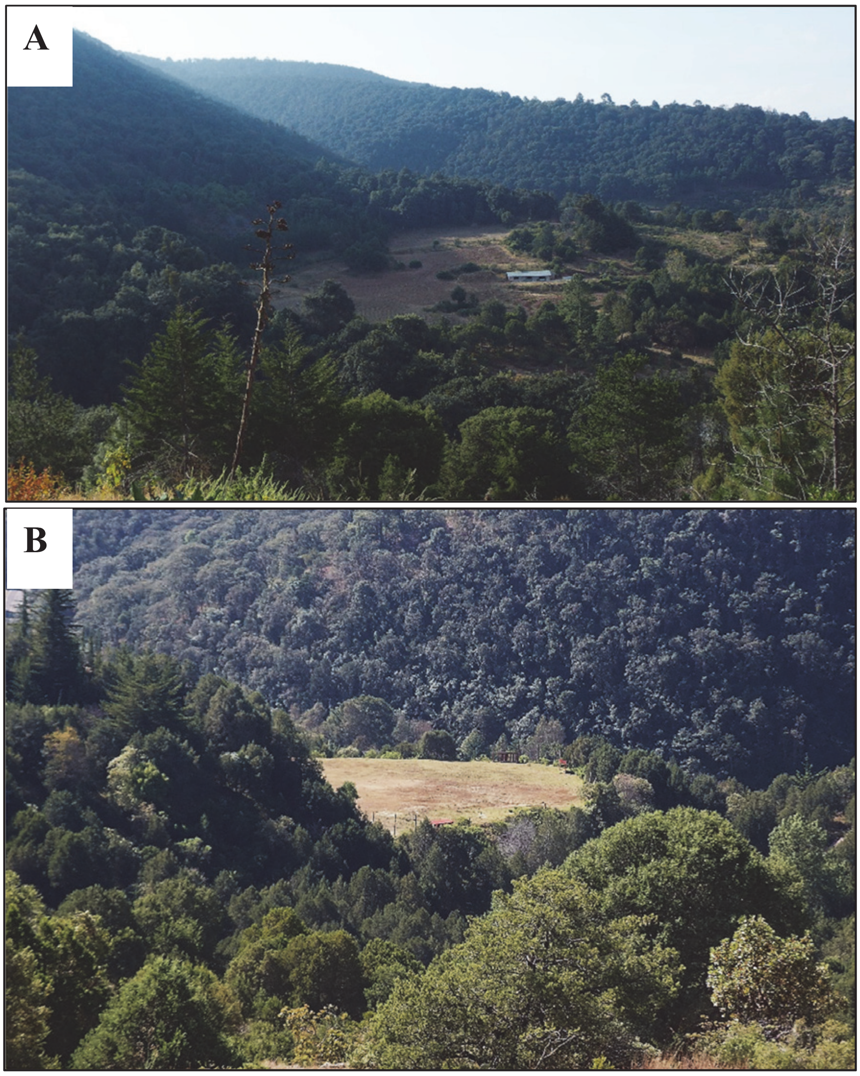

Figure 2. Control site, El Castillo, Tlacotepec, Michoacan (**A**); mining site, Mina Dos Estrellas (**B**), Photo authors: K.I. Lemus-Ramírez (**A**) and J.F. Villaseñor-Gómez (**B**).

between sites, we computed the qualitative Sorensen index and the quantitative Morisita-Horn index using Excel 2013. The former index is based on species presence/absence data, and indicates the composition resemblance of the communities; while the latter considers the number of individuals registered for each one of the species (Badii *et al.* 2007). To evaluate differences in species' abundance between sampling sites we applied a nonparametric Mann-Whitney U test using IBM SPSS Statistics 20.0). We also used an Analysis of Similarity (ANOSIM) to compare the degree of correspondence in the composition of communities (*sensu* Blake 2007, Edwards *et al.* 2011); as this method evaluates a dissimilarity matrix, values of R closer to zero reflect very similar communities, and values close to unity reflect significant differences between the communities being compared (PAST version 2.17 c). In order to gain further information about the species' contribution to the differences between communities, we applied a Similarity Percentage Analysis SIMPER (PAST version 2.17 c), that breaks up the contribution of each one of the species to the similarity observed between communities, and defines the most important species responsible for the observed pattern (Clarke 1993).

RESULTS

From June 2014 to June 2015 we conducted a total of 369 point counts (169 in the control site S_1 and 200 in the tailings site S_2), and detected a total of 4364 individuals ($S_1 = 2043$, $S_2 = 2321$) from 108 species and 30 families ($S_1 = 97$, $S_2 = 91$); 85 are resident, 20 are winter visitors, two are considered transitory, and one is an introduced resident species (Table 1). We identified ten functional or guild groups (groups of species in a community that exploit the same set of resources in a similar manner, but are not necessarily closely related taxonomically). In the two study sites the insectivorous guild was the most abundant (S_1 = 48% species, 35% individuals; S_2 = 51% species, 35% individuals), followed by the omnivorous guild (S_1

= 19% species, 30% individuals; S_2 = 20% species, 23% individuals). In general, the communities showed very similar functional structure (species: $\chi^2 = 1.928$, $P = 0.993$; individuals: $\chi^2 = 2.856$, $P = 0.970$; Fig. 3).

Species accumulation curves exhibited an asymptotic behavior suggesting an adequate sampling effort for the detection of most species in the area. The Completeness Index (CI = Sobs/Sest) that is computed along with log-linear 95% confidence intervals (CI), indicated the recording of 96% of species for the OTMD region. The number of estimated species for the control site S_1 was 83% of the species recorded (117 estimated species, IC = 104–157 species), meanwhile for the tailings site S_2, the estimated species corresponded to 93% of the detected ones (98 estimated species, IC = 93–116 species). Eighteen species were exclusive to the control site S_1, ten were exclusive to the tailings site S_2, and 88 species were present in both communities (Table 1). All exclusive species for each site were rare and infrequently recorded.

With respect to their relative abundances, our results showed that at the control site S_1, *Ptiliogonys cinereus* (Gray Silky-flycatcher), *Hylocharis leucotis* (White-eared Hummingbird), *Spizella passerina* (Chipping Sparrow), *Regulus calendula* (Ruby-crowned Kinglet), and *Turdus migratorius* (American Robin) were the most abundant species. Correspondingly, at the tailings site S_2, the species with the greatest relative abundance were *Setophaga coronata* (Yellow-rumped Warbler), *P. cinereus*, *H. leucotis*,

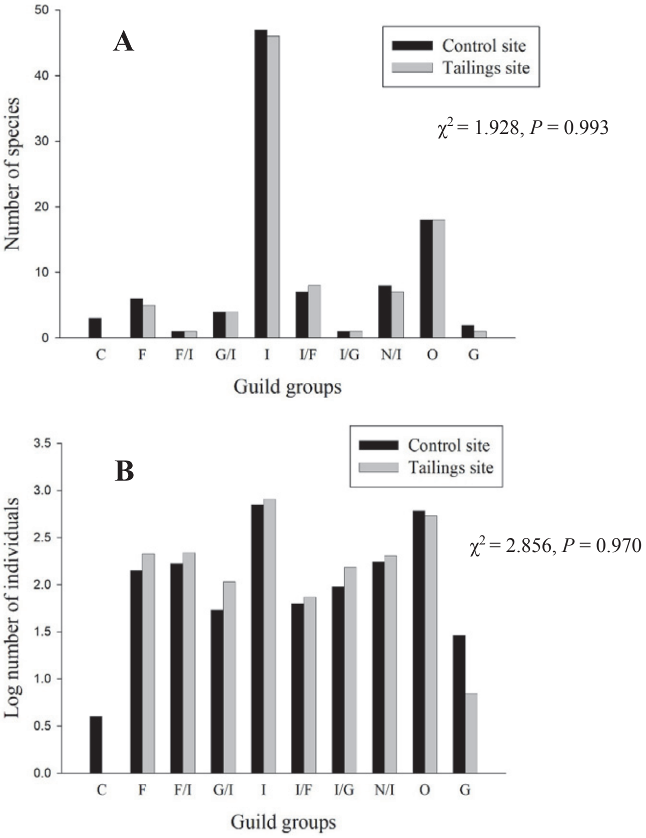

Figure 3. Bar chart of (**A**) number of species and (**B**) individuals belonging to different guilds at two sites within the El Oro-Tlalpujahua Mining District area. Legend: C: Carnivorous, F: Frugivorous, G: Granivorous, I: Insectivorous, N: Nectarivorous, O: Omnivorous.

Table 1. Seasonal status and relative abundances of bird species recorded in a control site and a mining site at El Oro-Tlalpujahua Mining District, central Mexico.

Family	**Common name**[a]	**Seasonal status**[b]	**El Castillo (S_1 Control site)**		**Mina Dos Estrellas (S_2 Mining site)**	
Species			**FRE S_1**[c]	**ABU S_1**[d]	**FRE S_2**[c]	**ABU S_2**[d]
Odontophoridae						
Colinus virginianus	Northern Bobwhite	PR	0.59	1.18	NR	NR
Columbidae						
Patagioenas fasciata	Band-tailed Pigeon	PR	0.59	0.59	NR	NR
Columbina inca	Inca Dove	PR	5.92	14.20	2.00	5.25
Cuculidae						
Geococcyx californianus	Greater Roadrunner	PR	0.59	0.59	NR	NR
Caprimulgidae						
Antrostomus arizonae	Mexican Whip-poor-will	PR	NR	NR	0.50	0.75
Trochilidae						
Colibri thalassinus	Mexican Violetear	PR	4.14	4.73	4.50	6.75
Eugenes fulgens	Rivoli's Hummingbird	PR	4.73	5.92	4.00	6.75
Lampornis clemenciae	Blue-throated Humming.	PR	1.78	2.96	2.50	3.75
Archilochus colubris	Ruby-throated Humming.	TR	1.18	1.18	NR	NR
Selasphorus platycercus	Broad-tailed Hummingbird	PR	1.78	1.78	0.50	0.75
Selasphorus rufus	Rufous Hummingbird	VI	0.59	0.59	0.50	0.75
Amazilia beryllina	Berylline Hummingbird	PR	0.59	1.18	3.00	6.00

Family Species	Common name[a]	Seasonal status[b]	El Castillo (S_1 Control site)		Mina Dos Estrellas (S_2 Mining site)	
			FRE S_1[c]	ABU S_1[d]	FRE S_2[c]	ABU S_2[d]
Hylocharis leucotis	White-eared Hummingbird	PR	63.31	85.21	59.50	128.25
Accipitridae						
*Accipiter cooperii***	Cooper's Hawk	VI	1.18	1.18	NR	NR
Buteo jamaicensis	Red-tailed Hawk	PR	0.59	0.59	NR	NR
Trogonidae						
Trogon mexicanus	Mountain Trogon	PR	4.14	5.92	NR	NR
Picidae						
Melanerpes formicivorus	Acorn Woodpecker	PR	9.47	15.98	18.50	64.50
Picoides scalaris	Ladder-backed Woodpeck.	PR	6.51	6.51	4.50	6.75
Picoides villosus	Hairy Woodpecker	PR	3.55	4.14	3.50	5.25
Colaptes auratus	Northern Flicker	PR	5.33	5.33	0.50	0.75
Tyrannidae						
Mitrephanes phaeocercus	Tufted Flycatcher	PR	8.28	8.88	5.50	10.50
Contopus pertinax	Greater Pewee	PR	14.79	15.98	12.00	18.00
Empidonax affinis	Pine Flycatcher	PR	0.59	0.59	NR	NR
Empidonax difficilis	Pacific-slope Flycatcher	VI	1.18	1.18	NR	NR
Empidonax occidentalis	Cordilleran Flycatcher	PR	12.43	13.02	10.00	17.25
Empidonax fulvifrons	Buff-breasted Flycatcher	PR	1.18	1.18	2.50	4.50
Sayornis nigricans	Black Phoebe	PR	NR	NR	0.50	1.50
Sayornis saya	Say's Phoebe	VI	0.59	1.18	NR	NR
Pyrocephalus rubinus	Vermilion Flycatcher	PR	2.96	5.33	0.50	0.75
Myiarchus tuberculifer	Dusky-capped Flycatcher	PR	1.78	2.37	1.50	3.00
Tyrannus vociferans	Cassin's Kingbird	PR	5.92	7.69	2.00	3.75
Tityridae						
Pachyramphus aglaiae	Rose-throated Becard	PR	0.59	0.59	0.50	1.50
Vireonidae						
Vireo huttoni	Hutton's Vireo	PR	5.92	7.10	5.50	9.00
Vireo cassinii	Cassin's Vireo	VI	4.73	5.92	2.50	4.50
Vireo plumbeus	Plumbeous Vireo	PR	0.59	0.59	0.50	0.75
Vireo gilvus	Warbling Vireo	PR	0.59	0.59	0.50	0.75
Corvidae						
Cyanocitta stelleri	Steller's Jay	PR	5.33	20.71	1.00	5.25
Corvus corax	Common Raven	PR	NR	NR	0.50	0.75
Hirundinidae						
Tachycineta thalassina	Violet-green Swallow	PR	0.59	0.59	1.50	2.75
Paridae						
Poecile sclateri	Mexican Chickadee	PR	3.55	8.28	1.00	4.50
Baeolophus wollweberi	Bridled Titmouse	PR	NR	NR	0.50	1.50
Aegithalidae						
Psaltriparus minimus	Bushtit	PR	8.88	56.21	9.00	116.25
Sittidae						
Sitta carolinensis	White-breasted Nuthatch	PR	23.08	29.59	12.00	18.75

Family **Species**	**Common name**[a]	**Seasonal status**[b]	**El Castillo (S_1 Control site)**		**Mina Dos Estrellas (S_2 Mining site)**	
			FRE S_1[c]	**ABU S_1**[d]	**FRE S_2**[c]	**ABU S_2**[d]
Certhiidae						
Certhia americana	Brown Creeper	PR	0.59	0.59	NR	NR
Troglodytidae						
Catherpes mexicanus	Canyon Wren	PR	1.78	1.78	2.00	3.00
Troglodytes aedon parkmani	House Wren (in part)	VI	7.10	8.28	3.00	5.25
T. aedon brunneicollis	House Wren (in part)	PR	2.96	2.96	8.50	14.25
Thryomanes bewickii	Bewick's Wren	PR	10.06	11.83	18.00	34.50
Campylorhynchus gularis	Spotted Wren	PR	0.59	1.18	NR	NR
Regulidae						
Regulus satrapa	Golden-crowned Kinglet	VI	0.59	0.59	NR	NR
Regulus calendula	Ruby-crowned Kinglet	PR	35.50	57.99	29.50	69.00
Turdidae						
*Myadestes occidentalis***	Brown-backed Solitaire	PR	12.43	15.38	22.50	38.25
Catharus aurantiirostris	Orange-billed Nightingale-Thrush	PR	0.59	0.59	4.00	7.00
Catharus occidentalis	Russet Nightingale-Thrush	PR	5.92	6.51	12.00	23.25
Catharus guttatus	Hermit Thrush	VI	0.59	1.18	NR	NR
Turdus assimilis	White-throated Thrush	PR	0.59	0.59	3.00	4.75
Turdus migratorius	American Robin	PR	33.14	56.80	33.00	86.25
Mimidae						
Melanotis caerulescens	Blue Mockingbird	PR	2.96	2.96	11.00	17.75
Toxostoma curvirostre	Curve-billed Thrasher	PR	7.10	8.88	7.50	12.75
Mimus polyglottos	Northern Mockingbird	PR	NR	NR	0.50	0.75
Ptiliogonatidae						
Ptiliogonys cinereus	Gray Silky-flycatcher	PR	25.44	99.41	37.50	163.50
Peucedramidae						
Peucedramus taeniatus	Olive Warbler	PR	18.93	21.30	13.00	19.50
Passeridae						
Passer domesticus	House Sparrow	PR/ INTRO	1.18	4.73	0.50	1.50
Fringillidae						
Euphonia elegantissima	Elegant Euphonia	PR	NR	NR	0.50	1.50
Haemorhous mexicanus	House Finch	PR	16.57	52.07	19.50	78.75
Spinus pinus	Pine Siskin	PR	4.14	8.88	3.00	9.75
Spinus psaltria	Lesser Goldfinch	PR	15.98	52.07	15.50	90.25
Passerellidae						
Arremon virenticeps	Green-striped Brushfinch	PR	NR	NR	0.50	1.50
Atlapetes pileatus	Rufous-capped Brushfinch	PR	2.96	3.55	3.50	9.00
Pipilo maculatus	Spotted Towhee	PR	15.38	18.93	20.50	38.25
Aimophila rufescens	Rusty Sparrow	PR	0.59	0.59	0.50	1.50
Melozone fusca	Canyon Towhee	PR	15.38	33.73	20.50	44.75
Oriturus superciliosus	Striped Sparrow	PR	5.33	14.79	NR	NR

Family **Species**	**Common name**[a]	**Seasonal status**[b]	**El Castillo (S_1 Control site)**		**Mina Dos Estrellas (S_2 Mining site)**	
			FRE S_1[c]	**ABU S_1**[d]	**FRE S_2**[c]	**ABU S_2**[d]
Spizella passerina	Chipping Sparrow	PR	4.73	60.36	1.50	6.00
Spizella atrogularis	Black-chinned Sparrow	PR	1.18	2.96	NR	NR
Melospiza melodia	Song Sparrow	PR	1.18	1.78	2.50	5.25
Junco phaeonotus	Yellow-eyed Junco	PR	15.38	34.32	22.00	64.50
Icteridae						
Sturnella magna	Eastern Meadowlark	PR	0.59	0.59	NR	NR
Icterus bullockii	Bullock's Oriole	PR	2.96	4.14	1.50	3.75
Icterus abeillei	Black-backed Oriole	PR	NR	NR	3.00	9.75
Icterus parisorum	Scott's Oriole	PR	0.59	1.78	1.00	5.25
Molothrus aeneus	Bronzed Cowbird	PR	0.59	0.59	0.50	1.50
Molothrus ater	Brown-headed Cowbird	PR	0.59	2.37	0.50	0.75
Parulidae						
Mniotilta varia	Black-and-white Warbler	VI	1.78	1.78	1.00	1.50
Oreothlypis superciliosa	Crescent-chested Warbler	PR	21.30	32.54	13.00	23.25
Oreothlypis celata	Orange-crowned Warbler	VI	4.73	7.69	10.50	24.00
Oreothlypis crissalis	Colima Warbler	VI	NR	NR	1.00	1.50
Oreothlypis ruficapilla	Nashville Warbler	VI	0.59	0.59	0.50	0.75
Geothlypis tolmiei	MacGillivray's Warbler	VI	NR	NR	0.50	0.75
Setophaga ruticilla	American Redstart	TR	0.59	0.59	NR	NR
Setophaga coronata	Yellow-rumped Warbler	VI	17.16	56.21	35.50	168.00
Setophaga graciae	Grace's Warbler	PR	NR	NR	0.50	0.75
Setophaga nigrescens	Black-throated Gray Warbl.	VI	1.78	1.78	2.50	3.75
Setophaga townsendi	Townsend's Warbler	VI	14.20	33.73	15.50	49.50
Setophaga occidentalis	Hermit Warbler	VI	9.47	17.75	5.00	11.25
Basileuterus rufifrons	Rufous-capped Warbler	PR	2.37	2.96	4.50	9.50
Basileuterus belli	Golden-browed Warbler	PR	4.73	7.10	1.50	3.00
Cardellina pusilla	Wilson's Warbler	VI	5.92	5.92	7.50	12.00
Cardellina rubrifrons	Red-faced Warbler	VI	NR	NR	1.00	2.25
Cardellina rubra	Red Warbler	PR	2.37	3.55	2.50	5.25
Myioborus pictus	Painted Redstart	PR	22.49	26.04	12.50	20.25
Myioborus miniatus	Slate-throated Redstart	PR	2.37	3.55	1.00	1.50
Cardinalidae						
Piranga flava	Hepatic Tanager	PR	6.51	6.51	7.50	13.50
Piranga ludoviciana	Western Tanager	VI	2.96	2.96	1.00	1.50
Piranga bidentata	Flame-colored Tanager	PR	1.18	1.18	1.00	2.25
Pheucticus melanocephalus	Black-headed Grosbeak	PR	27.81	38.46	18.50	37.50
Passerina caerulea	Blue Grosbeak	PR	2.96	5.92	1.50	3.00
Thraupidae						
Diglossa baritula	Cinnamon-bellied flowerpiercer	PR	1.78	4.73	0.50	0.75

(a) Common name according to AOS (2017). ** Species under special protection (SEMARNAT 2010). (b) Seasonal status, PR: Permanent resident, VI: Winter visitant, TR: Transitory, INTRO: Introduced. (c) FRE = frequency (probability of presence in point counts; (d) ABU = relative abundance expressed in number of individuals in 100 point counts; (e) NR = Non recorded species.

