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Cover: Adult Long-winged Harrier (*Circus buffoni*) predating an amphibian in the Pampas grassland of Uruguay, in August 2010. Baladrón *et al.* (in this volume) provide an activity budget and descriptions of hunting behavior of the species, in comparison to Roadside Hawk (*Rupornis magnirostris*) in the Pampas region of Argentina. Photo author: Alexandre T. Faitarone (http://www.wikiaves.com/192949).

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ARTICLE

Time-activity budgets and hunting behavior of the Roadside Hawk (*Rupornis magnirostris*) and the Long-winged Harrier (*Circus buffoni*)

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ABSTRACT: We conducted a study aimed to evaluate and compare the behavioral patterns of the Roadside Hawk (*Rupornis magnirostris*) and the Long-winged Harrier (*Circus buffoni*), two common but poorly known Neotropical raptors. From 2005 to 2008, we quantified the time-activity budgets of both raptors at the Pampas region of Argentina in order to determine their allocation of time to different activities, their foraging strategies and hunting modes, and whether their behavioral patterns change in different habitats and seasons. The Roadside Hawk and the Long-winged Harrier showed dissimilar activity patterns. Hawks devoted more time to perching (45.5% of total time) than harriers (13%), whereas harriers devoted more time to foraging (45%) than hawks (13%). No differences were found in the time they devoted to fly. In addition, both species differed in the use of flying modes, perching sites, and habitat types. Hawks preferably used cruising flights, perched on tall poles or trees, and were found in woodlands and urban areas. Harriers preferably used soaring and circle flights, perched on the ground, and were found in grasslands and agroecosystems. Notwithstanding, the most obvious difference between these raptors were their hunting modes: the Roadside Hawk behaved as a sit-and-wait predator and the Long-winged Harrier as a wide-foraging predator. These patterns seem to be consistent in different habitat contexts and showed certain differences between seasons. Our results suggest that these species may segregate spatially by utilizing different hunting habitats as well as behaviorally, by using different hunting modes.

KEY-WORDS: behavioral patterns, Neotropical raptors, Pampas region, sit-and-wait predator, wide-foraging predator.

INTRODUCTION

Time-activity budgets quantify how birds apportion time to various activities (Paulus 1988). These may reveal critical aspects of their use of the spatial and temporal dimensions, and are important to understand the niche partitioning among sympatric species (Schoener 1971). This approach has been extensively used in birds, showing that patterns of daily activity can vary widely between species and that they are important to determine the life history and ecological adaptations of birds (Hamilton *et al.* 2002). However, the study of behavioral patterns of raptorial birds is often difficult, because the seemingly limited repertoire of behaviors displayed and the long periods of inactivity typically attributed to these predators (Gaibani & Csermely 2007). For this reason, behavioral studies of raptors have been often overlooked.

The most diverse and detailed information on time-activity budgets of diurnal raptors (Falconiformes and Accipitriformes) that eat vertebrates in the Americas comes from studies conducted on Nearctic species. For example, Osprey (*Pandion haliaetus*; Stinson 1978, Levenson 1979, Jamieson *et al.* 1982), Ferruginous Hawk (*Buteo regalis*; Wakeley 1978), Red-tailed Hawk (*B. jamaicensis*; Soltz 1984), Peregrine Falcon (*Falco peregrinus*; Palmer *et al.* 2001), and Bald Eagle (*Haliaeetus leucocephalus*; Warnke *et al.* 2002). Comparatively, this kind of research has been much less developed in the Neotropics. The bulk of information available comes from Argentina and Chile and is limited to a few species: the Black-chested Buzzard-Eagle (*Geranoaetus melanoleucus*) (Jiménez & Jaksic 1989, de Lucca & Saggese 2012), the Variable Hawk (*G. polyosoma*) (Jiménez & Jaksic 1991, Baladrón *et al.* 2006), and the Harris Hawk (*Parabuteo unicinctus*) (Jiménez & Jaksic 1993, Santander *et al.* 2014). Thus, data on time-activity budgets is lacking for most Neotropical diurnal raptors.

The Roadside Hawk (*Rupornis magnirostris*) and the Long-winged Harrier (*Circus buffoni*) are two common, but little known raptor species of the Neotropics. These species are sympatric for the greater part of their distributions (del Hoyo & Collar 2014). The Roadside

Hawk (269 g; Dunning-Jr. 2008) is widespread from northern Mexico to Río Negro Valley in central Argentina (Thiollay 1994), where it inhabits woodlands and forest margins and, to a lesser extent, open fields near woodlands (Canevari *et al.* 1991). The Long-winged Harrier (420 g for males and 613 g for females; Dunning-Jr. 2008) is endemic of South America, ranging from Venezuela to Patagonia, occasionally reaching as far south as Tierra del Fuego in Argentina (Thiollay 1994). This raptor is found throughout open areas of central Argentina, Uruguay and Brazil, being common in grasslands, agricultural fields, savannas, marshes, and wetlands (Canevari *et al.* 1991, de la Peña 1992).

In the Pampas region of Argentina, these two raptor species belong to the same trophic guild, as both are considered major predators of small vertebrates. Previous studies performed at that region indicate that the Roadside Hawk consumes almost exclusively small mammals during winter, but also incorporates insects in its diet during summer (Baladrón *et al.* 2011), whereas the Long-winged Harrier consumes birds and small mammals, although seems to specialize in birds during the breeding season (Bó *et al.* 1996). Thus, it is expected that some degree of interference competition between them occurs. The use of different hunting habitats and/or hunting behaviors may help to reduce the interference among sympatric predators (Jaksic 1985). In this sense, the Roadside Hawk has been characterized as a passive search predator (Panasci & Whitacre 2000) and the Long-winged Harrier as an active search predator (Isacch *et al.* 2001). Notwithstanding, if these raptors are in fact segregated through the spatial, temporal, or behavioral dimensions is difficult to assert, as no quantitative studies on their behavioral patterns have been performed.

We conducted a study aimed to evaluate and compare the behavioral patterns of the Roadside Hawk and the Long-winged Harrier. Our specific objectives were: (1) to quantify time allocation of both species to daily activities, (2) to determine their foraging strategies and hunting modes, and (3) to assess whether their behavioral patterns change in different habitat contexts and between breeding and non-breeding seasons.

METHODS

The study was carried out in Mar Chiquita County, southeast Buenos Aires Province, Argentina (37°32'–37°45'S; 57°19'–57°26'W), which is located in the Pampas region. The landscape includes zones of native vegetation such as marshes and grasslands, and zones highly modified by the development of agriculture (Cabrera 1971, Bilenca & Miñarro 2004). Most of the land in the study area is devoted to grazing fields and pastureland and, to a lesser extent, to cropland which is cultivated for corn, soybean, and wheat production (Isacch 2008). Small villages and periurban areas, native woodlands, and tree plantations complete the landscape of the study area. This habitat heterogeneity supports a high faunal diversity, which represents a wide spectrum of potential prey for raptors (Iribarne 2001).

From 2005–2008, we registered raptors' activities during daylight by quantifying their time-activity budgets (Martin & Bateson 1993). Firstly, we looked for raptors by vehicle through paved and unpaved roads of the study area, and on foot in areas where species were previously registered. Once the bird was spotted, the individual was observed with 10 × 50 binoculars and all its activities registered in a digital voice recorder until it was lost from sight (continuous recording method; Gaibani & Csermely 2007). These recordings were later analyzed to determine the duration of all behaviors (Martin & Bateson 1993). The sampling was conducted in an opportunistic manner throughout the period and the search effort was evenly distributed across seasons (breeding and non-breeding) and habitat types. Habitat types were grouped in four categories: agroecosystems (crops, pastures and grazing fields), woodlands (native forests, groves at agroecosystem margins, and forestations), urban (small villages and periurban areas), and grasslands (tallgrass prairies, marshes, and psammophytic grasslands). No surveys were conducted in bad weather conditions.