Psaltriparus minimus (Bushtit) and *Spinus psaltria* (Lesser Goldfinch) (Table 1). On the other hand, the species with the highest frequency of occurrence in S_1 were *H. leucotis*, *R. calendula*, *T. migratorius*, *P. cinereus* and *Myioborus pictus* (Painted Redstart); while in S_2, the most frequent species were *H. leucotis*, *P. cinereus*, *S. coronata*, *R. calendula*, and *Myadestes occidentalis* (Brown-backed Solitaire) (Table 1).

The Mann-Whitney U test showed no significant differences in the average number of species and individuals per count between sites ($P > 0.1$). However, there were significant differences in the abundance of 18 species (Table 2). In reference to the similarity between sites, the Sorensen index revealed 85% qualitative similarity, while the Morisita-Horn index showed 93% quantitative similarity.

The Analysis of Similarity (ANOSIM) indicated a high level of correspondence between both communities ($R = 0.0445$, $P = 0.0001$). On the other hand, the SIMPER analysis suggested that the few extant differences between them are attributable to 18 species (Table 3), which add up to 62% of the differences between sites. The SIMPER test gives greater weight to abundance, such that species contributing to the differences between communities are those with the highest number of records. Overall the bird communities at the study sites were very similar to one another (as it was also evident with ANOSIM), although some species had clear differences in their abundance in both sites (Table 2), such as *S. coronata*, *M. caerulescens*, *O. superciliosus*, *C. auratus*, and *T. mexicanus.*

DISCUSSION

Despite the fact that the OTMD has historically been very important for its economic prosperity, biological inventories in the area are virtually non-existent. This work provides the first bird species inventory for Mina Dos Estrellas and Tlacotepec, with 108 species (19.7% of those registered in the state of Michoacan) (Villaseñor-Gómez 2005), and 83% of the species recorded from Sierra Chincua at MBBR (SEMARNAT 2001), the nearest area with available ornithological information. According to the NOM-059 (SEMARNAT 2010), two species are under special protection: *Accipiter cooperi* (Cooper's Hawk) and *M. occidentalis*.

After 65 years of the cessation of extractive mining activities, bird communities at the OTMD have a high degree of similarity (85% qualitative and 93% quantitative), a pattern that coincides with the results

Table 2. Mean relative abundance of the species with significant differences in abundance between study sites in El Oro-Tlalpujahua, Mining District, during 2014–2015.

Species	Individuals recorded	Feeding guild[a]	Mean Control Site, El Castillo S_1 (EE)	Mean Tilings site, Mina Dos Estrellas S_2 (EE)	*P*
Setophaga coronata	145	Omn	**0.237 (0.044)**	0 (0)	0.001**
Myadestes occidentalis	75	Fru	0.147 (0.032)	**0.25 (0.034)**	0.014*
Sitta carolinensis	69	Gra	**0.266 (0.042)**	0.120 (0.023)	0.008**
Myioborus pictus	68	Ins	**0.248 (0.037)**	0.130 (0.024)	0.010*
Oreothlypis superciliosa	67	Ins	**0.230 (0.036)**	0.140 (0.026)	0.045*
Melanerpes formicivorus	61	Omn	0.094 (0.022)	**0.225 (0.035)**	0.010*
Thryomanes bewickii	56	Ins	0.100 (0.023)	**0.195 (0.03)**	0.028*
Catharus occidentalis	40	Fru	0.065 (0.020)	**0.145 (0.03)**	0.043*
Oreothlypis celata	33	Ins	0.059 (0.021)	**0.115 (0.024)**	0.043*
Melanotis caerulescens	28	Ins/Fru	0.029 (0.013)	**0.115 (0.023)**	0.003**
Troglodytes a. brunneicollis.	22	Ins	0.029 (0.013)	**0.085 (0.020)**	0.025*
Cyanocitta stelleri	16	Omn	**0.076 (0.027)**	0.015 (0.011)	0.015*
Tyrannus vociferans	15	Ins	**0.065 (0.020)**	0.020 (0.010)	0.049*
Oriturus superciliosus	12	Omn	**0.071 (0.025)**	0 (0)	0.001**
Catharus aurantiirostris	10	Fru	0.005 (0.005)	**0.045 (0.016)**	0.035*
Colaptes auratus	10	Gra/Ins	**0.053 (0.017)**	0.005 (0.005)	0.005**
Trogon mexicanus	10	Ins/Fru	**0.059 (0.024)**	0 (0)	0.004**
Icterus abeillei	6	Ins	0 (0)	**0.030 (0.012)**	0.023*

(a) Fru: Frugivorous; Gra: Granivorous; Ins: Insectivorous; Omn: Omnivorous.
Non-parametric Mann-Whitney U tests: * $P < 0.5$ and > 0.1, ** $P < 0.01$; SE = Standard error.

Table 3. Contribution of the bird species to the differences between the communities at the control site and a mining site at El Oro-Tlalpujahua Mining District, central Mexico.

Species	Contribution (%) to the difference	Cumulative percentage of the difference	Species abundance per count at the control site	Species abundance per count at the mining site
Hylocharis leucotis	6.79	6.79	0.75	0.811
Setophaga coronata	5.18	11.97	**0.525**	**0.237**
Turdus migratorius	5.16	17.12	0.405	0.438
Ptiliogonys cinereus	4.96	22.08	0.465	0.325
Regulus calendula	4.53	26.61	0.32	0.432
Pheucticus melanocephalus	3.50	30.11	0.21	0.325
Haemorhous mexicanus	3.18	33.29	0.22	0.237
Junco phaeonotus	3.12	36.41	0.23	0.195
Melozone fusca	3.02	39.42	0.215	0.219
Myadestes occidentalis	2.83	42.26	0.25	0.148
Spinus psaltria	2.77	45.03	0.18	0.195
Pipilo maculatus	2.63	47.66	0.23	0.172
Sitta carolinensis	2.59	50.25	0.12	0.266
Myioborus pictus	2.50	52.75	0.13	0.249
Oreothlypis superciliosa	2.47	55.22	0.14	0.231
Setophaga townsendi	2.42	57.64	0.195	0.148
Melanerpes formicivorus	2.30	59.94	**0.225**	**0.0947**
Peucedramus taeniatus	2.22	62.16	0.13	0.195

of other studies. In southern Spain, at the Guadiamar corridor, a severely contaminated environment at the Aznalcollar mine, in restoration since 2000, Márquez-Ferrando (2008) found that the composition of bird communities exposed to mining waste remnants after eight years of abandonment was 80% similar to those at natural sites without exposure to mining wastes. Similarly, Osipov & Biserov (2017) studied the succession of bird communities in a Boreal Mountain-Valley landscape disturbed by gold mining in the Niman River (at the Bureya mountains, Russia); their findings indicate that sites with tailings 35–40 years after abandonment were similar in species composition to areas of valleys without disturbance, even though density of species was lower in the mining sites. On the other hand, abandoned tailing sites had a more complex successional vegetation and their communities of birds were more diverse and abundant, as were the mountain forest communities without disturbance. Nichols & Watkins (1984) and Armstrong & Nichols (2000) studied the avifaunal recolonization of rehabilitated bauxite mines in the Jarrah Forest of south-western Australia. They compared bird communities in a forest where extraction started in 1963 in rehabilitated Eucalyptus (*Eucalyptus marginata*) forest, and found that avian communities were very similar after a period of 24 and 30 years, and that the bird communities could reach up to 65% similarity within the first 4–5 years of abandonment, and 73.5% similarity after 16–17 years. According to this, similarity of communities increases with time in disturbed environments, where natural regeneration or restoration processes have taken place.

The area of OTMD has gone through a process of natural regeneration, in which those plant species most tolerant to disturbance, and/or those that were exploited to a lesser extent, reestablished the vegetation on the area, and its composition and structure support very similar bird communities. The reestablishment of forests with similar physiognomy in the study site may indicate the presence of suitable resources that maintain similar bird communities at both sites (McArthur & McArthur 1961). However, differences in the abundance of 18 species also suggests the existence of specific effects. They might be related to the sensitivity to pollutants, differences in the availability of specific resources (*e.g.*, food, breeding sites, feeding territories, perching structures), or other factors not taken into account (Loyn 1985, Gould & Mackey

2015). For example, differences found in *M. formicivorus* might reflect the presence of tall eucalyptus trees and snags at the tailings site (Mina Dos Estrellas), where most individuals were recorded. As suggested, food resources, perching structures, and breeding sites can be some of the primary limiting factors in the species distributions and preferences within a given habitat (Cody 1985, Hutto 1985, Jones 2001).

Studies on the effects of secondary succession in forests have shown that in general, early successional bird communities include more generalist granivorous, omnivorous and insectivorous species, considered as pioneer species indicative of disturbance (Rangel-Salazar *et al.* 2009, Becker *et al.* 2013). As succession progresses, structural diversity of vegetation increases and, depending on the community composition, specialized frugivorous, nectarivorous, and specialized insectivorous species (soil, bark, understory and foliage gleaning) colonize the habitat and increase in numbers (May 1982, Winkler 2005, Rangel-Salazar *et al.* 2009). Becker *et al.* (2013) found that bird communities in restored mining areas in southern Brazil had similar species richness between sites after 10–20 years of abandonment, although differences in the abundance of species according to feeding guild were evident: granivorous species decreased, whereas carnivorous, frugivorous, and nectarivorous increased (especially those forests dependent species); omnivorous species remained stable. Their findings suggest that effects could be reflected through changes in functional groups, or can be species specific. In the case of OTMD, some generalists, omnivorous and ground insectivorous species (*M. formicivorus*, *S. coronata*, *J. phaeonotus* and *O. celata*) were significantly more abundant in the tailings site, meanwhile at the control site more specialized species such as nectarivorous and bark insectivores prevailed (*H. leucotis*, *R. calendula*, *S. carolinensis*, *M. pictus* and *O. superciliosa*). Further study is needed to determine whether these differences are attributable to the existence of remnant mining effects after 65 years of abandonment.

Dendrochronological analysis of trees at MBBR suggested that individuals of Sacred Fir (*Abies religiosa*) are 106 years old, and those of Smooth-bark Mexican Pine (*Pinus pseudostrobus*) are 120 years old. Evidence indicates that the MBBR region has also been subjected to historical disturbance regimes caused by logging (Sáenz-Ceja 2015). The presence of old railway tracks in the core zone of MBBR at Sierra Chincua supports the idea of active logging in the past. Probably, regeneration processes took place almost at the same time, and, as such, the similarities in avian communities between MBBR and OTMD may reflect the effects of succession in a wider geographic area. We suggest that OTMD represents an important habitat for resident and migratory bird species in the surroundings of MBBR.

Information on remnant effects of abandoned mines is very scarce. It might prove useful to explore their effects on animal communities under scenarios of revegetation (natural succession) or restoration. Current information on mining impacts refers mostly to the response of biotic communities in active mining districts, where negative effects have been found on birds, rodents, and vegetation. In vertebrates, high concentrations of toxic elements are present in kidney and liver tissues, and they relate to their concentrations in the plants on which they feed (Espinosa-Reyes *et al.* 2014). Bioaccumulation of these elements is known to cause negative effects at the neurological (lethargy), physiological (chronic stress and changes in DNA structure), behavioral (decrease of appetite), and reproductive level (low production of eggs in birds) (Festa *et al.* 2003, Seewagen 2009, Chapa-Vargas *et al.* 2010), contributing to the decline of biodiversity at contaminated sites. The rivers of Santa Cruz, San Pedro and Colorado in Sonora, Mexico, which receive flows from copper mines, are very important sites for breeding and wintering birds, despite the negative impacts of their low water quality (Sprouse 2005, Villaseñor-Gómez 2006); they have not been studied in detail. Little is known on the effects of potentially toxic elements in tailing residual soils and their bioavailability. It would be necessary to study tailing chemistry, the exposure paths for those elements, and bio-magnification effects on functional groups or specific bird species that may be affected at the physiological level (Hudson & Bouwman 2008).

While the establishment of the DMOT historically generated a significant disturbance in the ecosystem, 65 years after the end of its activities current conditions seem favorable for the maintenance of avian communities as a major component of the regional biodiversity, since differences at the community level were not remarkable. Although it is not possible to assess the intensity of the environmental effects caused by mining at DMOT in the past, modification of the natural environment has left permanent traces, such as soil derived from tailings and the absence of some tree species (such as Sacred Fir, *A. religiosa*, present in neighboring forests) that were not able to cope with changes. The relative geochemical stability and the revegetation of tailings may indicate the existence of low intensity impacts at the present. Although there is no evidence at this time, the bioavailability of some potentially toxic elements could trigger processes of bio-magnification in some species, inducing negative health effects on bird individuals in the region. Therefore, it is important to continue working on this subject and to analyze some physiological indicators of performance (such as robustness, condition index, fat reserves, and the Heterophile/Lymphocyte Index) in local birds, in order to evaluate their health and fitness. We also suggest to gain further insights on the role of vegetation structure, functional responses of communities (through feeding guilds), and the current anthropogenic impacts that may be influencing bird communities.

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ARTICLE

Bird-epiphyte interactions in three Atlantic Forest environments in southeastern Brazil

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ABSTRACT: Epiphytes reach up to 67% of the total plant species richness in some tropical areas and act as diverse food resources that can be crucial in times of food scarcity. The avifauna assists in their reproduction, either through pollination or seed dispersal, thus creating a vast interaction spectrum between both communities within a continuous ecological process. Few scientific studies concerning avian and epiphytic community interactions are available and not much is known on their specific relationships. However, their absence can change existing ecological processes in habitats. With this in mind, a study undertaken at the Reserva Ecológica do Guapiaçu, Cachoeiras de Macacu, RJ analyzed bird and epiphytic interactions in three different environments: forest, fragmented forest and pastureland. The aim was to study how these interactions can vary according to their degree of conservation and successional stage. Three observation points were marked in a forest, nine points in forest fragments and ten observation points in the pastureland, thus providing a total of 1056 observation hours. As a result, 643 avian and epiphytic interactions were registered. We tested differences in the number of interactions between the areas. The initial hypothesis was that the largest number of registered interactions would occur in the preserved forest given its preserved state and existing biodiversity; however, the pasture area presented the highest number and variety of interactions. Most of the birds observed in the different habitats presented a high interaction in pasture areas where resource availability is reduced, making epiphytes an important food supply. Epiphytes permit a valuable network of interactions by attracting a high diversity of birds, especially those that disperse fruit or pollinate flowers, illustrating their importance within a degraded environment.

KEY-WORDS: bird diversity, bird interactions, conservation areas, mutualistic interactions, vascular epiphytes.

INTRODUCTION

Epiphyte plants comprise 33–50% of the total vascular flora of tropical forests and can reach up to 67% of the total plant species richness in some areas (Benzing 1990). This flora provides a variety of resources that are of great importance to birds, including maintaining or expanding bird diversity in Neotropical forests (Nadkarni & Matelson 1989), considering that epiphytes provide different resources such as nectar, fruits, seeds and water, as well as nesting material and nesting sites (Nadkarni & Matelson 1989, Sillet 1994). In some cases, such as in tank bromeliads, the morphology and imbricated arrangement of the leaves allow water and organic matter accumulation (Benzing 1990, Rocha *et al.* 2004), where invertebrates and small vertebrates that constitute prey for various species of birds live (Richards 1996, Rocha *et al.* 2004). In this way, epiphytes can provide resources during periods of scarcity, temporarily becoming an important source for different organisms (Nadkarni & Matelson 1989, Rocha *et al.* 2004, Cestari & Pizo 2008).

The interactions between birds and epiphytic plants can occur in different ways. Hummingbirds, as nectarivorous birds, commonly interact with species of epiphytic plants, especially bromeliads (Canela & Sazima 2003, Piacentini & Varassin 2007). However, insectivorous birds can also forage in epiphytes, using different tactics and parts of the epiphytes to obtain their resources (Sillet 1994). Frugivorous bird species are also able to consume fruits and seeds of epiphytes, not only being able to disperse them in trees of forest remnants, but also in deforested areas due to the use of isolated trees (Sheldon & Nadkarni 2013).