The behavior of both raptors was classified into three basic categories: flying, foraging, and perching (Table 1). Flying activities included all moves between hunting areas, changes of perching site, and high-altitude flights. Foraging included all those behaviors involved in prey capture, searching (active or passive), transporting, handling, and feeding. Perching activities included all behaviors made on perch except those related to foraging. In addition, we quantified the number and frequency of discrete events, such as capture attempts, vocalizations and other occasional behaviors. To standardize observation days and interval durations, time-activity budgets were expressed as the proportion of time spent in each activity respect to the total time registered (Martin & Bateson 1993). Given the limited observation time, the time-activity budgets of each species were calculated by pooling data of different ages (juveniles and adults) and sexes. Since the use of different hunting modes would be, at first, the most contrasting behavior of these species, we performed a more detailed description of their foraging activities with emphasis on the hunting technique used by each raptor (Jaksic & Carothers 1985). Values are reported as means ± standard error (SE).

We evaluated the agreement in the activity patterns between species, habitats (agroecosystems, woodlands, urban, and grasslands), and seasons (breeding and non-

TABLE 1. Ethogram showing the activities and sub-activities used to describe the time-activity budgets of the Roadside Hawk (*Rupornis magnirostris*) and the Long-winged Harrier (*Circus buffoni*).

Activity	Sub-activity	Definition
Flying	Circular flight	The individual flies in circles at elevated positions.
	Soaring/gliding	The individual flies helped by wind or heat currents, reduced wing movements.
	Cruising flight	The individual flies by only beating or combined with short soaring.
Foraging	Passive search	The individual regularly scan the patches from perches.
	Active search	The individual scan the patches on the wing, often diving.
	Feeding	The individual feeds on prey.
	Handling	The individual manipulates, plucks, or transports prey.
Perching	On perch	The individual rests or remains inactive on utility poles, fence posts or trees.
	On ground	The individual rests or remains inactive on the ground.
	Comfort	The individual performs maintenance activities (cleaning, grooming, preening).

breeding) using the Kendall's Coefficient of Concordance (W; Zar 2010). This coefficient examines the intensity of the association (*i.e.* agreement) among variables based on rank correlation. Kendall's W statistic ranges from 0 to 1, with higher values indicating higher concordance. The null hypothesis states that there is no agreement among variables. A Friedman's test is then made to determine the significance of W value in terms of the F-distribution. If P value is ≤ 0.05, then the null hypothesis is rejected, and it is accepted that there is association among variables (Zar 2010). In addition, differences in the percent of time devoted to each particular sub-activity were compared using Mann-Whitney U-tests (Zar 2010). All statistical analyses were carried out using R software (R Core Team 2015).

Furthermore, we compared the time-activity budgets between species through the similarity percentage (SIMPER) procedure (Clarke & Warwick 1994). This procedure examines the contribution of each activity category to the average dissimilarity between species, and the contribution to similarity within each species. Afterwards, we constructed a dissimilarity matrix (Bray-Curtis distance) with time-activity budgets of both raptor species in order to compare the similarity of their activity patterns. Time percentage data were transformed by taking square roots in order to diminish the influence of extreme values (Quinn & Keough 2002). Finally, we used non-metric multidimensional scaling analysis (nMDS) to represent dissimilarities between both raptor species. We used statistical software PRIMER v. 5 for all analyses (Clarke & Warwick 1994).

RESULTS

General activity patterns

In total, we registered 472 min of daily activity of the Roadside Hawk through 25 observation days (mean duration: 18.9 ± 5.4 min), and 323 min of activity of the Long-winged Harrier through 30 observation days (mean duration: 10.8 ± 3.4 min). Both species showed different daily patterns in their general activities (W = 0.55, $F_{8,8}$ = 1.26, P = 0.376). The most important differences were the percentage of time they allocated to perching (45.5% for the Roadside Hawk and 13.0% for the Long-winged Harrier; $U_{25,30}$ = 192, P = 0.004) and foraging (13% and 45%, respectively; $U_{25,30}$ = 197, P = 0.006; Figure 1).

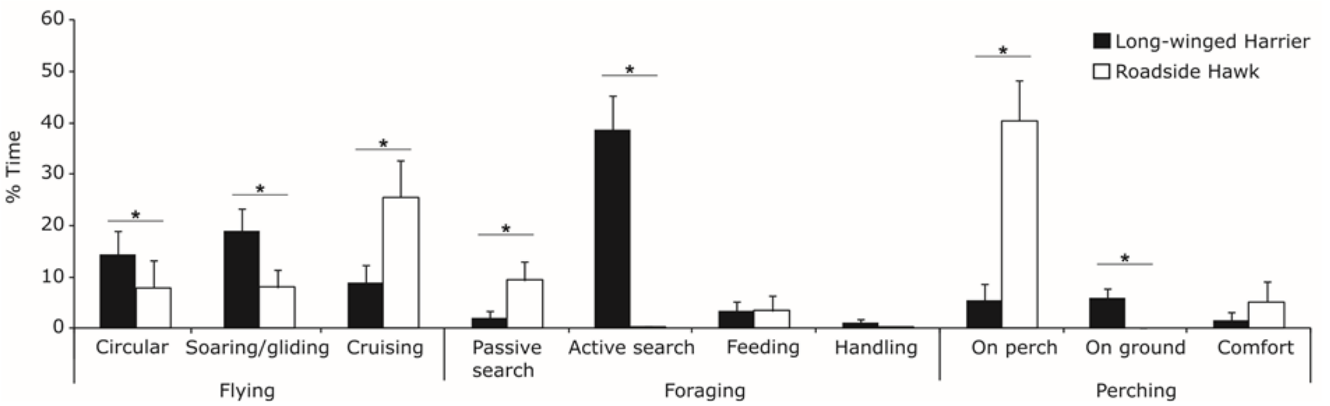

FIGURE 1. Time-activity budgets of the Roadside Hawk (*Rupornis magnirostris*) and the Long-winged Harrier (*Circus buffoni*), showing the general pattern of activities and sub-activities. Asterisks (*) indicate significant differences at P < 0.05 (see text for details).

Even though the Roadside Hawk and the Long-winged Harrier did not differ in the time they devoted to fly (41.5% and 42.0%, respectively; $U_{25,30} = 317.5$, $P = 0.59$), they differed in the use of flying modes: the Roadside Hawk used more often the cruising flight (> 64% of time devoted to fly) and the Long-winged Harrier used more frequently the circular flight and soaring/gliding (> 80% of the time). We also found differences between both species in relation to their preference by perching sites, since the Roadside Hawk used preferentially tall poles or trees as perching sites whereas the Long-winged Harrier used almost exclusively the ground (Figure 1). Notwithstanding, the most evident difference between both species was found during foraging activities, since the Roadside Hawk used preferentially the passive searching mode and the Long-winged Harrier the active searching (Figure 1). These different patterns of activity were evidenced by the limited overlap in their daily time-activity budgets in the SIMPER procedure (Table 2), as well as in the nMDS ordination analysis (Figure 2).

TABLE 2. Contribution of each sub-activity to similarity/dissimilarity in the time-activity budgets of the Roadside Hawk (*Rupornis magnirostris*) (RH) and the Long-winged Harrier (*Circus buffoni*) (LWH), according to SIMPER analysis. Sub-activities were arranged in decreasing order according to their contribution to dissimilarity.

Sub-activity	% Similarity		% Dissimilarity RH vs. LWH	
	RH	LWH	Contribution	Cummulative
Active search	0.02	48.75	20.63	20.63
On perch	50.5	0.89	19.18	39.81
Cruising flight	34.81	7.69	14.8	54.62
Soaring/gliding	5.04	22.45	12.8	67.42
Circular flight	0.88	11.96	11.31	78.72
Passive search	7.34	0.34	6.95	85.67
On ground	0	7.25	5.7	91.37
Comfort	1.21	0	3.89	95.26
Feeding	0.2	0.51	3.64	98.9
Handling	0	0.16	1.1	100
Average similarity	34.6	37.1		
Average dissimilarity			84.1	

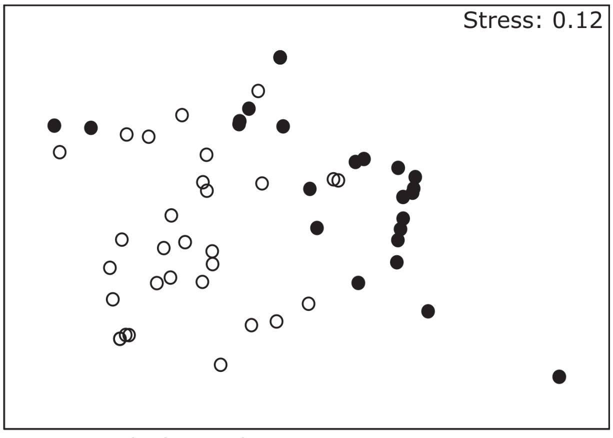

FIGURE 2. Non-metric Multidimensional Scaling ordination analysis (nMDS) based on dissimilarities in the time-activity budgets of the Roadside Hawk (*Rupornis magnirostris*) and the Long-winged Harrier (*Circus buffoni*).