The presence of epiphytes contributes to increase bird diversity in both conserved and anthropogenic areas (Nadkarni & Matelson 1989, Cruz-Angón & Greenberg 2005). So, it is an important aspect in Atlantic Forest, considering this is the more devastated and reduced Brazilian biome. However, few specific studies have been carried out to understand the relationships between epiphyte and bird communities in this biome. There are many studies of interactions between birds and plants in general, including epiphytes. These studies focus on guilds generally, such as frugivorous birds or hummingbirds (nectarivores) (Fadini & Marco-Jr. 2004, Ikuta & Martins 2013). Thus, they did not cover the entire bird community. Other studies focus on plant species and did not cover the entire plant community (for a review, see Cestari 2009). In Brazil, Cestari & Pizo (2008) and Pizo (1994) carried out further studies with a focus on understanding the role of the avian-epiphytic interactions.

The Atlantic Forest is considered one of the 34 biodiversity hotspots worldwide and is characterized by a high degree of fragmentation and anthropogenic actions (Myers *et al.* 2000). Anthropogenic actions affect the mutualistic interactions between fauna and flora, such as pollination and dispersion (Groombridge 1992). According to Jordano *et al.* (2006), efforts by the scientific community to investigate the effects of environmental degradation on ecological interactions did not begin until the 1990's. In a recent study, Hasui *et al.* (2017) found 832 bird species in Atlantic Forest and they suggest that this number reinforces the critical situation of taxa in this biome.

Thus, studies aimed at understanding the relationships between birds and epiphytes are necessary, especially in face of anthropic alterations such as the removal of vegetation cover and forest fragmentation, which can exert considerable disturbances to the interactions, and consequently lead to losses in interactions and the simplification of bird and epiphyte communities in tropical forests. The objective of the present study was to investigate the use of epiphytes by birds in three different environments within a continuum between preserved and degraded in an area of Atlantic Forest in order to answer the following questions: (1) Which bird species use epiphytes and how often do the interactions occur in the different environments studied? (2) What are the epiphytes and resources used? Our hypothesis is that native areas have higher interactions between birds and epiphytes considering that native areas have more diversity of birds and epiphytes.

METHODS

Study site

We conducted the study in the Guapiaçu Ecological Reserve (REGUA; 7380 ha; 22°25›S; 42°44›W) in the agricultural community of Guapiaçu, Cachoeiras de Macacu, Rio de Janeiro state, Brazil. The area belongs to a non-governmental organization (NGO) created in 1996 to protect the area from deforestation, hunting and resource exploitation. The reserve is located in the Atlantic Forest and has an area bordering several Conservation Units of the Rio Serrano Central Region, such as the Três Picos State Park and the Serra dos Órgãos State Park, with large old-growth forest remnants.

The area presents Dense Ombrophilous Forest (DOF) formations with different altitudes, with flat topography to cliffs and the presence of rocky outcrops (IBGE 2009). The climate of the region is tropical with rainy summers and dry winters, in which December and January are the rainiest months and June and July are the driest. The lower altitudinal areas have a history of occupation, alternative land use and pasture use of about a century. Agricultural practices were only interrupted in 2004 and these areas were then integrated to the Reserve (Azevedo 2012). Thus, REGUA covers large areas of preserved forest, pasture areas and forest fragments leftover from previously existing activities

Data collection

We selected three areas in the different environments found in the study area: continuous forest, forest fragments and pasture. We selected phorophytes with high epiphyte density. In the forest area, we selected three phorophytes as observation points and observed a 10 m radius in the environment. We also selected three fragment areas, and in each one we selected three phorophytes as the observation point, totaling nine phorophytes. In the pasture area, we selected 10 isolated trees that served as observation points and whose canopies did not connect to other trees. In all areas, the phorophytes were at least 50 m apart.

Observations were done monthly between February 2012 and October 2013. Each phorophyte was observed monthly for a period of 2 h. Observations were made between 6:00 h to 18:00 h. We observed each phorophyte for a total of 42 h throughout the study. We randomize the observation order of the points monthly in order to avoid trends in the records. We recorded the bird species that interacted with the epiphyte according to Sigrist (2009), identifying the resources extracted by the birds. The bird species were classified according to their diet categories (insectivorous, frugivorous and nectarivorous), based on both personal observations as well as in the literature (Cestari & Pizo 2008).

Considering that the availability of the epiphytes affects the number of interactions, we evaluated the density by the method of Sillet (1994). The phorophyte was divided into sampling units of about 1 m from the ground level to the tree canopy. Each epiphyte species was recorded at each interval. The availability of each species of epiphytes was:

$$DGep = \sum Gep/Ncil$$

where *DGep* is the availability of each species epiphytes, ΣGep is the sum of the total of individuals of this species and *Ncil* is the total of imaginary cylinders in which the species occurred. We measured the density only once throughout the study for each species separated by the areas where they occur.

Data analysis

We performed a generalized linear model (glm) using Poisson family with number of interactions as the response variable and area, epiphyte species and epiphyte density as predictor variables. After this analysis, we performed multiple comparisons using "agricolae" package. All analysis were performed using R software version 3.5.2.

RESULTS

We recorded 644 events of interactions between 17 bird species and six epiphytes in the three studied areas (Table 1; Fig. 1). Most of the interactions were recorded in the pasture areas (*n* = 566 interaction events, 87.9% of the total), while there were fewer interactions in the fragments (*n* = 63 events, 9.8%) and in the continuous forest (*n* = 15, 2.3%). Area affect interactions with pasture area containing the largest record of interactions ($P < 0.001$, $df = 2$; Fig. 2). Moreover, density and species identity also affected the number of interactions ($P < 0.001$, $df_{den} = 1$, $df_{spe} = 5$; Table 2).

The most representative bird families were Trochilidae, Thraupidae and Tyrannidae, which together represented 64.7% of the bird species observed. Tyrannidae presented the highest number of interactions (*n* = 239, 37.2% of the total), followed by Thraupidae (*n* = 189; 29.4%), Trochilidae (*n* = 110, 17.1%) and Fringillidae (*n* = 92, 14.3%). The other families represented only 2% of the interactions, with less than 10 interactions each.

The only bird recorded in interactions in all three analyzed areas was *Amazilia fimbriata* (Gmelin, 1788). The species with the highest number of interactions were *Pitangus sulphuratus* (Linnaeus, 1766) (*n* = 97 interactions, 15.1% of the total), *Euphonia chlorotica* (Linnaeus, 1766) (*n* = 92 interactions, 14.3%) and *Tyrannus melancholicus* Vieillot, 1819 (*n* = 80 interactions, 12.4% of the total). The registered birds mainly have generalist eating habits (*n* = 5 species, 29.5%) (Table 1). Exclusive frugivores, insectivores and nectarivores contributed with the same number of species (*n* = 4 species, 23.5% each group; Table 1).

The birds used four Bromeliaceae and two Cactaceae epiphytic species. *Aechmea nudicaulis* (L.) Griseb. had the highest number of recorded interactions (4.6 ± 5.5, 46.4%) and was different of *Rhipsallis baccifera* (JS Muell.). *Rhipsallis elliptica* (G. Lindb. ex K. Schum.) had the lowest number of interactions and was different of all other epiphytes (0.5 ± 0.6, 0.01%, Fig. 3). Another eight epiphytes species were present in the environments and were not used by birds, including species of Bromeliaceae, Araceae, Piperaceae and pteridophytes, among others.

Foraging was the most frequent use of epiphytes in all areas and included flower visiting, seed foraging and arthropod predation (forest = 66.7%, fragment = 85.5%, pasture = 43.3%) (Fig. 2). Flower visiting was the most common foraging type in the three areas and the only one observed in the continuous forest (Fig. 4). Regarding predation, the birds pick up arthropods living in the plant parts (bromeliad tank and dry parts).

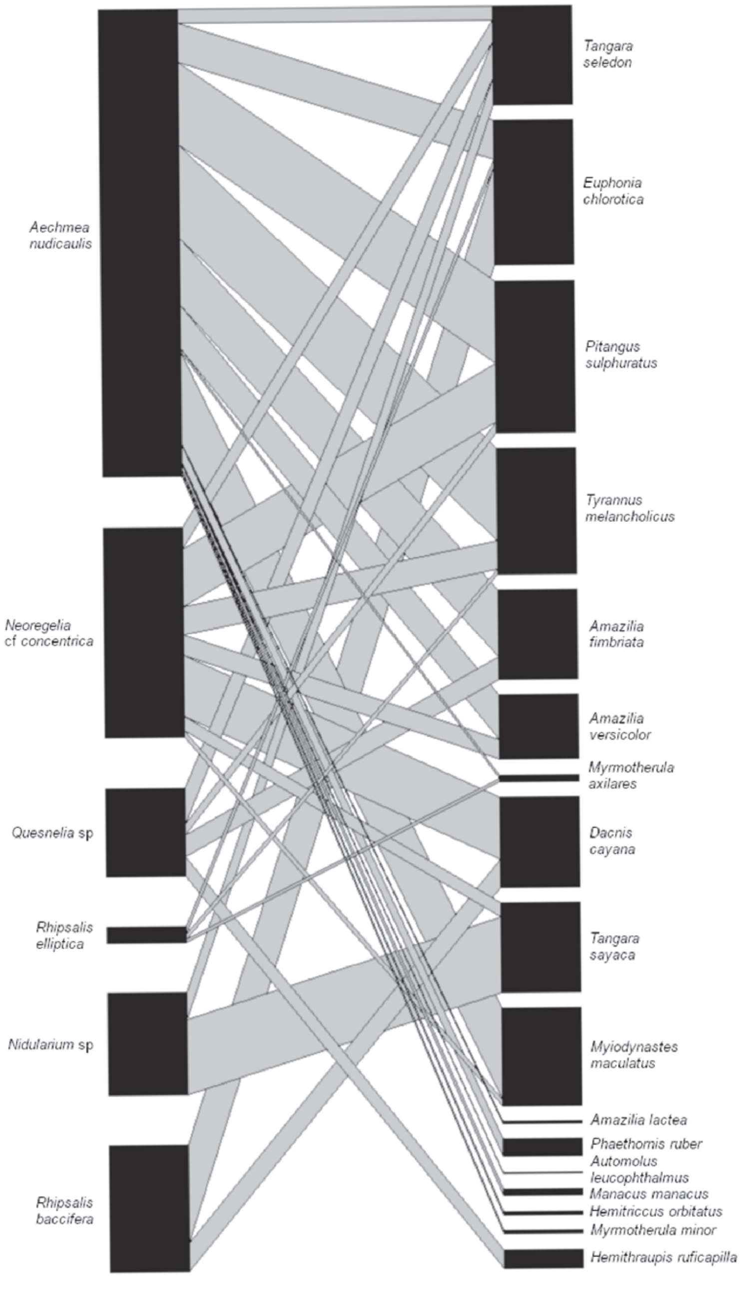

Figure 1. Interaction network between birds (right) e epiphytes (left) in Rio de Janeiro state, Brazil. The bar thickness is proportional to the total interactions performed by the species.

Table 1. Bird species interacting with epiphytes in the three study environments, with information on the areas where the interactions occurred and the diet category of the species, in Rio de Janeiro state, Brazil. Areas: Fo = forest, Fr = fragment, Pa = pasture. Diet: N = nectarivorous, F = frugivorous, I = insectivorous.

Bird species	Areas	Diet
Trochilidae		
Amazilia fimbriata (Gmelin, 1788)	Fo; Fr; Pa	N
Amazilia lactea (Lesson, 1832)	Fr	N
Amazilia versicolor (Vieillot, 1818)	Fr; Pa	N
Phaethornis ruber (Linnaeus, 1758)	Fo; Fr	N
Fringillidae		
Euphonia chlorotica (Linnaeus, 1766)	Fr; Pa	F
Furnariidae		
Automolus leucophthalmus (Wied, 1821)	Fo	I
Pipridae		
Manacus manacus (Linnaeus, 1766)	Fo; Fr	F
Rhynchocyclidae		
Hemitriccus orbitatus (Wied, 1831)	Fr	I
Thamnophilidae		
Myrmotherula axilares (Vieillot, 1817)	Fr	I
Myrmotherula minor Salvadori, 1864	Fr	I
Thraupidae		
Dacnis cayana (Linnaeus, 1766)	Pa	N/F/I
Hemithraupis ruficapilla (Vieillot, 1818)	Pa	F
Tangara seledon (Statius Muller, 1776)	Fo; Pa	F
Tangara sayaca (Linnaeus, 1766)	Pa	N/F/I
Tyrannidae		
Myiodynastes maculatus (Statius Muller, 1776)	Pa	I/F
Pitangus sulphuratus (Linnaeus, 1766)	Pa	I/F
Tyrannus melancholicus Vieillot, 1819	Fr; Pa	I/F

Table 2. Density of epiphyte species in the three study environments (forest, fragments and pasture) in Rio de Janeiro state, Brazil.

Epiphyte species	Forest	Fragments	Pasture
Aechmea nudicaulis	15.0	23.3	66.0
Neoregelia cf. *concentrica*	20.0	29.8	29.0
Nidularium sp.	0.0	0.0	9.0
Quesnelia sp.	0.0	0.0	8.5
Rhipsalis baccifera	8.3	21.6	57.5
Rhipsalis elliptica	10.0	33.2	19.0

In addition to the Trochilidae species, *Dacnis cayana* (Linnaeus, 1766) and *Tangara sayaca* (Linnaeus, 1766) also visited flowers of the bromeliad species. *Rhipsalis baccifera* and *A. nudicaulis* epiphytes had their seeds forraged by species of *E. clorotica*, *Myiodynastes maculatus* (Statius Muller, 1776) and *T. melancholicus*. Other uses of the epiphytes by the birds were to collect material for nests, baths and perches. The only epiphytes used for bathing were *A. nudicaulis* and *N. concentrica*. Many birds accessed the interior of the epiphytes, but it was not possible to identify the resources they used (forest = 13.3%, fragment = 9.7%, pasture = 38.9%).

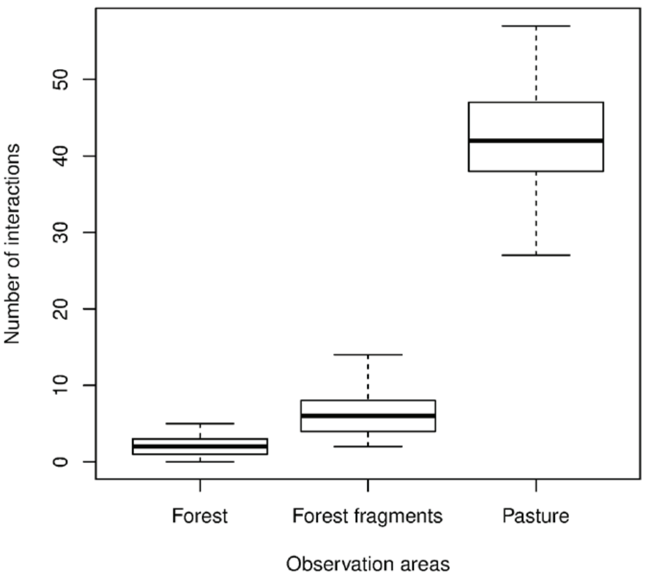

Figure 2. Number of records of interactions between birds and epiphytes in areas of forest, forest fragments and pasture in the study conducted at Guapiaçu Ecological Reserve, Brazil, over 21 months.

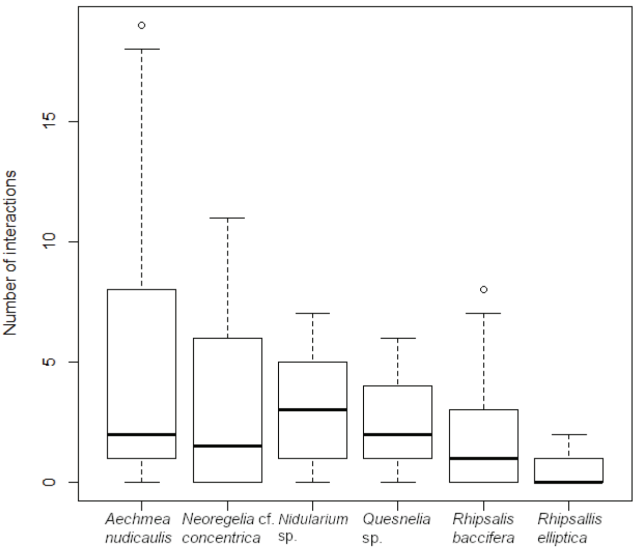

Figure 3. Number of records of interactions between birds and the different epiphytes species in the study conducted at Guapiaçu Ecological Reserve, Brazil, over 21 months.

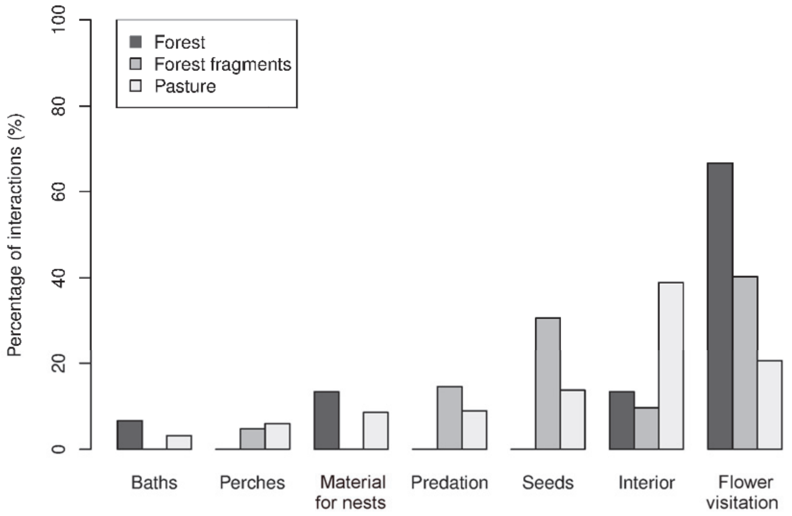

Figure 4. Absolute frequency of the different uses of the epiphytes by birds in the studied forest fragments and pasture areas at Guapiaçu Ecological Reserve, Brazil.

DISCUSSION

In the present study, we verified that the interactions mainly occurred in the pasture areas and that the birds had more interactions with a few epiphyte species. These epiphyte species offer varied resources and they occur densely in open areas like pastures. In addition, despite the high number of bird species performing interactions, most interactions were only performed by three species (*P. sulphuratus*, *E. chlorotica* and *T. melancholicus*), which accounted for approximately 42% of the interactions. These three species are frugivorous and/or insectivorous and are generalists in occupying habitat, which favoring their occupation at different studied areas.

The pasture trees in our study showed a high abundance of epiphytes representing an important source of resources. The density affected number of interactions and high values in pasture can explain the greater number of interactions recorded in this environment. Thus, the abundance of epiphytes and the availability of resources offered by them will influence the use by birds (Sheldon & Nadkarni 2013). Isolated trees in altered environments play a key role for biodiversity (Manning *et al.* 2006, Gibbons *et al.* 2008, Moga *et al.* 2016, Prevedello *et al.* 2018), serving as a shelter area and a source of resources for different animals, including birds (Pizo & Santos 2011, Barth *et al.* 2015). Moreover, these trees serve as the focal point for regeneration of disturbed landscapes (Schlawin & Zahawi 2008, Sandor & Chazdon 2014, Zwiener *et al.* 2014, Derroire *et al.* 2016), connecting habitat patches like "steppingstones" (*e.g.*, Prevedello *et al.* 2018) and as a colonization site by different epiphyte species (Poltz & Zotz 2011).

Vascular epiphytes occurring in isolated trees increase the availability of resources in isolated trees, providing additional resources for birds such as water, forage, material and nesting sites (Nadkarni & Matelson 1989, Sillett 1994, Rocha *et al.* 2004), having an important role in maintaining populations of bird species. This role becomes important in altered sites such as pastures or forest fragments. Epiphytes function as microhabitats that reduce the temperature, facilitating the permanence and use of these environments by the animals and offering resources throughout the year (Scheffers *et al.* 2014).

More preserved environments such as continuous forests can offer a great variety of resources coming from the different strata or synusiae of the forest (Wheelwright *et al.* 1984, Nadkarni & Matelson 1989). Thus, the epiphytes would be less important in environments with greater availability of resources, such as forests (Wheelwright *et al.* 1984). This explain the lower number of interactions in this habitat.

Aechmea nudicaulis showed the highest frequency of interactions with birds and the greatest variety of exploited resources (flowers, seeds, invertebrates, bathing water, nest material and perches). Due to their availability and concentric arrangement of the leaves, the plants of this family can offer a greater variety of resources for use by birds (Rocha *et al.* 2004, Cestari & Pizo 2008). Thus, they can accumulate water and organic matter in the bases of their leaves, creating a microcosm that allows colonization by invertebrate and vertebrate animals (Nadkarni & Matelson 1989), which can be used as resources by birds.

Among the recorded avifauna, *A. fimbriata* was present in all three environments, being a very well represented species in open areas and in forest edges, and with territorial behavior (Antas 2004). Hummingbirds are effective pollinators and their high frequency was fomented by higher availability of hummingbird-pollinated flowers in all sites (all studied bromeliads). For example, *A. nudicaulis* (Bromeliaceae), which has longer flowers and concentrated nectar, are frequently used by these birds, especially *A. fimbriata* (Canela & Sazima 2003). Hummingbirds increase the reproductive success rates of epiphytes by pollination, including in degraded environments (Martinelli 1997).

In a review of the use of epiphytes by birds in Brazil, Cestari (2009) recorded 42 studies that included interactions between these groups. According to the revised studies, 112 bird species were recorded interacting with 97 species of epiphytes. Our study included six bird species that did not appear in the survey conducted by Cestari (2009): *Hemitriccus orbitatus* (Wied, 1831), *Myrmotherula axillaris* (Vieillot, 1817), *Manacus manacus* (Linnaeus, 1766), *T. sayaca*, *T. melancholicus* and *M. maculatus*. This indicates that the number of bird species interacting with epiphytes may still be underestimated, and that studies involving different forest formations and stages of regeneration increase these numbers.

In conclusion, the presence of epiphytes is of great ecological importance for the environment and for birds, as they use the most varied resources such as water, nectar, seeds and invertebrates. These resources may be absent or few in a pasture environment. Thus, epiphytes are essential in these areas for maintaining various bird species. In addition, trees in the pasture can act as "stepping stones", and thus the epiphytes play an important role in providing resources for birds that are moving between fragments and continuous forest areas.

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ARTICLE

Habitat use and home range of a migratory bird, *Myiodynastes maculatus solitarius*, in an urban park in the Atlantic Forest, Brazil

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ABSTRACT: Detailed studies on the home range size and habitat use of a species are important for the understanding of population dynamics and density. The Southern Streaked Flycatcher (*Myiodynastes maculatus solitarius*) is a common, widely distributed austral migrant in Brazil that inhabits open areas, forest edges and urban parks. Surprisingly, very little information exists on even basic aspects of its natural history, and details about its habitat use and home range are essentially unknown. We estimated home range size and habitat selection by *M. m. solitarius* during the 2017–2018 breeding season at Parque Ecológico do Tietê, an urban park in São Paulo, Brazil. We mist-netted and banded three adult individuals, which were followed for a total of 91 h and 50 min to assess their habitat use and home range. Home range size was 5.40 ± 2.45 ha (95% kernel density) and 2.46 ± 1.70 ha (50% kernel density). We obtained 428 sight records of the three individuals, and the strata most frequently used were the canopy and mid-story, in some places with a relatively high percentage of tree cover. These individuals had a clear preference for forested areas ($n = 408$), as compared to isolated trees in open areas ($n = 20$). This study contributes to enhance our knowledge of the natural history of the species and offers important new data on various aspects related to the use of space. These results also suggest that urban green areas promote the occurrence of this species in cities, using urban parks to breed and as stopover sites during migration.

KEY-WORDS: behavior, bem-te-vi-rajado, São Paulo, Streaked Flycatcher, urbanization.

INTRODUCTION

The urbanization process may affect migratory bird species in many different ways, since they use different sites through the year for wintering, stopover and breeding (Martin & Finch 1995, Lees & Martin 2015). Moreover, annual variation in urban food resource availability may favor the permanence of resident species and negatively affect migratory species, due to interspecific competition for food and nesting sites (Leveau 2018). For this reason, the structure of urban green areas and heterogeneity of the urban matrix may influence a variety of natural history traits of these species, such as habitat use and home range size.

Home range is the area used by the individual during its daily activities, including foraging and reproduction (Burt 1943, Brown & Orians 1970, Powell 2000), and it is expected that a bird species meets its basic needs within its home range (Hutto 1985). The habitat selection in birds is a behavioral, physiological and ecological response (Cody 1985), which may result in a disproportionate use of habitat, directly influencing its survival (Hutto 1985). However, resource availability for birds in disturbed habitats can be diminished, affecting intraspecific competition (Greenberg 1986), nest predation (Rodewald *et al.* 2011) and food availability (Kohut *et al.* 2009).

Research on habitat requirements and behavior of migratory birds has almost exclusively occurred at temperate latitudes (*e.g.*, Dilger 1956, Blake & Karr 1987, Saab 1999, Norris *et al.* 2004), such that information on even basic aspects of the natural history of most migratory birds that breed in the Neotropics is still scarce. One such species is the Streaked Flycatcher (*Myiodynastes maculatus*), which occurs throughout most of the South and Central America and includes seven subspecies. The southernmost population refers to the subspecies *M. m. solitarius*, which performs poorly-known migratory movements, breeding in southern South America and moving northwards in the fall (Cueto & Jahn 2008, del Hoyo *et al.* 2018). Plumage and vocal differences indicate that this taxon may represent a valid species (del Hoyo *et al.* 2018), inhabiting different habitat types across South America, including open second-growth, forest edge and small clearings with scattered tall trees, in rural areas or even in urban parks (Sick 1997, del Hoyo *et al.* 2018). However, the basic natural history aspects of this species, such as habitat use and home range size, are still poorly known in both natural and urban areas.

In this study, we assessed the habitat use and estimated the home range size of *M. m. solitarius* during the breeding season in an urban park in São Paulo, Brazil. We aimed to answer three main questions: 1) What is the home range size of the species in urban parks? 2) Does habitat structure influence an individual's home range size? and 3) Does phytophysiognomy influence its foraging behavior?

METHODS

Study site

Our study was carried out at the Parque Ecológico do Tietê (hereafter PET), an urban park located between the cities of São Paulo and Guarulhos (Fig. 1). Nearly 300,000 people visit the park each year (DAEE 2019). We focused our research in São Paulo portion. The city is one of the largest and most populous cities in the world (> 12 million people), composed of > 50% urban structures (*e.g.*, buildings and impervious surfaces), embedded within the Atlantic Forest ecoregion (Muylaert *et al.* 2018).

We classified the park into three types of areas: A1) Areas formed by partially open vegetation and anthropic structures with relatively high numbers of people and cars, comprised of herbaceous, shrub, arboreous and canopy vegetation strata. The understory is composed by secondary vegetation in an initial state of regeneration, such as *Leucaena* spp., *Enterolobium* sp., *Cecropia* sp., *Handroanthus* sp., *Anadenanthera* sp., *Bombacopsis* sp., *Caesalpinia* sp., *Trema* sp., *Melia* sp., *Tipuana* sp., *Tibouchina* sp., and *Schinus* sp. In the canopy there are native species and exotics, such as *Schizolobium* sp., *Chorisia* sp., *Jacaranda* sp., and mainly *Eucalyptus* spp. and *Casuarina* spp. A2). This is a corridor attached to a small fragment of forest with vegetation that is beginning to regenerate, with herbaceous, shrub and arboreous strata present. Here, the understory is composed of reforested native, exotic and ornamental species, such as *Tibouchina* sp., *Handroanthus* sp., *Libidibia* sp., *Tipuana* sp., *Schinus* sp., *Cedrela* sp., *Anadenanthera* sp., *Melia* sp., *Casuarina* sp., *Leucaena* sp., *Ficus* spp., *Croton* sp. and *Cecropia* sp., as well as *Alchornea triplinervia*, which is very characteristic of the shrub stratum. A3) Located in an area of the park with limited public access, this area is mainly comprised by forest with tall trees, dominated by *Eucalyptus* spp. and *Casuarina* sp.; most of the *Eucalyptus* is dry or dead (J.G.V., pers. obs.). The understory comprises a less diverse, mostly secondary

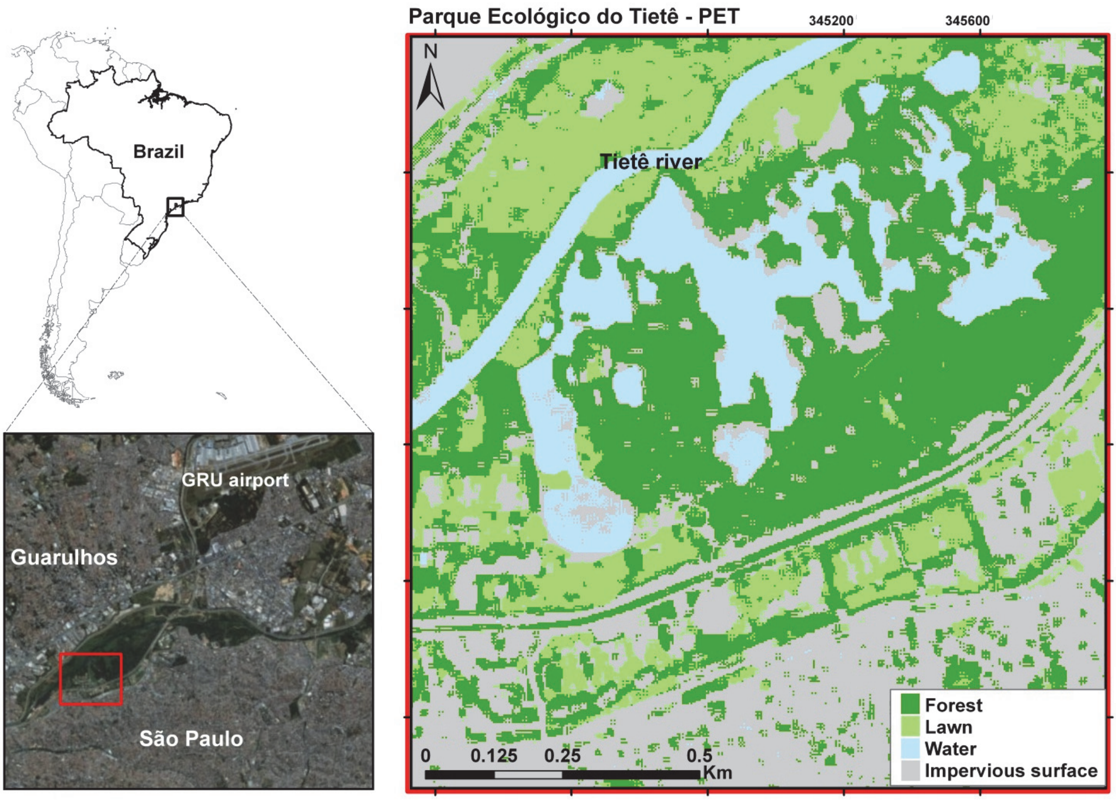

Figure 1. Map of the study area (Parque Ecológico do Tietê – PET) and its landscape components in São Paulo, Brazil.

plant community, with such species as *Anadenanthera* spp., *Melia* sp., *Leucaena* spp. and *Schinus* sp. This area is also bordered by a lake.

Fieldwork

In October 2017, we mist-netted three adult *M. m. solitarius*, which were banded with numbered and color bands for individual identification. The focal individuals were designated as A1, A2 and A3. They were followed and observed between 17 October 2017 and 31 January 2018 from 06:30 to 10:30 h, using methods described by Altmann (1974). Each individual was followed during 1 h, with its geographic coordinates registered every 10 min with the cellphone app GPS Geotracker. The following information was collected: date, initial and final time of observation, height of the vegetation stratum it was found in (high 15–20 m, middle 8–15 m and low 5–8 m), plant species it was found in, type of environment (forest or isolated tree) it was found in, height of the perch (high 15–20 m, middle 8–15 m and low 5–8 m) and stratum of foraging.

Each sampling day started with a different individual in order to minimize any time-related bias in behavioral measurements. The conspicuous vocal behavior of this species made it easy to locate, and individual identification was made using binoculars.

Analyses

Estimates of home range of *M. m. solitarius* were performed using kernel density estimation (Worton 1987), which is currently the most reliable and accurate home range estimator (Powell 2000, Jacob & Rudran 2003, Laver & Kelly 2008). We estimated 95% kernel density contours to determine the total home range and 50% kernel density of each individual, and used smoothing (h) and least square cross-validation (LSCV) (Worton 1987, Laver & Kelly 2008). Analyses were performed using the R 3.4.1 environment (R Core Team 2014) and "adehabitat" assembly packages (Calenge *et al.* 2009). The taxonomy used here follows the Brazilian Committee of Ornithological Records (Piacentini *et al.* 2015).

RESULTS

Home range

The mean home range size of the species was 5.40 ± 2.45 ha (95% kernel density) and 2.46 ± 1.70 ha (50% kernel density), described for each individual in Table 1. The largest home range, expressed as the 95% kernel contour was estimated for A1 (8.46 ha) and the smallest was for A3 (2.46 ha; Fig. 2). Home range size varied between months for all individuals, although it was different for each individual (Table 2). The three banded individuals were members of distinct social pairs, and we observed no home range overlap between the territories of each pair. Agonistic encounters were observed between individuals (*n* = 6), but only at home range boundaries.

During the observation of habitat use, we obtained 428 records of the three individuals. Across records, the high tree stratum was the most used (*n* = 247 total observations), followed by the middle (*n* = 141) and low strata (*n* = 40; Fig. 3). In general, birds were most often observed using perches in the higher strata (high = 171, middle = 177), followed by the low stratum (low = 80; Fig. 4). No individuals were seen foraging on the ground. Considering the substrates or perches selected, the A1 and A3 were similar (high = 11 and 8, respectively), (middle = 4 and 8, respectively) and (low = 5 and 5, respectively). While A2 used low perches in most capture activities (low = 33), followed by middle perches (*n* = 17). Moreover, in a total of 92 records, 84% of consumed food items were arthropods and 16% fruit. Individuals had a clear preference for forest habitats (*n* = 408) in comparison to open areas with isolated trees (*n* = 20; Fig. 5). Most

Table 1. *Myiodynastes m. solitarius* home range (ha), expressed as 50% and 95% kernel density of three individuals at Parque Ecológico do Tietê, São Paulo city, Brazil. SD = standard deviation.

ID	50%	95%
A1	1.41	8.46
A2	0.70	5.28
A3	0.35	2.46
Mean ± SD	2.46 ± 1.70	5.40 ± 2.45

Table 2. *Myiodynastes m. solitarius* home range (ha) according to 50% and 95% kernel density of three individuals of the species at Parque Ecológico do Tietê, São Paulo city, Brazil.

Id	October		November		December	
	50%	95%	50%	95%	50%	95%
A1	0.0	1.03	1.06	5.63	2.28	9.78
A2	0.34	0.68	0.70	3.16	0.33	1.63
A3	0.68	1.70	1.06	4.93	0.65	2.61

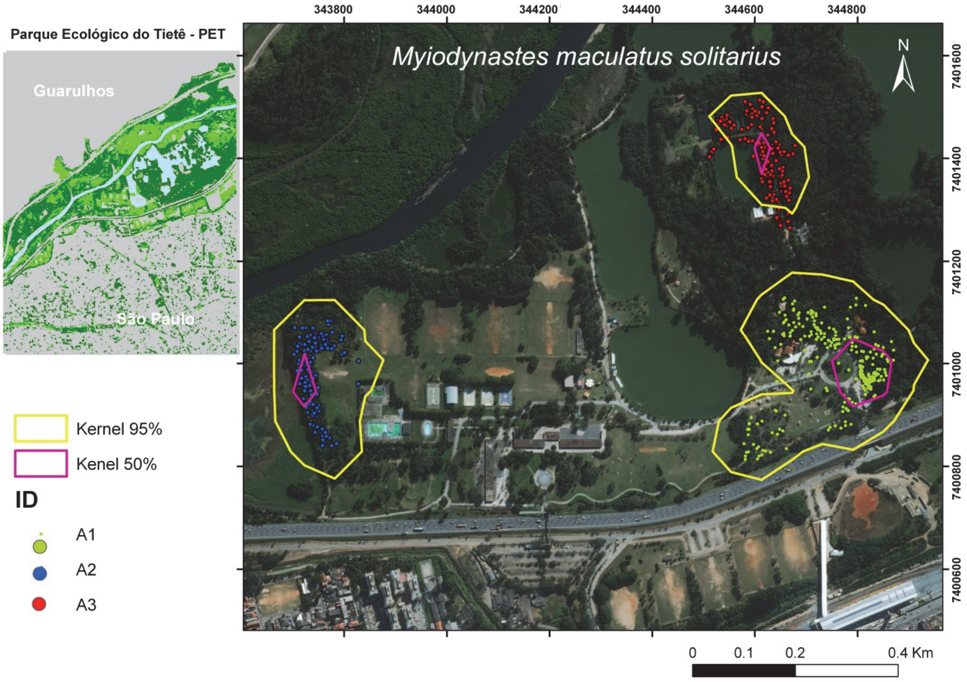

Figure 2. Points within polygons represent georeferenced fixes of observations of each bird during monitoring yellow polygons represent the 95% kernel density contours and pink polygons represent 50% kernel density, at Parque Ecológico do Tietê - SP, Brazil.