Foraging activity and hunting modes

The quantification of foraging activities of the Roadside Hawk and the Long-winged Harrier evidenced their different hunting modes and techniques. The Roadside Hawk behaved as a passive search predator. This species used almost exclusively the sit-and-wait technique, searching for prey from tall perches in bouts of 9.46 min ± 2.9 min (n = 12), interrupting this activity to make rapid changes of perch (8.25 ± 1.9 s), or more rarely for comfort behaviors. We observed only two events of prey capture by hawks, one of them on a small rodent and other on a passerine; no failed attempts were registered.

The quantification of foraging activities of the Long-winged Harrier showed that this species behaved as a wide-foraging predator, searching for prey on the wing in intervals of 1.29 min ± 0.18 min (n = 46). The technique was characterized by slow quartering over the vegetation (15.5 ± 1.8 s), which alternated with low flights and dives (15.8 ± 3.0 s). We registered 16 capture attempts, in which the harrier suddenly swoops onto the vegetation to catch prey. From total attempts, we registered three successful captures (efficiency: 19.0%), and only in one case we could determine the prey, a young Brown Hare (*Lepus europaeus*).

Spatial and seasonal variability

The Roadside Hawk was mostly registered at periurban areas (62.4% of total time), whereas the remaining time this species was found in woodlands. Even though perching activity (on perch) was more frequent in woodlands than in urban areas ($U_{8,17} = 6$, $P = 0.001$), the general behavior pattern did not differ between habitat types ($W = 0.83$, $F_{8,8} = 4.89$, $P = 0.018$). The Long-winged Harrier was registered mainly in grasslands (73.3% of total time), and agroecosystems in a lesser extent. The general pattern of activity did not vary according to habitat type for this raptor ($W = 0.80$, $F_{8,8} = 4.04$, $P = 0.032$), and median tests did not reveal differences between both habitats for any sub-activity (all $P > 0.250$).

The activity patterns of both species showed certain variability between breeding and non-breeding seasons (Roadside Hawk: $W = 0.72$, $F_{8,8} = 2.67$, $P = 0.093$; Long-winged Harrier: $W = 0.44$, $F_{8,8} = 0.80$, $P = 0.620$). In this sense, hawks used more frequently cruising flights during the breeding season than during the non-breeding season ($U_{10,15} = 38.5$, $P = 0.04$), whereas harriers devoted more time to active searching, feeding and handling during the non-breeding season than during the breeding season ($U_{8,22} = 44$, $U_{8,22} = 55$, and $U_{8,22} = 55$, respectively, all $P < 0.008$).

Vocalizations

Vocalizations were common for the Roadside Hawk, being registered in 68% of observation days, but they were quite uncommon for the Long-winged Harrier (< 17% of observation days). Hawks vocalized mainly during perching (87% of total vocalization events, n = 275), less frequently during flying (12.3%) and rarely during foraging (0.7%). Frequency of vocalizations averaged 4.1 ± 0.7 vocalizations per min in such events. Harriers vocalized mainly while flying (74% of total vocalization events, n = 42), and less frequently during perching (26%). Frequency of vocalizations of harriers averaged 1.2 ± 0.3 vocalizations per min.

DISCUSSION

In this study, we found that the Roadside Hawk and the Long-winged Harrier showed contrasting behavioral patterns in the Pampas region of Argentina. The analysis of their time-activity budgets revealed that the Roadside Hawk devoted most of its daily activity to perching and passive searching, whereas the Long-winged Harrier allocated most of its daily time to active searching and flight activities. These patterns seem to be consistent in different habitat contexts and showed certain differences between breeding and non-breeding seasons. In addition, these raptors differed in their hunting modes: the Roadside Hawk behaved mainly as a sit-and-wait predator whereas the Long-winged Harrier behaved as a wide-foraging predator, which coincides with previous descriptions for both species (Panasci & Whitacre 2000, Isacch *et al.* 2001). These contrasting patterns seem to represent opposite ends of the spectrum of hunting modes proposed for raptors (Jaksic 1985), which ranges from those that maximize prey encounter rates to those that minimize costs of searching, by waiting the most profitable prey (Jaksic & Carothers 1985).

The use of different hunting modes and the characteristics of the main prey of each raptor, *i.e.* rodents for the Roadside Hawk (Baladrón *et al.* 2011) and birds for the Long-winged Harrier (Bó *et al.* 1996), may determine their preference by different habitats. The Roadside Hawk used mainly periurban areas and woodland edges which provide fundamentally perching sites adequate to passive searching. From such elevated positions, hawks may have a broad vision of the hunting patches and enhance their chance of prey detection, especially rodents that thrive in periurban areas and field margins (Bilenca *et al.* 2007). The Long-winged Harrier showed affinity by open habitats, such as grasslands and agroecosystems, where this species may display more efficiently the active hunting mode. This may responds to the fact that this raptor usually displays the tactic of slow quartering flights over the vegetation surface to capture flushed birds (Simmons 2000, Isacch *et al.* 2001). Thus, it may be exploiting the broad offer of small birds that use grasslands and agroecosystems as refuge in the study area (Pretelli *et al.* 2013, Spinazzola 2013).

Although the time-activity budgets of both raptors did not vary according to habitat type, we did find some differences in their activity patterns between the breeding and non-breeding seasons. Such differences may be related to two main factors: (1) different energy demands and time allocation due to reproductive tasks (courtship, nest attendance, territoriality) during the breeding season and (2) changes in prey abundance and availability between both seasons (Newton 1979). The Roadside Hawk, for instance, used cruising flights more frequently during the breeding season. This may be linked to directional moves to change of hunting patches, but also with an increase in its territoriality and nest vigilance behaviors. This hawk has been characterized as opportunist (Beltzer 1990, Panasci & Whitacre 2000) and, in the study area, it may experience changes in its diet between the non-breeding season (mainly rodents; Baladrón *et al.* 2011) and the breeding season (more insects; Author's unpub. data). This may influence the foraging behavior through modulating the duration of hunting bouts and the extension of hunting areas. The Long-winged Harrier used soaring/gliding flights more frequently during the non-breeding season than during the breeding season. This may be due to the expansion of its hunting ranges as a result of the decrease in the availability of its main prey (birds; Bó *et al.* 1996, Pretelli *et al.* 2013), as well as to a reduction of its home range due to nest vigilance and territoriality during the breeding season (Simmons 2000).

We report for the first time on the time-activity budgets of two common, but poorly known species, the Roadside Hawk and the Long-winged Harrier. These raptors showed similarities in their sizes, food habits, and geographic distributions, but differed in their behavioral patterns. Our results suggest that they may segregate spatially by utilizing different hunting habitats as well as behaviorally by using different hunting modes. Such segregation may determine a low degree of interference competition between both raptors (Jaksic 1985), and may also explain the lack of aggressive encounters between them (Baladrón & Pretelli 2013). Although based on a modest amount of data, our study highlights the importance of quantifying the time-activity budgets of Neotropical raptor species in order to know how these predators segregate through different niche dimensions.