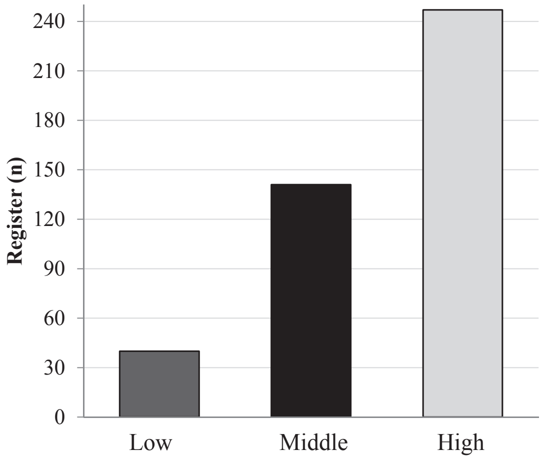

Figure 3. Tree strata used by *Myiodynastes maculatus solitarius* at Parque Ecológico do Tietê, Brazil.

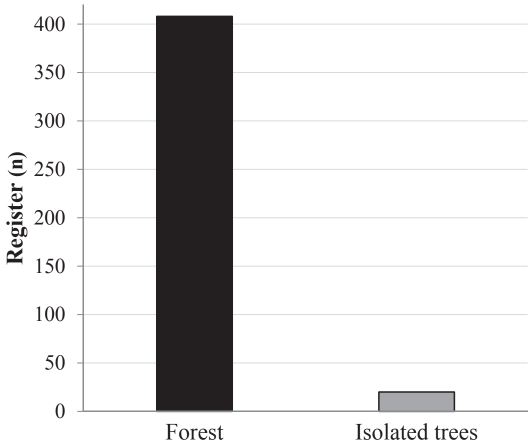

Figure 5. Habitat (forest or isolated trees) used by *Myiodynastes maculatus solitarius* at Parque Ecológico do Tietê, Brazil.

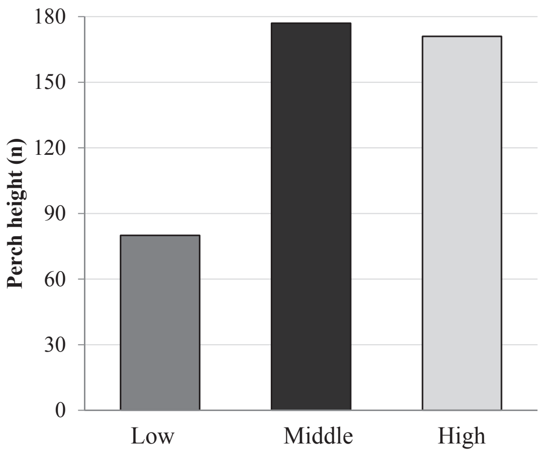

Figure 4. Height of perches used by *Myiodynastes maculatus solitarius* at Parque Ecológico do Tietê, Brazil.

observations in areas with isolated trees were of the A2 pair. The members of the pairs remained together during the entire observation period and we observed breeding activities of the A2 pair, which nested and produced three fledglings (Figs. 6A & 6B).

DISCUSSION

Information on home range size of birds in South American urban areas are scarce and have been estimated for only a few species (*e.g.*, Marantz *et al.* 2003, Hansbauer *et al.* 2008, Hilty 2011). As far as we know, this is the first assessment of the home range and habitat use of *M. m. solitarius* and our findings showed that its home range in

Figure 6. Banded *Myiodynastes maculatus solitarius* individuals at Parque Ecológico do Tietê, Brazil. (**A**) Individual A2, and (**B**) three chicks belonging to A2.

an urban area is smaller than those of most Tyrannidae species studied in natural areas (*e.g.*, Ribeiro *et al.* 2002, Lopes & Marini 2006, Jahn *et al.* 2010). Additionally, the presence of anthropogenic structures, as well as vegetation homogenization may increase the home range, since we registered *M. m. solitarius* feeding on fruits and arthropods, and in urban green areas food availability can be affected (Karr 1976, Jokimaki 1999).

Most of the work on home ranges of tyrant flycatchers in South America have been conducted in natural environments. In the rupestrian fields of Minas Gerais, the estimated home range size of *Knipolegus lophotes* (a species smaller than *M. maculatus*), is around 7 ha (Ribeiro *et al.* 2002) and in the Brazilian Cerrado, two Suiriri Flycatchers (*Suiriri suiriri* and *Suiriri affinis*) have home range sizes of up to 14.0 ha and 11.2 ha, respectively, both species using the canopy more often than other strata in Cerrado forest habitat (Lopes & Marini 2006). Another austral migrant, *Tyrannus melancholicus*, has a home range of 43.0 ± 22.6 ha for males and 45.6 ± 45.5 ha for females in the Bolivian Cerrado (Jahn *et al.* 2010), and in a mature *terra-firme* forest in the Peruvian Amazon, the austral migratory species *Legatus leucophaius* has a territory size of ~7 ha (Terborgh *et al.* 1990). Other studies have found that home ranges in urban environments are smaller than in rural or natural areas (*e.g.*, Roth-II *et al.* 2008, Chiang *et al.* 2012) and it can explain the size of home range in our results in comparison with other species of the family. Yet, the underlying mechanisms driving these patterns are still poorly understood, since a variety of interacting factors likely influence home range size in birds, including body size (Terborgh *et al.* 1990), foraging strategies (Jahn *et al.* 2010) and food availability (Newton 1979, Chiang *et al.* 2012), quality and structure of habitat (Chiang *et al.* 2012), sex and age, breeding period and time of the year (Hansbauer *et al.* 2008, Jahn *et al.* 2010).

We detected slight differences between the monitored pairs occupying different habitats, which was reflected in the size of their respective home ranges and in the way individuals used the site. The home range of A1 was more anthropized, and throughout the study this individual increased its home range from 2.31 to 6.84 ha, which is potentially due to its foraging strategy to secure sufficient food (Hansbauer *et al.* 2008). It was also possibly related to the termination of the reproductive period, after which birds are less restricted to being near the nest site (Hutto 1985). Moreover, the reduced tree cover in A1's home range may have contributed to its larger area. Here, the landscape is partially composed of lawn and buildings near the park entrance, where there is more circulation of people and cars (*i.e.*, the total area of buildings and impermeable anthropic structures occupy 0.81 ha of A1's home range). On the other hand, the landscape in A3's home range was mostly made up of forest with tall trees, including many *Eucalyptus* and dead trees, with only ~0.24 ha being composed of anthropic structures. In contrast, A2's home range was primarily composed of habitat with higher tree species richness, including native species. Moreover, in this area there are no anthropic structures and the landscape is only composed of forest intersected by a narrow trail, which potentially explains the smaller home range. A2 and its mate were also the only pair that nested and successfully reproduced, producing three fledglings (Fig. 6B).

Studies have shown that breeding birds may reduce their home range size during the egg and nestling stages (Amaral & Macedo 2003, Moraes *et al.* 2018). Our data refute those results, since in November the area occupied by A2 was larger, when the pair had nestlings and perhaps needed to fly distantly to search for food to feed themselves and their offspring. Although large gaps in information still remain on home range size and habitat requirements of birds in urban parks, most studies to date have found a negative effect of urbanization on breeding birds in urban green spaces, in comparison to those in rural areas (*e.g.*, Bezzel 1985, Jokimaki 1999, Shustack & Rodewald 2010). For example, in an urban park in Ohio, U.S.A., the migratory flycatcher *Empidonax virescens* was negatively affected by urbanization, altering its breeding schedule, such that it nested later and had less time to breed (Shustack & Rodewald 2010). Insectivorous birds that nest in cavities, such as *M. m. solitarius*, may also be especially affected by the presence of anthropic structures, as shown in a study on two species of the family Muscicapidae: *Ficedula hypoleuca* and *Muscicapa striata* (Jokimaki 1999).

Habitat selection by insectivorous birds is usually related to their ability to find, catch and handle insect prey, activities that can be facilitated in certain types of vegetation structure (Cody 1981). *Myiodynastes m. solitarius* can be found in several different types of habitat, even in more open urban green spaces (del Hoyo *et al.* 2018). However, the individuals we observed presented a clear preference for forested habitats in our study, since nearly 95% of the records were in places with more tree cover and more complex vegetation structure. On the other hand, the species appears to be adapted to breed in a wide diversity of habitat types, including areas where *Eucalyptus* is present (Marsden *et al.* 2001, Pereira *et al.* 2015). Based on personal observations of other individuals in the study area, we noticed the constant use of *Eucalyptus* for perching, foraging or nesting by *M. m. solitarius*, normally when the tree is dead and has cavities. In the study area, *Eucalyptus* are usually taller than other tree species, allowing *M. m. solitarius* that use *Eucalyptus* to perch and move in higher strata of the vegetation. A1 and A3 showed a clear preference to perch and forage in the middle and higher strata (81% of visualizations), as is typical of the species (*e.g.*, Sick 1997). The complexity of the vegetation contributes to resource availability for birds (MacArthur & MacArthur 1961), especially for insectivorous birds (Karr 1976), with vegetation structure and food supply usually positively related (Karr 1976). In many cases, a species can adapt to characteristics of the landscape changing their behavior and home range (Chiang *et al.* 2012). Even though *M. m. solitarius* presented some plasticity in terms of its habitat use, our results suggest that the tree cover is important for the species.

The PET is certainly an important breeding habitat for this and other migratory bird species, offering resources absent in other green spaces in São Paulo (Barbosa *et al.* in prep.). Basic information about a species' ecology, such as home range size and habitat use, provides crucial information to develop effective conservation planning (*e.g.*, Luck 2002, Oppel *et al.* 2004). Our study contributes to improving our understanding on various aspects of the natural history *M. m. solitarius* in an urban area in the Atlantic Rainforest, and highlights the importance of urban green spaces such as the Parque Ecológico do Tietê for the conservation of migratory bird species that breed in the region or stopover during migration.

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SHORT-COMMUNICATION

First nest description of the Azure-shouldered Tanager (*Thraupis cyanoptera*, Thraupidae)

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ABSTRACT: The genus *Thraupis* represents the typical tanagers, and despite the commonness of some species their reproductive aspects are poorly documented. Here we provide the first description of nests and nestlings of the Azure-shouldered Tanager, *Thraupis cyanoptera*, and we provide additional information on eggs. We found three active nests at Carlos Botelho State Park, southeastern Brazil, in September and October 2014, and in November 2016. The nests were built within large tangles of bromeliads, 4.1–5.2 m above ground. They were shallow bottom-supported cups, composed mainly of elongated stripes of dry bromeliad leaves. Eggs were subeliptical, with white background color and small brown spots and blotches evenly distributed throughout the surface. Nestlings had pink skin and gray down, with ocher bill and white swollen flanges. Although more forest-dwelling than other congeners, the Azure-shouldered Tanager seems to tolerate some habitat disturbance, as nests were observed in clearings.

KEY-WORDS: Aves, breeding biology, nesting biology, reproduction, *Tangara*.

The genus *Thraupis* (Thraupidae, subfamily Thraupinae) is composed of seven species of small Neotropical passerines that represent the typical tanagers (Burns *et al.* 2016). They are characterized by discrete plumages, predominantly bluish and olive, and absence of sexual dimorphism in most species (Ridgely & Tudor 1989). They inhabit humid forests or wooded areas, various types of open areas, and even urban environments (Ridgely & Tudor 1989, Hilty 2019). Despite the commonness of some taxa, reproductive aspects are generally poorly documented, although nests and eggs have been well-described except for the Azure-shouldered Tanager, *Thraupis cyanoptera*, the Golden-chevroned Tanager, *Thraupis ornata*, and the Glaucous Tanager, *Thraupis glaucocolpa* (Hilty 2019).

The Azure-shouldered Tanager is endemic to the Atlantic Forest of southeastern Brazil, and can be found from the slopes of Serra do Mar to humid montane forests from southeast Bahia, Minas Gerais and Espírito Santo states, southern to Rio Grande do Sul (Ridgely & Tudor 1989, Hilty 2019). It is more forest-dwelling than some congeners, occurring in forest canopy, but also in borders and secondary growth (Ridgely & Tudor 1989, Naka *et al.* 2002). The only information on the reproductive biology of this species is the description of two eggs as being pale blue with a few round spots of very dark purple color (Ogilvie-Grant 1912), and a mention by Kirwan (2009) that "a nest was being built on a bromeliad epiphyte in a tree about six meters high, to which parents carried grass, and fine and large materials". Here we present the first description of nests and nestlings of the Azure-shouldered Tanager, and we provide additional egg information.

This study was carried out at Carlos Botelho State Park (PECB) (24º06'55''–24º14'41''S; 47º47'18''–48º07'17''W), state of São Paulo, Brazil. The PECB has an area of 37,644 ha, between altitudes of 20–1000 m a.s.l., and vegetation cover is composed predominantly of primary Atlantic Forest. The average rainfall is 1676 mm and average temperature between 18°C and 20°C (Ferraz & Varjabedian 1999). The region where the nests were found had an altitude of 714–837 m a.s.l., in an area in which the vegetation is classified as submontane rainforest (Oliveira-Filho & Fontes 2000).

During 2014/2015 and 2016/2017 breeding seasons we located the nests of the Azure-shouldered Tanager following adult birds when they were carrying material for nest construction or food to attend nestlings (Martin & Geupel 1993). When nests and eggs were found, measurements and photos were taken (Figs. 1 & 2). Eggs and nests were measured with a metal caliper accurate to 0.1 mm, and the eggs were weighed to the nearest 0.1 g using a spring scale. Nest architecture and eggs shape were classified according to Winkler (2004).

During two non-consecutive breeding seasons, we found three nests in the middle of the same large tangle of bromeliads. The epiphytes were agglomerated in the trunk of an approximately 12 m high three, only 6 m from one of the buildings of the Park's administrative facilities (24°03'23''S; 47°59'36''W) (Fig. 1). The first nest was found in 09 September 2014 in construction stage, and on 18 September it contained two eggs. The second nest was found on 18 October 2014 with two nestlings, and the third nest was found on 17 November 2016, with two nestlings in early developmental stage. The first nest was abandoned in incubation stage, and the fate of others nests is unknown.

Nests were shallow cups built mainly of elongated stripes of dry bromeliad leaves, and in a smaller amount other dry leaves. Slender elongated pieces of vines were used in nest rims, and incubatory chamber was lined with finer vegetal fibers, grass leaves, and in one nest black fungal hyphae (Fig. 2A). They were bottom-supported and were placed deep in the middle of the epiphyte tangle, where light exposition was minimal and where they were likely protected from rain. Measurements of the first nest were: outer diameter 15.4 cm, inner diameter 6.7 cm, depth 2.9 cm, height 5.3 cm, and it was 4.4 m above ground. The second nest had an outer diameter of 13.8 cm, inner diameter of 7.2 cm, depth of 4.0 cm, height of 7.6 cm, and it was 5.2 m above ground. The third nest was 4.13 m above the ground, and its measurements were not taken because it was partially destroyed about 20 days later, when we returned to collect the data. In 1 h focal observation during the construction stage of the first nest, adults brought nest materials five times, with both adults carrying and depositing nest materials. The eggs

Figure 1. Nesting sites of the Azure-shouldered Tanager (*Thraupis cyanoptera*, Thraupidae) at Carlos Botelho State Park, state of São Paulo, Brazil. (**A**) Nesting tree and bromeliads overview; (**B**) detailed view of a nesting site within a large bromeliad tangle. Photo author: Daniel F. Perrella.

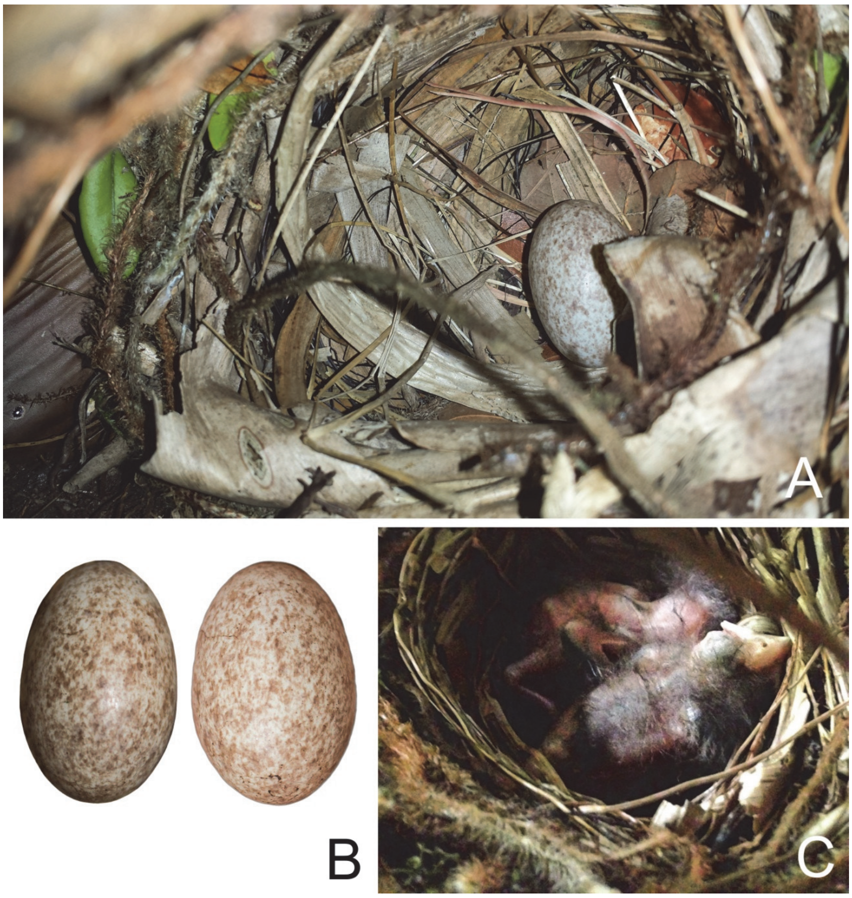

Figure 2. Nest, eggs and nestlings of the Azure-shouldered Tanager (*Thraupis cyanoptera*, Thraupidae). (**A**) Details on nest material and nest shape; (**B**) eggs shape and markings; (**C**) nestlings in early developmental stage. Nest and egg sizes are presented in the main text. Photo author: Daniel F. Perrella & Michele V. Katayama.

were subeliptical with white background color and small brown spots and blotches that were evenly distributed throughout the egg surface (Fig. 2B). They measured 28.0 × 18.6 mm and 29.9 × 18.2 mm, and both had mass of 4.5 g. The nestlings had pink skin and gray down, with ocher bill and white swollen flanges (Fig. 2C).

The dates in which we found the nests of the Azure-shouldered Tanager fall within the breeding season of other Thraupidae previously studied in southeastern Brazil, including the Burnished-buff Tanager, *Tangara cayana* (September–December, Marini *et al.* 2007), the Red-crested Finch, *Coryphospingus cucullatus* (October–February, Zima & Francisco 2016), and the Grassland-yellow Finch, *Sicalis luteola* (October–February, Freitas & Francisco 2012). In all these cases, nesting activities started at the end of the dry season in the region.

The cup-shaped nests of the Azure-shouldered Tanager, with nest walls constructed mainly of elongated pieces of dry leaves followed the general pattern found for other congeners, *i.e.*, the Palm Tanager, *Thraupis palmarum* (Mitchell 1957, Isler & Isler 1999), the Blue-gray Tanager, *Thraupis episcopus* (Skutch 1954), the Yellow-winged Tanager, *Thraupis abbas* (Edwards & Tashian 1959, Isler & Isler 1999), and the Sayaca Tanager, *Thraupis sayaca* (Almeida *et al.* 2012, de la Peña 2016). However, available descriptions suggest that materials used in nest lining and other materials used in nest walls in smaller amounts can vary within the group, and also probably within species, as black fungal hyphaes were found in the incubatory chamber of only one of the three nests found. Notably, at least Blue-gray and Sayaca Tanagers use spider webs to bound nest material together (Skutch 1954, M.R.F., pers. obs.), which we did not observe for the Azure-shouldered Tanager.

The white egg background color and the high density of brown markings do not match the egg descriptions previously provided by Ogilvie-Grant (1912) that eggs were pale blue with a few round spots of very dark purple color. As we observed eggs from only one nest, it is to be confirmed if this incongruence represents possible intraspecific egg color variations. In the Sayaca Tanager, for instance, egg background color can indeed vary from white to bluish green (M.R.F., pers. obs.). Within the genus *Thraupis* relevant variations can also be found in nest placement. While we observed the nests of the Azure-shouldered Tanager inside bromeliads, the Palm Tanager often build nests in the basis of palm leaves (Mitchell 1957, Isler & Isler 1999), and Blue-gray (Skutch 1954) and Yellow-winged Tanagers (Edwards & Tashian 1959) can build their nests both in palm leaves or in bifurcations of shrubs or trees.

Although reported as more forest-dependent than other congeners (Ridgely & Tudor 1989), the Azure-shouldered Tanager seem to support some levels of habitat disturbance as nests were observed in anthropic clearings (present study) and even in urban areas from coastal cities (Kirwan 2009). We are unaware about how dependent the Azure-shouldered Tanager is from large bromeliads to build their nests, but available data suggest that keeping this type of vegetation may contribute with the persistence of this species in disturbed habitats.

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SHORT-COMMUNICATION

Waterbirds catch and release a poisonous fish at a mudflat in southeastern Australia

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ABSTRACT: Several waterbird species prey on fishes, and usually use only one sensory mode to detect this prey: herons hunt visually guided, whereas ibises mostly search tactilely guided. I report herein events in which a heron and an ibis caught and released a poisonous fish at a mudflat in southeastern Australia. A Great Egret (*Ardea alba*) that targeted small gerreid fishes caught and immediately released the very toxic pufferfish *Tetractenos hamiltoni*, with bill washing and discomfort movements afterwards. Two Australian White Ibises (*Threskiornis molucca*) that probed for bottom-dwelling fishes and crabs caught and handled these pufferfishes for about 60 s, before releasing them. Next, the birds dipped the bill in the water and resumed hunting. Pufferfishes are rarely preyed on by birds, but an Australian bird that feeds on this fish type is the Silver Gull (*Chroicocephalus novaehollandiae*), which eats the pufferfish *Torquigener pleurogramma* when it is nontoxic or less harmful.

KEY-WORDS: *Ardea alba*, fishing, prey handling, *Tetractenos hamiltoni*, *Threskiornis molucca*.

Several waterbird species habitually prey on fishes, and mostly use only one sensory mode to detect this prey type. For instance, herons and cormorants hunt their prey guided visually, whereas ibises and spoonbills usually search for their prey guided tactilely (Kushlan 1976 & 1977, Recher *et al.* 1983, Swennen & Yu 2004 & 2008, White *et al.* 2007, Heath *et al.* 2009, Murray & Shaw 2009). Fish species hunted by herons and ibises vary greatly, but pufferfishes are an uncommon prey of fish-eating birds (Wodzinsky & Moreland 1966, Recher & Recher 1968), likely due to powerful toxins secreted by most pufferfish species and their ability to inflate the body (Whitley 1953, Burklew & Morton 1971, Wainwright & Turingan 1997, Isbister *et al.* 2002, Oliveira *et al.* 2003). I report herein three episodes of a very poisonous pufferfish caught and released by a heron and an ibis species at a mudflat (tide-influenced marsh) in southeastern Australia.

I observed the three catch and release events at the mudflat (33°50'18''S; 151°04'47''E; 2 m a.s.l.) of the Waterbird Refuge wetlands at the Sydney Olympic Park in the urban area of Sydney, New South Wales, southeastern Australia. At the observation site the mudflat is connected to the Parramatta River estuary and is influenced by the tidal regime of the river. Besides the heron and the ibis, other diurnal fish-eating waterbird species (three herons, three cormorants, one spoonbill, and one gull) used the site or closely adjacent areas to forage. As hunting episodes generally are fortuitous and brief, the three events were opportunistically observed with bare eye or through a 70–300 mm telephoto lens mounted on a SLR camera from a distance of about 3–8 m. Throughout the observational sessions, I used the *ad libitum* and sequence samplings (Altmann 1974), which are adequate to record fortuitous or rare events. Voucher digital photographs are on file at the Museu de Zoologia da Universidade Estadual de Campinas (ZUEC).

On 11 January 2019 at mid-morning, I observed a Great Egret (*Ardea alba*) precisely and successfully striking at juvenile gerreid fishes called Common Silverbiddy (*Gerres subfasciatus*) in the receding tide, when it caught and immediately released a poisonous pufferfish locally named Common Toadfish (*Tetractenos hamiltoni*). Afterwards, the heron washed the bill twice (Fig. 1A) and displayed repeated signs of discomfort: it opened and closed the bill, and shook the head. After about 2–3 min, the egret resumed hunting at the same place. The pufferfishes are very common at the study site, where they move and forage solitarily or in groups of up to about 20–30 individuals and often approach or join the Silverbiddy groups (Fig. 1B).

On 08 February 2019 at late morning, I observed an Australian White Ibis (*Threskiornis molucca*) walking slowly, probing in the then murky water and preying on bottom-dwelling fishes and crabs, when it caught a Common Toadfish (Fig. 2A). The bird handled the

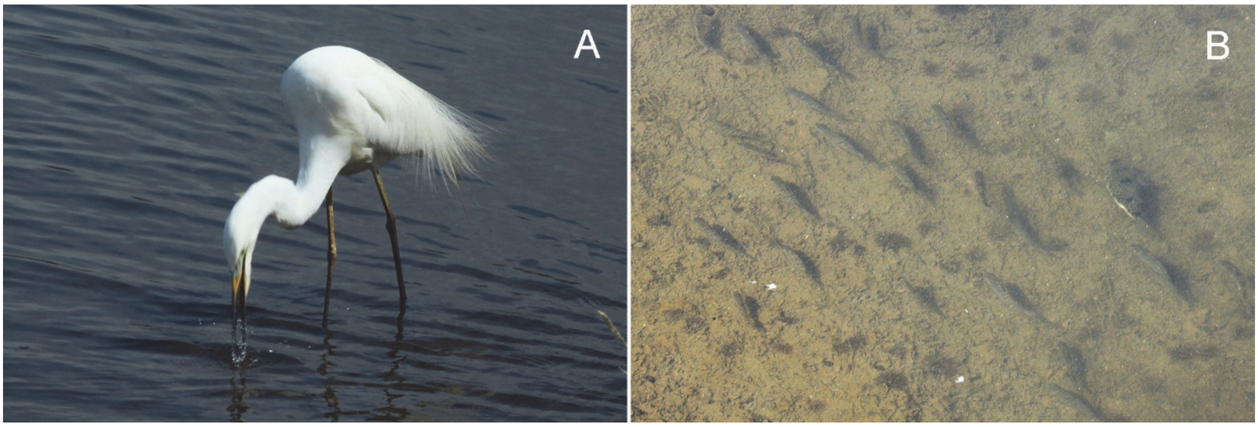

Figure 1. While targeting juvenile Common Silverbiddy (*Gerres subfasciatus*) as prey, a Great Egret (*Ardea alba*) washes bill after it caught and immediately released a pufferfish (*Tetractenos hamiltoni*) in the receding tidal current (**A**). A group of juvenile Common Silverbiddy moves against the receding tide, the pufferfish *T. hamiltoni* (outermost spotted fish at right) joining the group (**B**).

Figure 2. An Australian White Ibis (*Threskiornis molucca*) holds a pufferfish (*Tetractenos hamiltoni*) it caught while probing in muddy water (**A**). The ibis releases the pufferfish after handling it for about 60 s (**B**).

pufferfish for about 60 s, and from time to time it made 2–3 lateral movements with its bill in the water before releasing the fish (Fig. 2B). After the pufferfish release, the bird dipped the bill in the water once and resumed hunting. On 18 November 2018 near midday I observed another ibis that caught and released a toadfish, but I had no the same advantageous view as in the description above. However, I noticed that after catching the pufferfish the ibis handled it for about 60 s and appeared to "cleanse" the fish thoroughly with lateral movements of the bill in the water. After this handling the bird released the pufferfish, dipped the bill in the water and resumed hunting.

The three episodes reported herein indicate that the pufferfish *T. hamiltoni* is an unsuitable and potentially dangerous prey for at least a heron and an ibis species at the studied wetlands, and I think that this assumption may be extended to other heron species, the spoonbill, and the gull as well. The observed Great Egret individual hunted the Common Silverbiddy juveniles with precise visually-oriented strikes, and it likely caught the pufferfish by mistake: an individual of the latter could have intercepted the heron's strikes at the targeted prey, as the two fish species sometimes mingle (present study). The immediate release of the pufferfish and the ensuing bill washing plus the discomfort movements of the egret may be related to the fact that several chemical compounds are aversive to birds and the avoidance reaction occurs at the first contact (Clark *et al.* 2014). On the other hand, the observed ibises were hunting with tactile-oriented shallow probing (*sensu* Kushlan 1977) in murky water and they caught the pufferfishes possibly without recognizing them immediately as an unpalatable and potentially dangerous prey. A possible explanation for the birds handling the fishes for a while before releasing them would be that the ibis is less sensitive than the heron to the pufferfish poisonous secretion, or that its gustatory sense is less developed than that of the heron (Birkhead 2013, Clark *et al.* 2014), but this remains speculative and needs testing. However, the mere bill dipping in the water before the ibises resumed hunting may lend some support to this suggestion.

Fish-eating birds rarely prey on pufferfishes and when they do, the prey is either small, mildly toxic or nontoxic, or taken sporadically or in very small numbers (*e.g.*, Wodzinski & Moreland 1966, Recher & Recher 1968, Hensley & Hensley 1995, McGrouther 2019). Additionally, toxicity varies between pufferfish genera (Oliveira *et al.* 2003) and some species within the same genus, *e.g.*, *Sphoeroides*, may vary from extremely toxic to completely nontoxic (Burklew & Morton 1971).

An Australian fish-eating bird that forages on a pufferfish species is the Silver Gull (*Chroicocephalus novaehollandiae*) that eats the Weeping Toadfish (*Torquigener pleurogramma*) when it is nontoxic or less harmful, as this fish seems to be hazardous only when its gonads are enlarged (McGrouther 2019). An additional or alternative explanation would be that the Silver Gull possibly tolerate toxins (or toxin levels) that could be unpalatable or dangerous to other bird species. However, I have observed that *T. hamiltoni* discarded by fishermen on jetties near the study site were not eaten by any Silver Gull from groups of 5–20 individuals that lingered there waiting for a morsel such as fish offal or a discarded catch. A few birds inspected the pufferfishes, pecked at them or pinched them once and lost interest on this potential food afterwards. These observations lend support to my assumption that *T. hamiltoni* is hazardous for fish-eating birds in general. The toxin of this pufferfish have caused severe illness and even human deaths (Whitley 1953, Isbister *et al.* 2002), and it seems reasonable to assume that it would kill birds as well.

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Hybridization between Yellow-billed Cardinal *Paroaria capitata* and Red-crested Cardinal *P. coronata* in southern Argentina

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ABSTRACT: The genus *Paroaria* is a group of conspicuous songbirds widely distributed in South America that has been studied recently to delimit its species and establish their phylogenetic relationships. Although hybridization has been reported between the most phylogenetically related species of the genus, we here present a case of hybridization between the Yellow-billed Cardinal (*P. capitata*) and Red-crested Cardinal (*P. coronata*) for the first time, two phylogenetically unrelated members of the group. This data contributes to the knowledge of this avian group whose systematics is still under debate.

KEY-WORDS: breeding biology, hybrids, interbreed, Neotropical birds, Patagonia

Species delimitation has been a crucial topic in the natural history of birds, both for systematic and ecological studies (de Queiroz 2007). Systematic studies on the genus *Paroaria*, a group of conspicuous songbirds widely distributed in South America (Jaramillo 2011), indicate that it comprises six to eight species splitted into two ecological groups: the riparian species (*P. gularis*, *P. baeri*, *P. xinguensis*, *P. capitata*, *P. cervicalis* and *P. nigrogenis*) and the open-forest species (*P. coronata* and *P. dominicana*) (Dávalos & Porzecanski 2009). Estimated divergence times range from 3.7 to 5.0 mya for the split between the open-forest *vs.* riparian clades, which has led them to show at present both morphological (Jaramillo 2011) and genetic (Dávalos & Porzecanski 2009, Areta *et al.* 2017) differences. During the last decades, it has been reported some natural hybridization between species of this genus, for example between *P. baeri* and *P. gularis* (Jaramillo 2011, Lopes & Gonzaga 2013, Areta *et al.* 2017), two non-sister species but still phylogenetically close "riverines" (Dávalos & Porzecanski 2009). However, in captivity conditions, hybridization has also been reported among less related *Paroaria* species (*P. dominicana* and *P. nigrogenis*, two genetically distant species; McCarthy 2006) and even with species of other genera and even families (*P. coronata* with *Sicalis flaveola*, *Gubernatrix cristata*, *Cardinalis cardinalis*, *Chrysomus ruficapillus* and *Molothrus bonariensis*; McCarthy 2006). In this contribution, we present the first record of natural hybridization between Yellow-billed and Red-crested Cardinal (a riverine and an open-forest cardinal respectively, two phylogenetically distant species in *Paroaria*).

This study was conducted at Viedma, Río Negro province, northeastern Patagonia, Argentina (40°48'S; 63°01'W; Fig. 1). The study area is representative of the "Monte" ecoregion (Brown *et al.* 2006), with large areas of native xerophytic vegetation altered by extensive and low-density cattle grazing. This region is characterized by warm summers (maximum temperature of 42.3°C) and cold winters (minimum temperature of -13.5°C), with most precipitations occurring between November and March. The National Meteorological Survey of Argentina from 1987–2017 reports mean annual rainfall as 257 mm and mean annual temperature as 15°C. At the local scale, the nesting territory was located on the southern margin of the Negro River, in a wetland dominated by the exotic *Salix viminalis* (Salicaceae). The area was surveyed every 5–8 days, since the first evidence of hybridization, with the help of binoculars and photographic cameras.

In March 2016 (end of 2015–2016 breeding season) we located an interspecific pair moving together in the nesting area (Fig. 2A). We inspected the surroundings shrubs and forests to locate the nest (see details in Segura *et al.* 2015), but we could not find it. On 18 April, we saw both parents with a fledgling for the first time (Fig. 2B & C) and delivering food to it. We observed the family group until the beginning of June, and since then, we

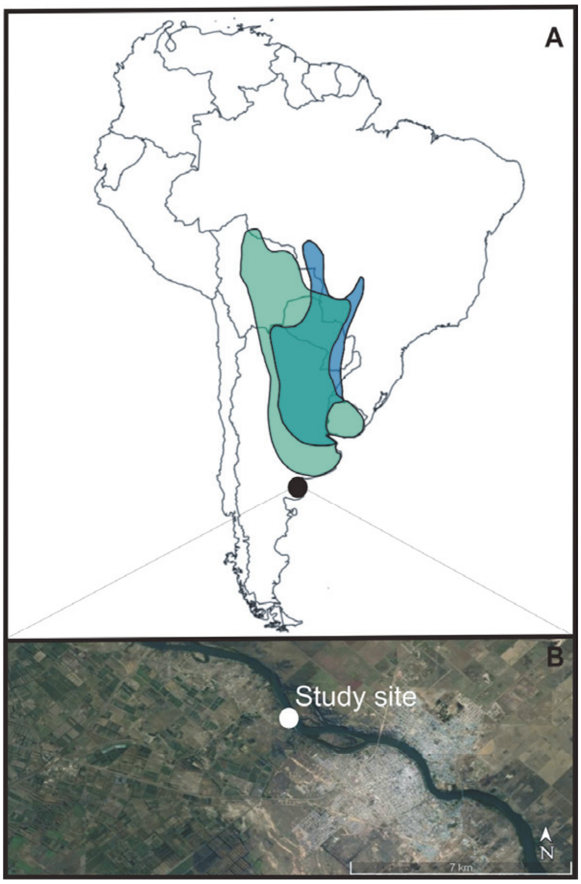

Figure 1. Distribution area of the Yellow-billed Cardinal *Paroaria capitata* (blue shaded) and Red-crested Cardinal *P. coronata* (green shaded) in South America (**A**); Jaramillo 2011). Area surveyed in this study (**B**).

detected only adults throughout the winter, until spring began. The size and plumage of our hybrid juvenile (Fig. 2D) strikingly resembled that of *P. capitata* juveniles (Fig. 2E), although the bill color and tarsus were gray, like *P. coronata*.

In the last decades, individuals of both species have been reported in atypical southern localities in relation to the original distribution (Fig. 1). For example, on web platforms such as EcoRegistros (2018) or eBird (2018), the records of both species in the Negro River (northern Patagonia) and cities in southern Buenos Aires province (central-eastern Argentina) are increasingly frequent. A possible explanation is that both species are traditionally captured and sold in illegal trade in a large fraction of their distribution area (UNEP-WCMC 2009), and the release of individuals from captivity in areas near urban centers would explain this atypical distribution.