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ARTICLE

Effects of different environmental enrichment items on the behavior of the endangered Lear's Macaw (*Anodorhynchus leari*, Psittacidae) at Belo Horizonte Zoo, Brazil

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ABSTRACT: Environmental enrichment is a technique applied to enhance welfare of captive animals by introducing items that create a complex and stimulate enclosure. In poor environments, animals can exhibit abnormal and stereotypic behaviors due to boredom and stress. Animals behaving normally and with high levels of welfare are suitable and preferred to participate in conservation efforts such as reintroductions. The aim of this study was to evaluate the effects of environmental enrichment items on the behavior of the endangered Lear's Macaws held at the Belo Horizonte Zoo, Brazil. Ninety hours of behavioral data were collected, divided into three equal-length treatments: baseline, enrichment and post-enrichment. Data were collected using focal sampling with instantaneous recordings every minute. Environmental enrichment decreased the expression of abnormal behaviors and increased macaw activities. Thus, environmental enrichment proved to be effective in the maintenance of normal behaviors and should be continually used to increase the welfare of Lear's Macaws.

KEY-WORDS: abnormal behavior, bird, food enrichment, Psittaciformes, welfare.

INTRODUCTION

Animal welfare can be defined as the maintenance of good physical and mental health of animals by attending their needs (Young 2003). Animal welfare can be compromised in captivity due mainly to stress caused by the limited space, high number of individuals at the same cage or loneliness, and lack of stimulation (Newberry 1993, Morgan & Tromborg 2007, Borges *et al.* 2011). In such situations, animals can exhibit abnormal and stereotypic behaviors (Mason & Rushen 2006, Mason 2010); the most common abnormal behaviors recorded for birds are feather plucking, pacing, self-mutilation, and bar or/and wall pecking (Engebretson 2006, Speer 2014).

Environmental enrichment is a technique created to increase the welfare of captive animals (Shepherdson *et al.* 1998). It consists in the introduction of items inside the enclosure that stimulate animals to behave normally (Young 2003). Enrichment items provide the opportunity to increase exploratory, consummatory, predatory and social behaviors, as well as to enhance motor skills, decreasing stress and the expression of abnormal behaviors, ameliorating animal welfare (Cubas *et al.* 2006). Thus, it is important to provide environmental enrichment for captive animals, as the reduction of stress levels is normally followed by an increase in reproduction success, which helps in species conservation efforts (Pizzutto *et al.* 2009).

Lear's Macaw (*Anodorhynchus leari*, Psittacidae) is an endangered Brazilian bird (MMA 2014, IUCN 2015), only occurring in Jeremoabo, Euclides da Cunha and Canudos municipalities, in Bahia state, northeastern Brazil (Lima *et al.* 2003). The main threats to the species are hunting, habitat destruction, and illegal trade (ICMBio 2012). According to the latest census of the species, only 1294 macaws were recorded in natural habitat in 2014 (CEMAVE, unpub. data). Due to its rarity, Brazilian zoos kept in their collections only 31 individuals of the Lear's Macaw in 2010, being three held at Belo Horizonte Zoo (BH Zoo), Minas Gerais state, southeastern Brazil (ICMBio 2012). Macaws are often considered as "hardfruit specialist" birds, including a number of hard-husked fruits (*e.g.* palms) in their diet, especially the Licuri Palm (*Syagrus coronata*, Arecaceae) (Brandt & Machado 1990, Sick 1997, Lima *et al.* 2014). Its specialized diet also contributes to its threat status, since Licuri Palm has been used in the commerce and subsistence of local people in Bahia (Crepaldi *et al.* 2004). To keep the welfare of captive individuals is important, among other reasons, because they can be reintroduced in the wild or being part in a captive reproduction management, since wild populations of *A. leari* shows low levels of genetic variation (Presti *et al.* 2011), thus, contributing effectively to the conservation and maintenance of wild populations.

Some studies have been conducted applying environmental enrichment to psittacines (Field & Thomas 2000, Evans 2001, Kim *et al.* 2009, Sgarbieiro 2009, Webb *et al.* 2010, Andrade & Azevedo 2011, van Zeeland *et al.* 2013), but none evaluated how environmental enrichment influences Lear's Macaw behaviors or any other *Anodorhynchus* species. In general, psittacines respond positively to enrichment, decreasing the expression of abnormal behaviors and increasing the expression of normal behaviors. Thus, the aim of this study was to evaluate how environmental enrichment items would influence the behavior of two captive individuals of Lear's Macaw. We expected that environmental enrichment decreases the exhibition of abnormal behaviors and elicits more activity and normal behaviors.

METHODS

Study place, animals and maintenance

The study was conducted in an off-exhibit area of Belo Horizonte Zoo (BH Zoo; 19°51'S; 44°01'W). One male and one female Lear's Macaws were studied. Male was arising from the Lymington Aviary, São Paulo, Brazil; female was arising from the Loro Parque, Spain. Both individuals arrived at BH Zoo in 2010 and were held together in a 64 m^2, 4 m tall enclosure. Birds were fed twice a day at 09:00 h and 14:00 h with a mixture of parrot ration and vegetables. Water was provided *ad libitum*.

Experimental protocol

The study was divided into three treatments of 30 h each, totalizing 90 h of behavioral data: baseline, enrichment (when the enrichment items were available) and post-enrichment (birds with no enrichment, when conditions returned to those of the baseline) (Young 2003). Behavioral data were recorded during the three experimental treatments, using focal sampling method associated with instantaneous recording of behaviors every minute (Altmann 1974). Data were collected on Mondays and Wednesdays, from 07:00 h to 09:00 h, and this time was chosen because macaws showed to be most active during this period of day (based on 12 h of preliminary observations made on September 2013). Each treatment lasted 15 days and the study was run from October to December 2013.

An ethogram was developed based on 12 h of preliminary observations and on scientific literature (Uribe *et al.* 1982, Prestes 2000, Schneider *et al.* 2006) (Table 1). Feather plucking and pacing were considered abnormal behaviors because they were performed in a stereotypic way (repetitive performance with no apparent reason; Mason & Rushen 2006).

The environmental enrichment items used were: bamboo forest, coconuts, grape, pumpkins filled with hazelnuts, hazelnuts wrapped in banana tree leaves, corn on the cob, parrot sticks, and cardboard boxes filled with

TABLE 1. Ethogram for Lear's Macaws (*Anodorhynchus leari*) studied at the BH Zoo, Brazil.

Acronym	Behavior	Description
FED	Feeding	Macaw eats the ration.
VOC	Vocalizing	Macaw vocalizes.
WB	Walking on bars	Macaw walks hanged on bars by its feet or beak.
IN	Inactive	Macaw is inactive or sleeping.
FLY	Flying	Macaw flies through the enclosure.
ALP	Allopreening	Macaw manipulates the feathers of the other individual with its beak.
PAC	Pacing – abnormal behavior	Macaw walks from one side to another, repetitively and with no apparent reason.
WAL	Walking	Macaw walks on the perch.
HAB	Hanging on bars	Macaw hangs on the ceiling bars of the enclosure.
RUB	Rubbing beak	Macaw rubs its beak against the perch.
PEB	Pecking bars	Macaw pecks the bars of the enclosure.
MRO	Manipulating rocks	Macaw manipulates with its beak rocks caught on the enclosure's floor.
FPL	Feather plucking – abnormal behavior	Macaw plucks its own feathers.
II	Interacting with items	Macaw beaks the environmental enrichment items.
OTH	Other behaviors	Drinking water, scratching, and bathing.

grass and coconut. Only one item was offered to the bird each day; each item was offered twice, and they were never offered in consecutive days. Items were inserted in the enclosure five minutes before data collection, once a day, and remained inside the enclosure until afternoon, when they were removed.

Statistical analysis

Data were tested for normality using the Anderson-Darling test. Since data did not meet the requirements for parametric statistics, nonparametric statistical tests were used throughout. Friedman's test was used for comparing if the behavior of the macaws differed between treatments and environmental enrichment items. Dunn's test was used for *post-hoc* analysis in both comparisons (Zar 1998). Wilcoxon's test was used for comparing if the behaviors of male and female macaws differed between each other. All tests were run using Minitab 15®.