The sympatry area between both species is extensive (Fig. 1) and the contact is not recent (Dávalos & Porzecanski 2009, Areta *et al.* 2017). However, no hybrids have been reported within this area. On the one hand, this lack of previous reports could be simply due to an artifact of poor sampling, but considering that both species are conspicuous and relatively common in their respective habitats, it is unlikely that this could be the reason. However, there may be some behavioural or ecological barriers within their sympatry area (Randler 2006) that keep them from hybridizing in a natural way. Although our birds paired and reproduced in natural conditions, we

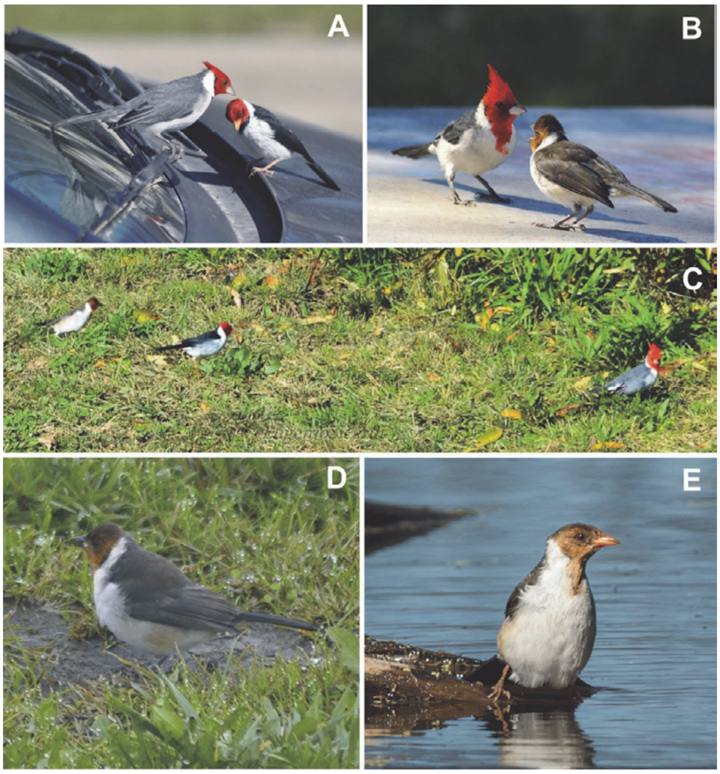

Figure 2. Mixed breeding pair composed by a Yellow-billed Cardinal, *Paroaria capitata*, and a Red-crested Cardinal, *P. coronata* (**A**). Red-crested Cardinal feeding the hybrid fledging (**B**). Familiar group moving together on the ground (**C**). The hybrid fledging (**D**). A pure Yellow-billed fledging (**E**). Photo authors: Graciela Balda (**A**, **B**, **D**), Eugenio Sicardi (**D**), Giselle Mangini (**E**).

do not ignore the particular situation regarding the lack of conspecifics in an unusual austral distribution area for both species, which could have favored the interspecific hybridization (see Baker 1996).

It has been discussed that genetic differences between the related *P. capitata* and *P. cervicalis* (and even *P. gularis*) are so small that cases of hybridization are expected (Dávalos & Porzecanski 2009), but *P. capitata* and *P. coronata* are more divergent (Dávalos & Porzecanski 2009, Areta *et al.* 2017). In this sense, phylogenetic results within *Paroaria* indicate that the mitochondrial gene tree contained a deep split between open-forest (*P. dominicana* and *P. coronata*) and riparian species (all other *Paroaria*). Our results show that, despite this genetic split, they still maintain the ability of interbreeding as an ancestral condition (see Podos & Nowicki 2004).

Even though we cannot infer if the hybrid offspring has post-zygotic barriers to freely interbreed with the parental species, the fact that two genetically distant *Paroaria* may naturally hybridize, as first reported here, may be an additional evidence that tropical bird species, and *Paroaria* species in particular, may hold the potential to mate and interbreed for a very long time after speciation (Weir & Price 2011, Areta *et al.* 2017). The genus *Paroaria*, therefore, may represent an interesting system to further research on the role of hybridization on the evolution and speciation of birds.

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SHORT-COMMUNICATION

First documented record of Cerulean Warbler *Setophaga cerulea* (Parulidae) in Brazil

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ABSTRACT: Cerulean Warbler (*Setophaga cerulea*; Parulidae) is a "Vulnerable" species which breeds in North America and migrates to winter in South America. Here we present the first documented record of the species in Brazil. One male was photographed foraging in the canopy of secondary forest on Santa Catarina island, south Brazil, on 07 April 2018. At the time of the record the species was expected to be on migration north to North America. Since the individual was heading south it is assumed that it was lost. This record can then be potentially explained by the vagrancy theory of reverse migrants.

KEY-WORDS: Atlantic Forest, mariquita-azul, migration, Santa Catarina, vagrancy.

The Cerulean Warbler (*Setophaga cerulea*) is a migratory passerine of the Parulidae family and is listed as "Vulnerable" by the IUCN Red List of Threatened Species (Birdlife International 2016). The species breeds in eastern U.S.A. and Canada during the northern hemisphere spring and summer. After that it migrates south to winter on the eastern slopes of the Andes, from southern Colombia and Venezuela to Ecuador, southeastern Peru and northern Bolivia (Skolnik *et al.* 2012). On its way to South America it is a passage migrant through the Atlantic coast of Central America. In its wintering area individuals have most often been observed within a narrow elevation range of 500–2000 m (Robbins *et al.* 1992).

To date, Cerulean Warbler was included on the secondary list of Brazilian birds based on two visual records, which were without supporting physical evidence (Piacentini *et al.* 2015). These two previous undocumented records were on October 1980, in Serra do Tinguá, Rio de Janeiro state, southeastern Brazil, at 330 m a.s.l. (Scott & Brooke 1985); and during fieldwork in Monte Belo, Minas Gerais state, southeastern Brazil, with no precise date, but between 1981 and 1986 (Pacheco *et al.* 2014).

Here we present the first documented record of Cerulean Warbler for Brazil (Fig. 1). One adult male was seen actively foraging between the leaves of an Inga tree (*Inga* sp.) on 07 April 2018 in a forest patch at the Parque Natural Municipal do Maciço da Costeira, Florianópolis, Santa Catarina (27°38'45.61''S; 48°29'29.75''W; Fig. 2). The individual was observed foraging between 9:40 and 10:00 h. The foraging mode observed was foliage gleaning, which is regularly observed for the species in North America (Jones *et al.* 2000). Repeated visits to the same location for several days following the first record failed to relocate the species.

The forest fragment where the species was recorded is a patch of secondary forest located behind a quarry in the south of Santa Catarina island. The individual was emitting some calls spontaneously but did not react to playback of the species. The lack of vocal response is an indicative that the individual was not defending a territory (Catchpole & Slater 2003), which was expected since this is a non-breeding area for the species and also out of the reproductive season.

Our record represents not only the first documented record in Brazil, but the most austral one. The recorded individual can be considered as a vagrant as it was outside its regular migratory route (Veit 2000). This is similar for other records of North American warblers found in Brazil (Deconto & Vallejos 2017, Somenzari *et al.* 2018). At the time of record the individual was expected to be returning to North America, but it is postulated it was heading in the opposite direction. This is the second case of a North American warbler recorded in Santa Catarina at a time when they are found in North America (Garcia 2016). Considering these aspects, our conclusion is that these records can be explained by the vagrancy theory of reverse migrants (Gilroy & Lees 2003), in which birds deviate by around 180 degrees of their route, thus going in the opposite direction than expected (Alerstam 1990).

Figure 1. Adult male Cerulean Warbler (*Setophaga cerulea*) perched on a branch of an Inga tree, photographed on 07 April 2018 in Florianópolis, Santa Catarina, Brazil. Photo author: Fernando B. de Farias.

Figure 2. Winter distribution of the Cerulean Warbler (*Setophaga cerulea*; green area) with the two undocumented records in southeastern Brazil (blue dots) and the new record in Santa Catarina, southern Brazil (red star). Adapted from Birdlife International.

Also, our finding reinforces the importance of maintaining monitoring efforts even in urban forest fragments and especially in poorly-sampled areas. Records such as the one reported here are useful to adding information to our understanding of vagrancy theories (Gilroy & Lees 2003) and identifying the paths and deviations of bird migration.

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SHORT-COMMUNICATION

Distribution extension of the Spectacled Petrel (*Procellaria conspicillata*) off the Argentine continental shelf and oceanic adjacent waters

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ABSTRACT: The Spectacled Petrel *Procellaria conspicillata* is endemic of the Tristan da Cunha Archipelago, in the South Atlantic Ocean. However, it is scarcely detected in waters off Argentina beyond its traditional distribution along the southwest Atlantic during the breeding season. This study compiles distributional records of Spectacled Petrel for the target area (chiefly between 38°S to 46°S and 23°W to 57°W) obtained in situ, from non-systematic observations at sea, between 2015 and 2018 (totaling 4 trips); and by literature review. Nineteen new sightings of the species are presented. In 46 sightings a total of 65 individuals were recorded chiefly within waters of the Argentine continental shelf (< 200 m) (46%) and oceanic adjacent waters (54%). The bulk of the sightings (95%) were obtained during the species breeding season. In addition, we report the southernmost record of the species in oceanic waters for the southwest Atlantic (46°10'S; 57°06'W).

KEY-WORDS: breeding season, endemic, *Procellaria* petrels, range extension, southwest Atlantic.

The Spectacled Petrel (*Procellaria conspicillata*) disperses in the South Atlantic Ocean, from the north of Brazil to Argentina and off the western coast of southern Africa (Enticott & O'Connell 1985). It is considered a vagrant to the Indian Ocean, where it has been reported in the vicinity of Amsterdam Island and Australia (Onley & Scofield 2007, Shirihai 2008). The species is endemic of Inaccessible Island in the Tristan da Cunha Archipelago (Enticott & O'Connell 1985, Ryan 1998, Ryan & Moloney 2000). Its breeding season begins in September, with egg-laying in late October, hatching in mid-December, and fledging of chicks in early March (Ryan & Moloney 2000, Ryan *et al.* 2006).

The total breeding population of Spectacled Petrel was estimated to be approximately 10,000 pairs in the 2004/2005 breeding season (Ryan *et al.* 2006). However, recent studies updated its population estimate to 14,400 breeding pairs (Ryan & Ronconi 2011). During 19th and early 20th Centuries the species was threatened by the egg predation by wild pigs (Ryan 1998, Ryan *et al.* 2006), which has led to a significant reduction in the population (Ryan *et al.* 2006), with a lowest estimate of a few tens of pairs in 1937 (Hagen 1952). However, breeding birds are still affected, to a lesser extent, by heavy rains on their nesting colonies (Ryan *et al.* 2006). Currently, the Spectacled Petrels are threatened mainly by the increased mortality associated with longline fishing vessels, chiefly in waters where they overlap with Brazilian fisheries fleet (Olmos 1997, 2001, Bugoni *et al.* 2009, Branco *et al.* 2014). The species is listed as "Vulnerable" by the International Union for the Conservation of Nature (IUCN) (BirdLife International 2018) due to its small breeding range and its susceptibility to stochastic events and human activities (ACAP 2018).

During the breeding season, the species feeds mainly in areas adjacent to Inaccessible Island, notably on the Walvis Chain, and moving further south on the continental shelf of South Africa up to 41°S near the Agulhas Bank (Enticott & O'Connell 1985, Camphuysen 2001). However, recent studies conducted with satellite transmitters showed the Patagonian shelf off Argentina as a feeding site by at least some tracked individuals (Reid *et al.* 2014). Previous platform-of-opportunity based studies of the at-sea distribution of the Spectacled Petrel revealed that breeding individuals regularly attend waters of the southwestern sector of the Atlantic Ocean, including the Argentine continental shelf (< 200 m depth) and adjacent oceanic areas (Imberti 2002, Savigny 2002, White *et al.* 2002, Black *et al.* 2005, Morrison & Henry 2006, Ginsburg & DeWitt 2013, Chavez *et al.* 2014, Seco-Pon

& Stein-III 2015, Quiñones & Imberti 2018).

This study updates the information on the Spectacled Petrel distribution in the Argentine continental shelf region and adjacent oceanic waters during the species' breeding season.

Sightings were accomplished opportunistically aboard different vessels performing distinct activities and routes within the Argentine continental shelf region and adjacent oceanic waters (see Table 1 for details). The range of activities and routes of these vessels include (1) tourism in southern Patagonia, the Antarctic Peninsula and the Malvinas/Falkland Islands (three trips), and (2) commercial seismic surveys in adjacent oceanic waters within the Argentine Basin (one trip). The sightings were made during the austral summer (January–February), from 2015 to 2018. For each sighting, the sea state (measured on the Beaufort scale) and wind intensity (in knots) were registered.

Table 1. Summary of extant and recent sighting records of the Spectacled Petrel (*Procellaria conspicillata*) in waters of the southwest Atlantic off Argentina and oceanic adjacent waters, 2002–2018. F = flying, E = eating, S = sitting on the water, n.r. = not reported.

Date (dd/mm/yyyy)	Location	No. of birds	Behavior	Source
09/02/2000	48°47'S; 62°21'W	3	S	Savigny 2002
03/2000	50°20'S; 57°41'W	1	n.r.	White *et al.* 2002
12/1996	54°23'S; 55°45'W	1	n.r.	White *et al.* 2002
13/03/2000	46°14'S; 59°11'W	1	n.r.	Imberti 2002
13/03/2000	45°28'S; 58°54'W	1	n.r.	Imberti 2002
14/03/2000	41°44'S; 57°36'W	2	n.r.	Imberti 2002
14/02/2004	n.r.	1	n.r.	Black *et al.* 2005
29/03/2006	n.r.	1	n.r.	Morrison & Henry 2006
03/02/2013	38°11'S; 54°55'W	1	F	Ginsburg & DeWitt 2013
13/02/2014	38°55'S; 56°00'W	3	F	Seco-Pon & Stein-III 2015
18/01/2016	38°25'S; 54°48'W	9	S,E	Quiñones & Imberti 2018
24/02/2008	38°47'S; 55°44'W	1	F	Chavez *et al.* 2014
27/02/2008	38°46'S; 55°44'W	1	F	Chavez *et al.* 2014
04/03/2008	38°39'S; 55°41'W	2	F	Chavez *et al.* 2014
09/03/2008	39°03'S; 55°52'W	1	F	Chavez *et al.* 2014
13/03/2008	39°02'S; 55°53'W	1	F	Chavez *et al.* 2014
15/03/2008	39°00'S, 55°53'W	1	F	Chavez *et al.* 2014
19/03/2008	39°04'S; 55°51'W	1	F	Chavez *et al.* 2014
10/04/2010	36°26'S; 54°09'W	1	S	Chavez *et al.* 2014
30/01/2012	44°20'S; 61°15'W	1	S,E	Chavez *et al.* 2014
24/02/2013	43°49'S; 59°46'W	1	F	Chavez *et al.* 2014
25/02/2013	43°39'S; 59°41'W	1	F	Chavez *et al.* 2014
26/02/2013	43°34'S; 59°33'W	1	F	Chavez *et al.* 2014
27/02/2013	43°27'S; 59°40'W	1	F	Chavez *et al.* 2014
01/03/2013	42°01'S; 58°33'W	1	F	Chavez *et al.* 2014
19/11/2013	34°32'S; 52°25'W	2	F	Chavez *et al.* 2014
28/05/2014	42°06'S; 58°15'W	1	S	Chavez *et al.* 2014
15/01/2015	39°13'S; 56°08'W	1	F	Present study
11/01/2016	39°29'S; 53°35'W	1	F	Present study
09/01/2017	38°28'S; 53°53'W	2	F	Present study
08/01/2018	42°58'S; 56°47'W	1	F	Present study
08/01/2018	42°59'S; 56°43'W	1	F	Present study
09/01/2018	42°58'S; 56°45'W	1	F	Present study

Date (dd/mm/yyyy)	Location	No. of birds	Behavior	Source
09/01/2018	42°57'S; 56°46'W	1	S	Present study
09/01/2018	43°20'S; 56°34'W	2	S	Present study
11/01/2018	43°05'S; 56°04'W	1	F	Present study
11/01/2018	43°05'S; 56°17'W	1	F	Present study
18/01/2018	44°22'S; 57°05'W	1	F	Present study
19/01/2018	46°10'S; 57°06'W	2	F	Present study
24/01/2018	43°13'S; 56°23'W	1	F	Present study
30/01/2018	42°57'S; 55°48'W	1	F	Present study
30/01/2018	43°13'S; 56°20'W	1	F	Present study
31/01/2018	43°21'S; 55°51'W	1	F	Present study
31/01/2018	43°05'S; 55°15'W	2	F	Present study
01/02/2018	43°18'S; 55°50'W	1	F	Present study
01/02/2018	43°11'S; 56°29'W	1	F	Present study

The bulk of the sightings included single individuals (79%), flying at a minimum distance of 200 m from the stern of the ship (Figs. 1 & 2). Few sightings (n = 2) consisted of individuals recorded either floating and/or actively feeding. Nineteen sightings encompassing up to 23 individuals were made from the vessels (Table 1), mainly between 38°S to 46°S and 23°W to 57°W. Overall (pooled) sightings occurred on the shelf-break and the continental shelf, mainly at depths ranging from 84 m to 6280 m (Fig. 1). The closest position of a Spectacled Petrel sighting from the South American continent was about 95 nautical miles (175 km) SE off Mar del Plata, Argentina. At the time of the sightings, sea state (measured on the Beaufort scale) varied between 2 and 6, and wind speed between 11.7 kt and 29 kt. On some occasions (~5% of total sightings) the species was observed in assemblages together with other seabirds, chiefly the White-chinned Petrel (*P. aequinoctialis*) and the Great Shearwater (*Ardenna gravis*) (tourism and seismic observations combined).