RESULTS

Comparison of behaviors expressed by macaws during the three treatments

During the enrichment treatment, male expressed more the feeding behaviors, interacting with items, and walking on bars (Table 2). Behaviors like inactive, walking on bars, and hanging on bars decreased during the enrichment treatment (Table 2). The abnormal behavior pacing decreased during the enrichment treatment, remaining low even during the post-enrichment treatment; the abnormal behavior feather plucking also decreased during the enrichment treatment, but increase in the post-enrichment treatment (Table 2). Vocalizing was exhibited more frequently during the post-enrichment treatment (Table 2).

Female fed, vocalized, walked on bars and interacted more with items during the enrichment treatment (Table 3). Inactivity was less frequently recorded during the enrichment treatment (Table 3). All other behavioral expressions were not influenced by the enrichment items (Table 3).

Comparison between the behavioral expression of male and female macaws during the enrichment treatment

Seven behaviors differed between male and female macaws during the enrichment treatment: feeding, vocalizing, inactive, flying, interacting with items, walking and hanging on bars (Figure 1). Inactivity, hanging on bars and vocalizing were more commonly exhibited by the female when compared to the male; the three other behaviors were more expressed by the male macaw (Figure 1).

TABLE 2. Mean ± standard error of the number of behavioral registers and Friedman's results for the male Lear's Macaw of BH Zoo, Brazil, during the three treatments of the study (baseline, enrichment and post-enrichment). FEE – feeding; VOC – vocalizing; WB – walking on bars; IN – inactive; FLY – flying; ALP – allopreening; PAC – pacing; WAL – walking; HAB – hanging on bars; RUB – rubbing beak; PEB – pecking bars; MRO – manipulating rocks; FPL – feather plucking; II – interacting with items; OTH – other behaviors. Same superscript letters indicate statistical differences between treatments according to the Dunn's *post-hoc* test.

Behavior	Treatments			F	P
	Baseline	Enrichment	Post-enrichment		
FEE	19.06 ± 1.32	44.40 ± 4.26^{a}	13.80 ± 1.26^{a}	22.53	<0.0001
VOC	25.73 ± 2.56	18.46 ± 3.40^{a}	31.00 ± 1.79^{a}	7.23	0.0269
WB	6.73 ± 1.00^{a}	1.60 ± 0.49^{ab}	8.26 ± 1.13^{b}	13.63	0.0011
IN	11.73 ± 2.50^{ab}	1.13 ± 0.53^{a}	2.80 ± 1.05^{b}	11.70	0.0029
FLY	2.26 ± 0.35	1.33 ± 0.46	0.93 ± 0.30	3.73	0.1546
ALP	2.13 ± 0.46	2.26 ± 0.76	2.20 ± 0.49	0.40	0.8187
PAC	1.66 ± 0.56^{a}	0.93 ± 0.38	----^{a}	6.53	0.0381
WAL	4.00 ± 0.74	4.00 ± 1.55	3.93 ± 0.93	1.90	0.3867
HAB	21.86 ± 1.24^{a}	15.40 ± 3.48^{b}	42.66 ± 2.59^{ab}	22.43	<0.0001
RUB	1.06 ± 0.37	0.26 ± 0.15	----	4.13	0.1266
PEB	5.33 ± 1.24	1.60 ± 0.46	3.13 ± 0.72	3.33	0.1889
MRO	3.46 ± 0.88	0.86 ± 0.44	0.46 ± 0.25	5.70	0.0578
FPL	7.13 ± 1.72^{a}	0.53 ± 0.32^{a}	4.40 ± 1.11	8.40	0.0150
II	5.73 ± 1.73^{a}	25.80 ± 3.64^{ab}	3.20 ± 0.93^{b}	20.43	<0.0001
OTH	2.06 ± 0.62	1.40 ± 0.58	3.20 ± 1.20	2.63	0.2680

TABLE 3. Mean ± standard error of the number of behavioral registers and Friedman's results for the female Lear's Macaw of BH Zoo, Brazil, during the three treatments of the study (baseline, enrichment and post-enrichment). FEE – feeding; VOC – vocalizing; WB – walking on bars; IN – inactive; FLY – flying; ALP – allopreening; PAC – pacing; WAL – walking; HAB – hanging on bars; RUB – rubbing beak; PEB – pecking bars; MRO – manipulating rocks; FPL – feather plucking; II – interacting with items; OTH – other behaviors). Same superscript letters indicate statistical differences between treatments according to the Dunn's *post-hoc* test.

Behavior	**Treament**			**F**	**P**
	Baseline	**Enrichment**	**Post-enrichment**		
FEE	19.26 ± 1.20	30.00 ± 3.12^{a}	11.73 ± 1.10^{a}	16.90	0.0002
VOC	37.06 ± 3.33	32.13 ± 3.13^{a}	38.73 ± 2.05^{a}	9.30	0.0096
WB	6.33 ± 0.78^{a}	1.53 ± 0.37^{a}	3.20 ± 0.89	10.83	0.0044
IN	21.66 ± 4.52	6.20 ± 1.63^{a}	28.33 ± 2.85^{a}	16.23	0.0003
FLY	0.93 ± 0.26	0.26 ± 0.15	0.40 ± 0.21	2.53	0.2818
ALP	2.13 ± 0.46	2.26 ± 0.76	2.20 ± 0.49	0.40	0.8187
PAC	2.66 ± 1.29	0.53 ± 0.36	0.20 ± 0.20	3.03	0.2194
WAL	0.86 ± 0.41	1.46 ± 0.59	0.93 ± 0.30	0.13	0.9355
HAB	20.13 ± 2.40	26.86 ± 3.88	31.40 ± 2.32	5.20	0.0743
RUB	0.46 ± 0.32	0.53 ± 0.29	----	0.70	0.7047
PEB	3.46 ± 1.12	2.20 ± 0.69	1.80 ± 0.51	2.63	0.2680
MRO	1.33 ± 0.60	1.66 ± 0.59	0.66 ± 0.41	1.63	0.4419
FPL	----	----	----	0.00	1.0000
II	2.26 ± 0.93^{a}	13.53 ± 2.93^{ab}	0.26 ± 0.26^{b}	14.23	0.0008
OTH	1.40 ± 0.41	0.80 ± 0.41	0.13 ± 0.13	4.43	0.1090

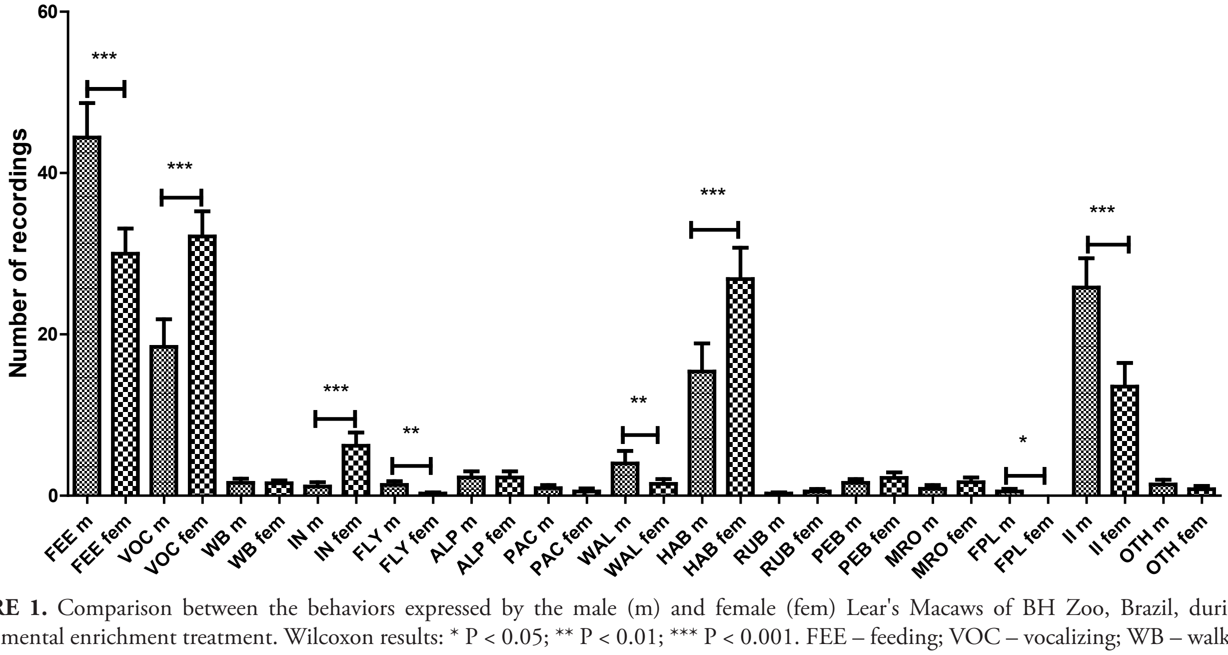

FIGURE 1. Comparison between the behaviors expressed by the male (m) and female (fem) Lear's Macaws of BH Zoo, Brazil, during the environmental enrichment treatment. Wilcoxon results: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. FEE – feeding; VOC – vocalizing; WB – walking on bars; IN – inactive; FLY – flying; ALP – allopreening; PAC – pacing; WAL – walking; HAB – hanging on bars; RUB – rubbing beak; PEB – pecking bars; MRO – manipulating rocks; FPL – feather plucking; II – interacting with items; OTH – other behaviors.

Comparison between the behavioral expressions of macaws in relation to the different environmental enrichment items

All behaviors expressed by the male were exhibited equally with all enrichment items. Female became more inactive when using the corn on the cob item, and expressed more frequently the behavior manipulating rocks when grapes were offered as enrichment (Figure 2). All other behaviors were expressed in the same amount by the female macaw, independent on the environmental enrichment item offered.

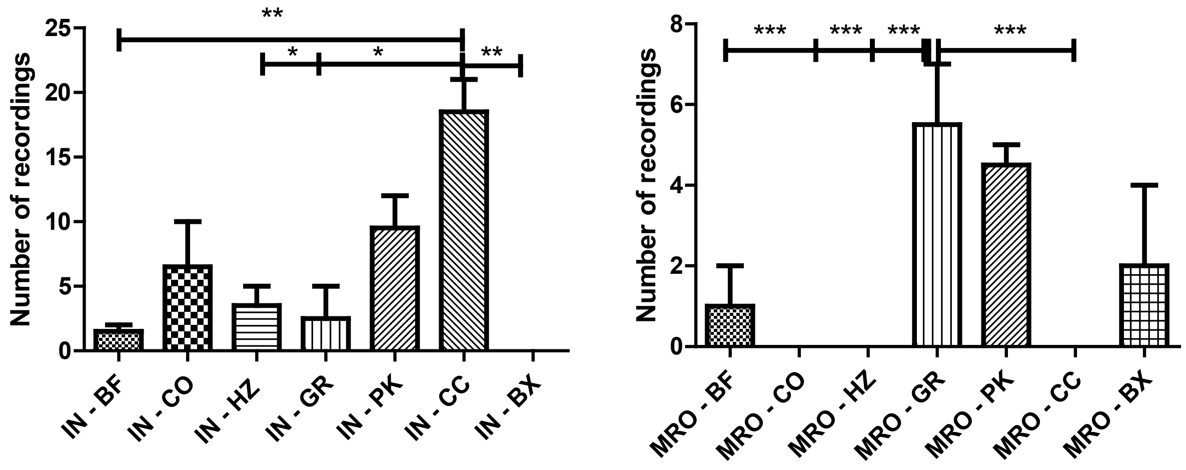

FIGURE 2. Comparison between the behaviors expressed by female Lear's Macaw of BH Zoo, Brazil, during the offering of the environmental enrichment items. Friedman results: * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$. IN – inactive; MRO – manipulating rocks; BF – bamboo forest; CO – coconut; HZ – hazelnuts wrapped in banana tree leaves; GR – grape; PK – pumpkins filled with hazelnuts; CC – corn on the cob; BX – cardboard boxes filled with grass and coconut.

DISCUSSION

Environmental enrichment proved to be positive for the male Lear's Macaw since its abnormal behaviors (pacing and feather plucking) decreased and its activity increased with its use. For the female Lear's Macaw, although the expression of the abnormal behavior pacing presented a slightly decrease during the enrichment treatment, this difference was not significantly, showing that the environmental enrichment items were not sufficient to modify this behavior.

The use of environmental enrichment for parrots is now common and results are in general positive, with birds increasing their activity and diminishing the exhibition of abnormal behaviors (Coulton *et al.* 1997, Meehan *et al.* 2004, Lumeij & Hommers 2008, Andrade & Azevedo 2011). Foraging increased significantly for both Lear's Macaws studied: despite the availability of their regular diet, macaws forage more upon the enrichment items, providing more evidence for contrafreeloading in psittacines, as observed by Coulton *et al.* (1997), Inglis *et al.* (1997) and Lumeij & Hommers (2008). The increase in activity levels could be related to the increase in food ingestion due to the food enrichments; more food ingested means more energy available for activities (Crocker *et al.* 2002). Decrease in inactivity has been related to the increase of welfare of birds (Azevedo & Faggioli 2001, Meehan 2002, Sgarbieiro 2009).

The abnormal behavior feather plucking is indicative of stress (Borges *et al.* 2011). Environmental enrichment decreased significantly this behavior for male Lear's Macaw (female did not express this behavior), reinforcing how important is to promote stimuli-rich captive environments for birds. Lumeij & Hommers (2008) showed that feather plucking was inversely related to foraging in African Gray Parrots (*Psittacus erithacus*). When food enrichment was offered to Grey Parrots, feather plucking almost disappeared. In nature, parrots forage for more than 6 h per day (Snyder *et al.* 1987), but in captivity this behavior can last less than 20 minutes, allowing parrots to spend more time exhibiting other behaviors, such as feather plucking, especially in cages without proper stimuli. The reduction of feather plucking by male Lear's Macaw indicated that his welfare increased.

Pacing, another abnormal behavior indicative of stress, decreased both for male and female Lear's Macaws, but not significantly during the enrichment treatment. The same result was found by Andrade & Azevedo (2011) when studying Turquoise-fronted Parrot (*Amazona aestiva*). This reduction may indicate that although items stimulated the expression of more normal behaviors, they were not capable to extinguish the expression of pacing, and new items should be tested.

The exhibition of walking on bars decreased during the enrichment treatment, what was also observed by Andrade & Azevedo (2011), and this result was related to the increase of interaction with items. Macaws walked to the enrichment items and spent long periods interacting with them.

Both macaws exhibited the behavior manipulating rocks. Meehan *et al.* (2004) stated that when psittacines live on non-enriched cages, they tend to chew bars, perches or rocks to wear their beaks. This activity occupy the time of birds, diminishing tediousness (Meehan *et al.* 2004). However, when expressed for long periods of time, this behavior can be considered abnormal. Assis (2013) observed that Cockatiel (*Nymphicus hollandicus*) living in enriched cages chew less than Cockatiels living in non-enriched cages. In the present study, male Lear's Macaw showed a significant decrease of the expression of the manipulating rock behavior, but the female showed no difference between treatments. We hypothesized that or the enrichment items used were not sufficient to wear the beak of the female, or this behavior was exhibited in an abnormal way (quantitatively abnormal). Behavioral budget and veterinary evaluations on the beak growth and size could be conducted to test these hypotheses. More abrasive environmental enrichment items could also be provided to help birds in beak wearing.

None enrichment items used in this study elicited different behaviors exhibited by male Lear's Macaw, but corn on the cob stimulated the female become more inactive than other items, and grape stimulated more manipulating rock than other items. Grape was one of the softest enrichment items used and the lack of abrasive characteristics may stimulated rock use. Corn on the cob was almost ignored by the female, which may be responsible for the increase in inactivity when this item was offered.

In conclusion, both food and physical enrichment influenced the behaviors expressed by Lear's Macaws, most positively, increasing macaw activity and decreasing the amount of abnormal behaviors expressed by the male. Male and female, however, differed in their responses to the enrichment items, thus, the results should be taken carefully. Additional items should be experimented and evaluated, aiming the extinction of abnormal behaviors for birds, but a routine of environmental enrichment, with items that elicits different birds senses and skills, should be implemented.