The compilation of previous records and the updated information presented here (Fig. 1 & Table 1) clearly denote the use by the Spectacled Petrel, at least by some individuals, of the Argentine continental shelf and adjacent oceanic waters. They were recorded over 2000 nm (3700 km) from its breeding area and more than 1080 nm (2000 km) from the main area used by the species during the breeding season. Previous studies indicated that breeding adults concentrate their feeding activities along the mid-Atlantic ridge and along the continental shelf edge between 25–40°S, with 50% of the feeding activities occurring around 500 km from their colony (Reid *et al.* 2014). Despite those findings, sightings of

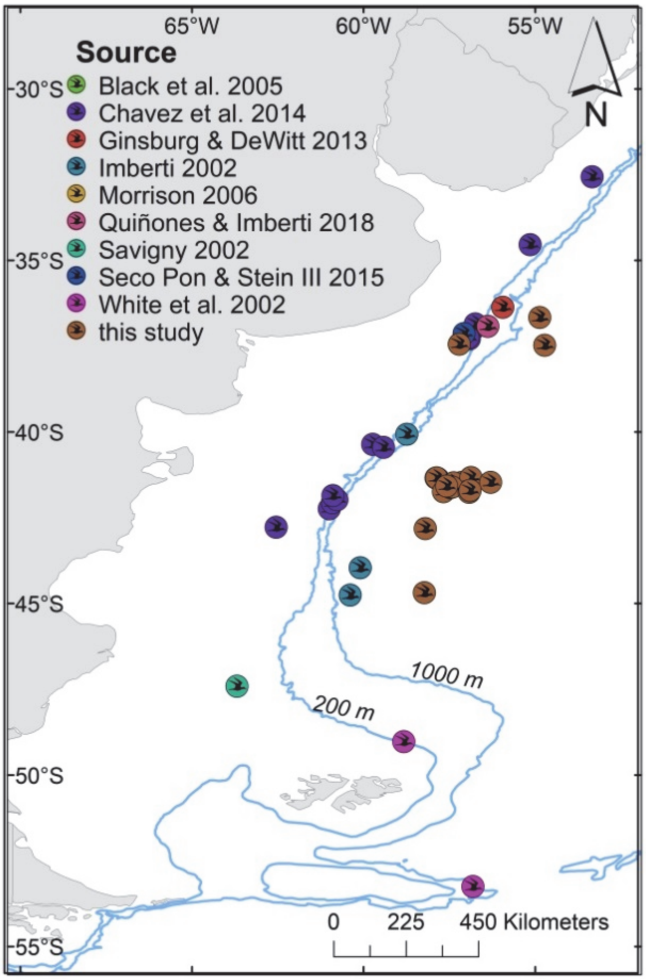

Figure 1. Distribution of sightings of Spectacled Petrels (*Procellaria conspicillata*) in the Argentine continental shelf and adjacent oceanic waters for the period 2002–2018, based in literature review and records from this study. Continuous lines represent the 200 m and 1000 m depth isobaths.

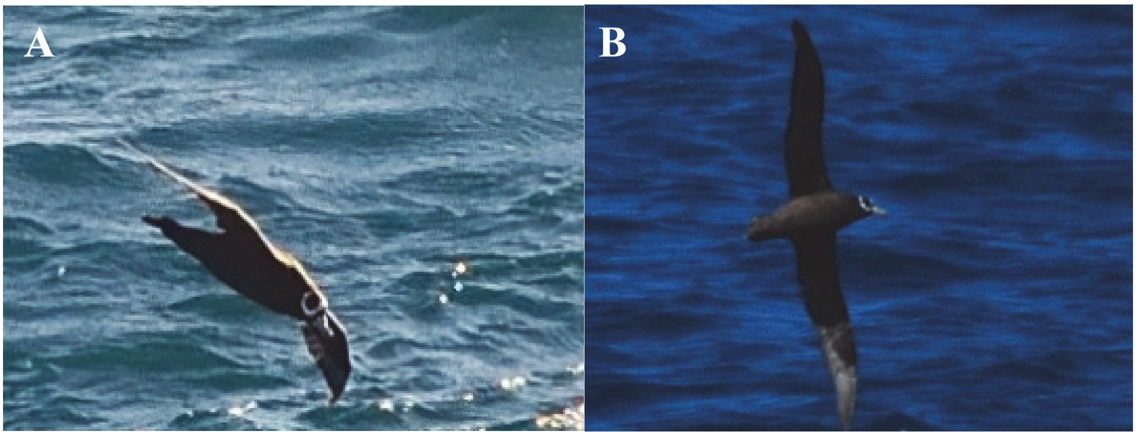

Figure 2. Spectacled Petrels (*Procellaria conspicillata*) sighted in (**A**) Argentine continental shelf waters on 15 January 2015 (39°13'S; 56°08'W); and (**B**) in adjacent oceanic waters off Argentine shelf on 31 January 2018 (43°05'S; 55°15'W). Photo author: J.P. Seco Pon (**A**), M. Hernandez (**B**).

the species in the Patagonian shelf waters off Argentina were expected as Reid *et al.* (2014) also revealed the use of this area as a feeding site by at least some individuals. Outside the breeding season, the species is found in deeper waters (> 3000 m depth) and shelf edges (1000–3000 m depth) (Bugoni *et al.* 2009). The main wintering area of this species occurs along the Brazilian continental shelf between São Paulo and Rio Grande do Sul states, in south-southeastern Brazil (Bugoni *et al.* 2009).

The presence of birds recorded in Argentine waters and adjacent oceanic waters could be due to the propensity of some individuals to attend commercial fishing activities, as is the case of the Spectacled Petrels recorded by Chavez *et al.* (2014) and Seco-Pon *et al.* (2017). Still, no bycatch of the species has been recorded so far in fisheries operating within the Argentine Economic Exclusive Zone (Seco-Pon *et al.* 2015). Other confirmed records of Spectacled Petrels interacting with fisheries in the region were obtained in Uruguay (Jiménez & Domingo 2007, Jiménez *et al.* 2011) and southern Brazil (Olmos 1997, Bugoni *et al.* 2009, Branco *et al.* 2014). There, the species is bycaught in longline fisheries at a rate estimated at 0.005 birds/1000 hooks and 0.008 birds/1000 hooks in pelagic longline fishing vessels operating off Uruguay and Brazil, respectively (Jiménez & Domingo 2007, Bugoni *et al.* 2008).

The paucity of Spectacled Petrel records from Argentine waters may be due to a combination of the relatively low numbers of individuals present in the waters off Argentina during the breeding season as revealed by the literature review presented here or to the lack of personnel trained to identify them. Given that fisheries remain the main threat posed to this species (ACAP 2018), it is of great importance to increase the sampling effort to better understand the distribution and abundance of this species in the Patagonian shelf region and its interaction with human activities.

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SHORT-COMMUNICATION

First record of Grey Gull *Leucophaeus modestus* in Brazil

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ABSTRACT: We report the first record of Grey Gull (*Leucophaeus modestus*) in Brazil. On 21 April 2019 at 08:31 h, the second-cycle bird was photographed walking near a small stream that flows into the sea on Ilha Comprida, state of São Paulo, southeastern coast of Brazil. The occurrence of a single individual on the Atlantic coast of the South American continent lead us to propose that the species is a vagrant in Brazil.

KEY-WORDS: beach monitoring, Ilha Comprida, Lariidae, new record, vagrant species.

Grey Gull *Leucophaeus modestus* has a restricted distribution to the western region of Central and South America, occurring in Ecuador (Mills 1967, Santander *et al.* 2013), Peru (Hughes 1968, Pulldo *et al.* 1996, Valega 2007) and Chile (Barros *et al.* 2015). There are also occasional records in Costa Rica (Sandoval & Sánchez 2012), Argentina (Carrillo 2015) and Colombia (Estela *et al.* 2010). In the Atlantic portion of the American Continent its occurrence is sporadic, with records on Falkland Islands in 1953 and 1991 (Carrillo 2015).

Grey Gull is commonly found in coastal areas, foraging directly on the sea surface (Duffy 1980) or along the shoreline (Howell *et al.* 1974). During the breeding period it moves inland, nesting in a distant desert region in Chile, up to 100 km from the coast (Erize *et al.* 2006). It is one of the few bird species adapted to nest in the Atacama Desert (Chile), considered the world's driest environment (Aguilar *et al.* 2012). The species' nesting site was described only in 1943 by Goodall & Johnson (1945) in a desert area in the province of Antofagasta (Chile), answering one of the major questions on the species ecology.

There are nine Gull species recorded in Brazil: three resident species, three visitors from the north or south and three vagrant species (Piacentini *et al.* 2015). This article presents the first documented record of Grey Gull for the Brazilian territory.

During daily monitoring of beaches performed by *Instituto de Pesquisas Cananéia* for *Projeto de Monitoramento de Praias – Bacia de Santos* (PMP-BS), which covers the coasts of the states of São Paulo, Paraná and Santa Catarina, the bird was first recorded on 21 April 2019 at 08:31 h. It was observed walking on the beach at the northern portion of Ilha Comprida (24°42'27.8''S; 47°28'16.8''W), on the southern coast of the state of São Paulo, southeastern Brazil (Fig. 1). Faced with the researchers' approach, the bird had difficulties to fly, trying to run away. The bird was detected during three other consecutive days, moving to the south (5 km away from the first location).

This is a second-cycle bird, since it was gray with brownish shades (Figs. 2A & B), differing from adults with grayish plumage, whose head is whitish during the reproductive period (Harrison 1983). Another characteristic that proves this bird to be second-cycle is the end of the secondary feathers presenting a white band (Harrison 1983). Other diagnostic characteristics contributed to the species identification, such as the beak, feet, tarsus and black end of wings contrasting with gray plumage, as well as the previously mentioned white band at the end of the secondary feathers, which is absent in young birds (Harrison 1983, Erize *et al.* 2006; Fig. 2C).

The occurrence of Grey Gull in the Brazilian coast can be interpreted as an occasional event, due to the absence of previous records and the fact that the species is typical of the western part of the continent, occurring mainly in Chile, Peru and Ecuador (BirdLife International 2019). The bird observed probably hit the Atlantic coastline in one of two main ways: moving inland though the continent, or bordering the coast.

The first hypothesis is supported by the fact that the species reproduces in desert areas in the interior of Chile (Barros *et al.* 2015), approximately 2000 km distant, in a straight line, from the coast of São Paulo. However,

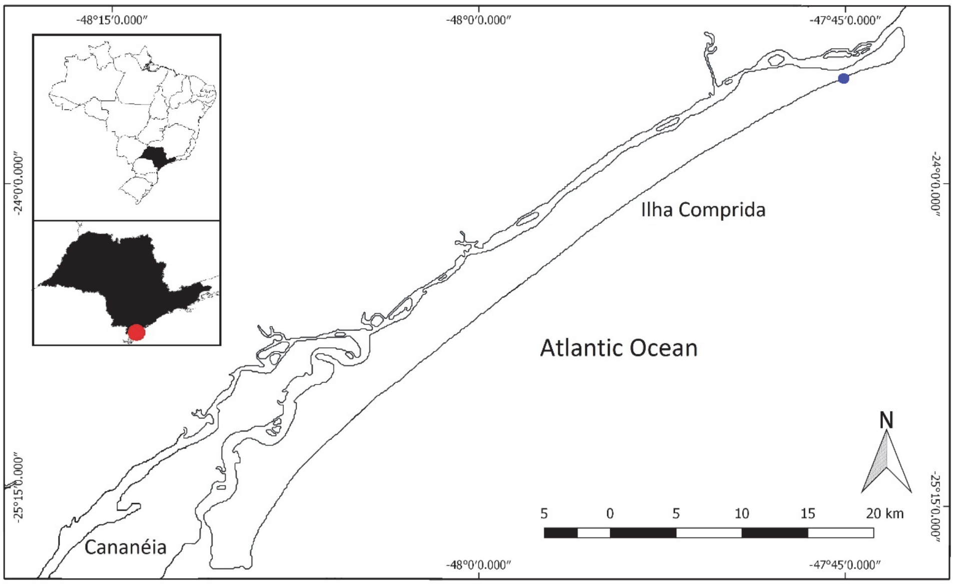

Figure 1. Map of the place where the Grey Gull (*Leucophaeus modestus*) was first registered (blue circle) on Ilha Comprida, state of São Paulo, southeast Brazil.

Figure 2. Grey Gull (*Leucophaeus modestus*) registered on Ilha Comprida, southeastern Brazil. Detail of gray plumage with brownish shades (**A** & **B**) and white strip on the secondary remnants visible in flight (**C**) that characterized this species. Photo author: Rafael Murro Sardinha (**A** & **B**), Kelly Panssard (**C**).

to do this, the bird would cross the Andes. Goodall & Johnsons (1945) report Grey Gull nesting in altitudes of up to 2335 m and the recent record for Argentina in Salta also supports that the bird can fly up to 4300 m (Carillo 2015). This suggests that the species could fly in high altitudes and consequently surpass the mountain range in its lowest sectors.

The second possible route would be flying along the coast from the south. This is also supported by literature, since Carrillo (2015) cites two records of the species on the Falkland Islands. Thus, the individual may have crossed from the Pacific to the Atlantic Ocean in the southernmost portion of the continent through Argentina and then moved up along the coast to São Paulo.

Within the Lariidae family, species recorded in Brazil such as Sabine's Gull (*Xema sabini*, Lees *et al.* 2014), Laughing Gull (*Leucophaeus atricilla*, Lima *et al.* 2010), Franklin's Gull (*Leucophaeus pipixcan*, Dias *et al.* 2010), Lesser Black-backed Gull (*Larus fuscus*, Girão *et al.* 2006), Olrog's Gull (*Larus atlanticus*, Belton 1984) and Ring-billed Gull (*Larus delawarensis*, Sick 1979) can move to locations far from their breeding areas. These species are considered seasonal visitors (*L. atricilla* and *L. atlanticus*) or vagrant (*X. sabini, L. pipixcan* and *L. fuscus*) in Brazil (Piacentini *et al.* 2015). Thus, Grey Gull would also be considered vagrant, since its record in Brazil is punctual.

We report a relevant record for Brazilian avifauna, since the occurrence of Grey Gull draws attention to the fact that the species has moved quite a lot from where it naturally occurs. Vagrancy in birds is commonly explained by the presence of species in population expansion (Veit 2000, Lees & Gilroy 2009), pursuit of resources (Berthold 1993, Lees & Gilroy 2009) and disorientation caused by natural or anthropogenic events (Patten & Marantz 1996, Gilroy & Lees 2003, Pfeifer *et al.* 2007). With regard to the climatic interference in the life cycle of Grey Gull, Aguilar *et al.* (2016) cites that the reproductive season of 2014–2015 was influenced by the climatic phenomenon El Niño, which caused a reduction in the availability of resources and led the species to reproduce in areas closer to the coast. Thus, in the present case, we can speculate that its occurrence in southeastern Brazil may have been influenced by some climatic weather that could have disoriented the bird, which could explain the fact that it took the bird some time to fly away after the approach of the team. Another possibility is simply that the bird dispersed from its original area of occurrence searching for food. Thus, both cases reinforce the fact that the species is considered vagrant.

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The following *abbreviations* should be used: h (hour), min (minute), s (second), km (kilometer), m (meter), cm (centimeter), mm (millimeter), ha (hectare), kg (kilogram), g (gram), mg (milligram), all of them in lowercase (not capitals) and with no "periods" ("."). Use the following *statistical notations: P, n, t, r, F, G, U, df* (degrees of freedom), χ^2, ns (non-significant), CV (coefficient of variation), SD (standard deviation), SE (standard error). With the exception of temperature and percentage symbols (*e.g.*, 15°C, 45%), leave a space between the number and the unit or symbol (*e.g.*, $n = 12$, $P < 0.05$, 25 min), also in figures and tables.

Latin words or expressions should be written in italics (*e.g.*, *i.e.*, *c.*, *et al.*, *in vitro*, *in vivo*, *sensu*, *a priori*). The same rule applies to words in a language distinct from the manuscript language, *i.e.*, English, but does not apply to references, which follow distinct format rules, as indicated below. Numbers one to ten should be written out, unless a measurement (*e.g.*, four birds, 6 mm, 2 min); from 11 onwards use numbers.

Author *citations* in the text must follow the pattern: (Pinto 1964) or Pinto (1964); two publications of the same author must be cited as (Sick 1985, 1993) or (Ribeiro 1920a, b); Two authors are cited in text with "&" (*e.g.* Aleixo & Pacheco 2006). Three or more authors must be presented as the first author followed by *et al.* (*e.g.* Aleixo *et al.* 2013). Avoid multiple citations in text, such as more than 3 references to support an idea or information. Multiple references should be listed in chronological order (*e.g.* Sick 1997, Narosky & Yzurieta 2003, BirdLife International 2015). Unpublished information by third parties must be credited to the source by citing the initials and the last name of the informer followed by the appropriate abbreviation of the form of communication: (H. Sick, pers. comm.) or V. Loskot (*in litt.*); unpublished observations by the authors can be indicated by the abbreviation: (pers. obs.); when only one of the authors deserves credit for the unpublished observation or another aspect cited or pointed out in the text, this must be indicated by the name initials: "... in 1989 A.S. returned to the area...". *Unpublished manuscripts* (*e.g.*, technical reports, Undergraduate Monographs, M.Sc. Dissertations and Doctoral Thesis) and *meeting abstracts* should be cited only exceptionally, in cases they are absolutely essential and no alternative source exists. The *reference* list must include all and only the cited publications (titles written in full, not abbreviated), in alphabetical order by the authors' last name:

Articles

Fargione J., Hill J., Tilman D., Polasky S. & Hawthornez P. 2008. Land clearing and the biofuel carbon debt. *Science* 319: 1235–1238.

Santos M.P.D. & Vasconcelos M.F. 2007. Range extension for Kaempfer's Woodpecker *Celeus obrieni* in Brazil, with the first male specimen. *Bulletin of the British Ornithologists' Club* 127: 249–252.

Worthington A.H. 1989. Adaptations for avian frugivory: assimilation efficiency and gut transit time of *Manacus vitellinus* and *Pipra mentalis. Oecologia* 80: 381–389.

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Sick H. 1985. *Ornitologia brasileira, uma introdução, v. 1*. Brasilia: Editora Universidade de Brasilia.

Book Chapters

Thiollay J.M. 1994. Family Accipitridae (hawks and eagles), p. 52–205. In: del Hoyo J., Elliott A. & Sargatal J. (eds.). *Handbook of birds of the world, v. 2 (New World vultures to guineafowl)*. Barcelona: Lynx Editions.

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Novaes F.C. 1970. *Estudo ecológico das aves em uma área de vegetação secundária no Baixo Amazonas, Estado do Pará*. Ph.D. Thesis. Rio Claro: Faculdade de Filosofia, Ciencias e Letras de Rio Claro.

Cavalcanti L.M.P. 2014. *Sazonalidade na estação reprodutiva de aves de uma área de Caatinga e sua relação com a precipitação.* Bachelor's Monograph. Mossoró: Universidade Federal Rural do Semiárido.

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IUCN. 1987. A posição da IUCN sobre a migração de organismos vivos: introduções, reintroduções e reforços. http://iucn.org/themes/ssc/pubs/policy/index.htm (access on 25 August 2005).

Dornas T. 2009a. [XC95575, *Celeus obrieni*]. http://www.xeno-canto.org/95575 (access on 25 February 2012).

Pinheiro R.T. 2009. [WA589090, *Celeus obrieni* Short, 1973]. http://www.wikiaves.com/589090 (access on 05 March 2012).

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