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A case of Straight-billed Reedhaunter (*Limnoctites rectirostris*: Furnariidae) nesting in Teasel (*Dipsacus fullonum*: Dipsacoideae)

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ABSTRACT: I present a case of a Straight-billed Reedhaunter (*Limnoctites rectirostris*) nesting in Teasel (*Dipsacus fullonum*), an exotic plant widely distributed in the study area in northeast of Buenos Aires province, Argentina. *Limnoctites* nests specifically in Eryngo (*Eryngium*), however I show here that it may also nest in other plants with fairly similar (thistle-like) characteristics, when in close proximity to *Eryngium*. The nest, active with one egg and two chicks, was destroyed by a rainstorm which toppled the Teasel. Since the structure did not fall completely to the ground the nestlings initially remained alive, but eventually perished, although the nest was not destroyed.

KEY-WORDS: Argentina, breeding, exotic plant, nesting behavior.

Nesting sites of the Straight-billed Reedhaunter (*Limnoctites rectirostris*: Furnariidae) are restricted to their preferred habitat: Eryngo (*Eryngium* sp.: Apiaceae), with *E. pandanifolium* and *E. eburneum* being the only host species identified to date (Daguerre 1933, Pereyra 1938, Narosky *et al.* 1983, Ricci & Ricci 1984, Babarskas 1998, Babarskas & Fraga 1998, Babarskas & López-de-Casenave 1998, López-Lanús *et al.* 1999, Babarskas *et al.* 2003). In each and every case the nests have been constructed on *Eryngium* and there is no mention of it using any other kind of plant.

On 21 November 2001 I found an active nest of *L. rectirostris* placed on a plant of Teasel (*Dipsacus fullonum*: Dipsacoideae). It was located in the Otamendi Nature Reserve (*Reserva Natural Estricta Otamendi*) located at 34°13'03.7''S; 58°53'33.5''W, in the borough of Campana, Buenos Aires province, Argentina. Teasel is an exotic plant, originally from Europe, which is widespread in South America. During 2001, in the Otamendi Reserve an explosive growth of Teasel occurred, forming patches as large as half a hectare. At the site where the nest was located, the flowering Teasel was within a one-hectare patch of Pampas Grass (*Cortaderia selloana*: Danthonioideae), forming a dense green thicket about 2 m in diameter, where the Pampas Grass subsided. A patch of *E. eburneum* grew next to the Teasel, intermixed in places with some Waxy-leaf Nightshade (*Solanum glaucophyllum*: Solanaceae).

This patch of mixed vegetation maintained well-differentiated communities, while the ground beyond descended very gradually towards a partly flooded area dominated by Bulrush (*Schoenoplectus americanus*: Cyperaceae). The section was delimited to the West, some 70 m away, by a wire fence and a water-filled drainage canal, covered by patches of Espadaña Reeds (*Zizaniopsis bonariensis*: Ehrhartoideae), lacking *E. pandanifolium*. It was at this place that an adult *Limnoctites* was seen feeding and I noted its direction of flight to the nest, which was subsequently located.

The nest construction material, the height above ground, its ovoid shape with a side entrance and its color were no different to previously-described nests (Ricci & Ricci 1984, Babarskas 1998, Babarskas & Fraga 1998, Babarskas & López-de-Casenave 1998, López-Lanús *et al.* 1999, Babarskas *et al.* 2003). However, instead of being placed in the center of a *Eryngium* with radial arrangement of its leaves, it was placed on a Teasel. The site chosen for its construction was next to several *Eryngium*, with the entrance facing towards them. The Teasel entirely supported the structure, with the nest resting on the base of one of its leaves (which regularly store rainwater and dew in the same way as occurs in *Eryngium*), and attached on one side to the spiny stem.

This way of supporting the nest is identical to nests on *Eryngium*, although rather than using three or four leaves to hold it down, they used just one attachment

- in this case the spiny, vertical and rigid main stem of the Teasel. On the whole, the height of the Teasel clump exceeded that of the surrounding *Eryngium*, but the nest, however, was placed close to the base such that its height above ground was equivalent to other nests previously recorded (*c.* 20 cm). Only one part of the nest, on the side opposite to the Teasel stem, had been secured to the end of an *Eryngium* leaf, providing only a secondary degree of support.

Due to the toppling of the Teasel by the wind before the discovery of the nest, as had equally happened to the rest of the Teasel patch, which had fallen in the same direction, the nest was found accidentally tilted and almost detached from the Teasel. This was caused by the windy and rainy weather of the previous day. Part of the attachment of the nest to the Teasel stem was slightly released, and the entrance to the nest was somewhat tiled downwards (main axis *c.* 45°). Inside it was found an unhatched egg and two active and apparently in good health chicks, with remiges visibly fledged but their skin was mostly bare (as they were indeed very young chicks). The end of the *Eryngium* leaf (flexible, especially at the tip) had not assisted in avoiding the fall of the nest (that had originally been vertical) together with the Teasel, which as a result had become twisted and bent. The weight of the structure, on account of the chicks and of the nest being wet on the outside, may have contributed to the tilting of the nest by gravity. Adults roamed the site throughout the time during data collecting, even feeding chicks after my notes.

When I returned to the site again on 25 November the nest was found empty, but showed no sign of destruction. I found a fecal sac on a Teasel leaf, one centimeter away from the structure. The wrapping and contents were still damp, suggesting that the chicks may have been predated upon only recently. I dismiss the fact that the chicks may have left the nest by themselves on account of the early fledging stage observed only four days earlier.

This record provides data for the first time of a *Limnoctites* nest constructed on a plant other than *Eryngium*, in this case exotic Teasel (*Dipsacus*) which, due to the spiny features of its structure and being located next to the usual *Eryngium* habitats of *Limnoctites* was used for this purpose. Nevertheless, the Teasel failed to properly support the nest in the event of a storm, and on being toppled by the wind, resulted in the detachment and instability of the structure. Although it continued to be used (as I found the adults still feeding the chicks), finally the nestlings perished.

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SHORT-COMMUNICATION

First description of the nest of White-browed Antpitta *Hylopezus ochroleucus*

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ABSTRACT: The reproductive biology of White-browed Antpitta (*Hylopezus ochroleucus*) is completely unknown. We describe a nest and nestlings found at the *Parque Natural Municipal do Distrito de Brejinho*, Araripe, Ceará. Brazil. The nest was a loose, shallow, open cup of sticks built into a tangle of branches and vines 0.5 m above the ground. The two nestlings were first seen on 5 April 2015, with closed eyes, bright orange bills and mouth linings, and dark grayish-pink skin, devoid of natal down, with contour feather tracts beginning development (under the skin). Six days later they had a dense coating of red-brown, wool-like down, their eyes were beginning to open, and secondary feathers were emerging. We compare our findings to related species and other members of the family Grallariidae.

KEY-WORDS: breeding biology, caatinga, Grallariidae, nestling, reproduction.

Following the recent description of the Alta Floresta Antpitta (*Hylopezus whittakeri*) and splitting of Snethlage's Antpitta (*H. paraensis*) from Spotted Antpitta (*H. macularius*) (Carneiro *et al.* 2012), there are currently 10 recognized species of *Hylopezus* antpittas (Remsen-Jr. *et al.* 2015). Unlike the more montane *Grallaricula* and *Grallaria* antpittas, whose reproductive biology has received a good deal of recent attention (see Greeney *et al.* 2008, Greeney 2012a, Greeney & Jipa 2012), the breeding of lowland *Hylopezus* antpittas is relatively poorly known (Krabbe & Schulenberg 2003). Nests are properly described for only three of the ten species: Streak-chested Antpitta (*H. perspicillatus*; Skutch 1969, Pollock 2013); Spotted Antpitta (Tostain 1986); Masked Antpitta (*H. auricularis*; Maillard-Z. 2012, Greeney 2014a). Kirwan (2009) made brief observations of an inactive nest, apparently of Speckle-breasted Antpitta (*H. nattereri*), but the reproductive biology of White-browed Antpitta (*H. ochroleucus*) is completely unknown (Greeney 2014b).

White-browed Antpitta was, for many years, treated as conspecific with Speckle-breasted Antpitta, despite striking differences in voice, plumage, habitat and distribution (Whitney *et al.* 1995). Recent molecular studies, however, suggest that Speckle-breasted Antpitta is more closely related to Masked Antpitta, while White-browed Antpitta is most likely sister to the Spotted Antpitta "species group" (Carneiro & Aleixo 2012). White-browed Antpitta is a Brazilian endemic, inhabiting the semi-deciduous and Caatinga woodlands of northeast Brazil, from Ceará southward to Minas Gerais states. As it is known from few areas that are formally protected (Anjos 2002, Dornelas *et al.* 2012), it is currently considered "Near Threatened" by BirdLife International (2015). Here we provide the first information on the reproductive biology of White-browed Antpitta, based on a nest found in the Parque Natural Municipal do Distrito de Brejinho, Araripe, Ceará (7°13'28"S; 39°59'36"W, 690 m a.s.l.).

On 25 March 2015, at 10:45 h, JLGL and TT received a response from a White-browed Antpitta after playing a recording of its vocalization. When the responding individual continued to vocalize, giving its full song ("*whu-whú, whu- whú-whu-whu-wheú-wheú-wheú-wheú-wheú-wheú-wheú-wheú*" following Ridgely & Tudor 2009), they left the trail and discovered that the adult was responding while seated on a nest only 10 m from the trail (Figure 1). After taking several pictures from a distance, they left the area without flushing the adult. On 5 April, at 10:30 h, JLGL flushed an adult from the nest as he approached, revealing the presence of two young nestlings (Figure 2). The adult dropped from the nest and disappeared silently into the undergrowth. The young had their eyes still closed and were completely devoid of natal down. Their skin was dark grayish-pink and their bills were bright orange. Contour feather tracts were visible under the skin. Although there are no concrete data available for other *Hylopezus*, based on direct experience with the nestlings of *Grallaricula* (HFG, pers. observ.), which also lack natal down (Greeney 2012b), we estimate that the young were no more than one day old. On 11 April, at 08:20 h, JLGL again flushed a brooding adult from the nest. The adult's response, however, was very different than on the previous visit. This time, after dropping to the ground below the nest, the adult dropped its wings to the ground and ran back and forth in small semi-circles, dragging its wings through the leaf litter. It remained within 1 m of JLGL and continued to feign injury during the brief period he remained at the nest. This time, the nestlings were well-covered in dense, wool-like down feathers. The feathers of the capital and spinal tracts were dark rufescent brown, those of the humeral tracts were slightly paler, and the feathers of the femoral, pelvic spinal, and ventral abdominal tracts were pale rusty-buff. Flight feather pins were emerged through the skin roughly 1.5–2 cm, with the primary feather sheaths unbroken and those of the secondaries with 1–3 mm of bright ochraceous-buff feather vanes exposed at their tips. The nestlings' eyes were just beginning to open, their bills were still bright orange, but with the inflated rictal flanges slightly paler, more yellow-orange. We did not visit the nest again.

FIGURE 1. Adult White-browed Antpitta *Hylopezus ochroleucus* at its nest, 25 March 2015, Araripe, Ceará, Brazil. Photo: Thiago Tolêdo.

The nest itself was a rather frail-looking, shallow cup built of loosely-woven sticks, leaf petioles, and thin vines (Figure 2), falling into the "low cup/base" category of Simon & Pacheco (2005) and overall rather similar to the nests of most Columbidae. It did not have a well-defined inner cup lining, but thinner, more flexible leaf petioles appeared to be more abundant within the internal portions. It was built 0.5 m above the ground and supported from below by 5–6 thin, overlapping lianas and branches which were partially held up by a dead, 3–4 cm-diameter stick angled at roughly 45° below the tangle. The nest was fairly exposed above, with only sparse vegetation more than 1 m above the nest providing shade. The surrounding forest was typical deciduous Caatinga habitat with a relatively dense understory of small dicots and tangled vines. It was in arid, uneven, hilly terrain, more than 500 m from the nearest riparian area. In order to minimize disturbance to the nest, we did not measure it directly. Instead, using a total adult length of approximately 13 cm (Greeney 2014b), we estimate that the nest was 12–15 cm in diameter externally, with some of the longer twigs extending beyond the bulk of the nest an additional 4–5 cm. We estimate that the total external height (thickness) of the nest was 5–7 cm, the internal diameter was 6–7 cm, and the internal depth was 3–4 cm.

FIGURE 2. Unfeathered nestlings in the nest of White-browed Antpitta *Hylopezus ochroleucus*, 5 April 2015, Araripe, Ceará, Brazil. Photo: Jefferson Luis Gonçalves de Lima.

The nest of White-browed Antpitta, in being a broad, rather shallow cup somewhat poorly supported from below by overlapping small supports, is similar in placement and general shape to those described for other *Hylopezus* (Krabbe & Schulenberg 2003). Compositionally, our nest of White-browed Antpitta appears nearly identical to that of the single described nest of Spotted Antpitta, described by Tostain (1986) as being very sparsely-built of thin twigs, having little or no inner lining, and bearing resemblance to the nests of columbids. Nests of the other two species of *Hylopezus* with published information appear to differ in including more material (especially humid, decaying leaves) and by having at least a rudimentary lining of the inner cup (flexible rootlets or thin petioles) (Skutch 1969, 1981, Robinson *et al.* 2000, Maillard-Z. 2012). It appears that the nest of *H. nattereri* (Kirwan 2009, A. Bodrati, pers. comm.) may be most similar to that of *H. ochroleucus*, but show some characters resembling the nests of *H. perspicillatus* and *H. macularius*.

Streak-chested Antpitta, the only *Hylopezus* with a previously published description of its nestling, apparently hatches completely devoid of natal down (Skutch 1969, 1981). There is no published description of the older nestlings for any *Hylopezus* species, but the nestlings of Streak-chested Antpitta pictured in Pollock (2013) appear nearly identical to the nestlings observed here, in their covering of wool-like, reddish-brown down and bright orange bills. Interestingly, the lack of natal down and subsequent development of dense reddish-brown down is a character that, so far as is known, *Hylopezus* shares with *Grallaricula* (Greeney *et al.* 2004, Greeney & Miller 2008, Niklison *et al.* 2008, Greeney & Jipa 2012, Greeney *et al.* 2012). Thrush-like Antpitta (*Myrmothera campanisona*) also hatches with a bright orange bill and without down (Gustavo Londoño, pers. comm.) and, though currently undescribed, should *Myrmothera* nestlings later develop a similar coating of reddish down, then nestling appearance and development would appear to be fairly conserved between these three genera. These shared ontogenetic characters provide strong support for the hypothesis that *Hylopezus*, *Grallaricula*, and *Myrmothera* form a sister clade to the remaining antpitta genus, *Grallaria* (Rice 2005). Unlike members of this clade, the nestlings of *Grallaria* hatch with natal down and their secondary coating of nestling down is somewhat variable in color between species (Greeney *et al.* 2008, Greeney 2012b). Finally, the shallow, saucer-like form of the nest of White-browed Antpitta provides further evidence that *Hylopezus* also build nests similar to *Grallaricula* (Greeney *et al.* 2008) and *Myrmothera* (Tostain & Dujardin 1988, Barber & Robbins 2003, Greeney *et al.* 2005), but unlike the deep, bulk cup nests of *Grallaria* (Greeney *et al.* 2008).

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ARTICLE

Is hearing believing? Patterns of bird voice misidentification in an online quiz

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ABSTRACT: This study aims to uncover patterns of species identification error in bioacoustic surveys of central Amazon birds. To quantify errors, we developed an on-line quiz based on vocalizations of an undisclosed set of 41 antbird (Thamnophilidae) and woodcreeper (Dendrocolaptinae) species. We invited experts to answer the quiz and obtained 820 answers from 20 participants. The answers were compared to the results of a binomial experiment with a success probability of 0.5; *i.e.* we examined whether participants identified species correctly more often than expected by the toss of a coin with a 50% chance of producing the right identification. We also examined whether species were correctly identified more often than expected under a similar coin toss experiment. Quiz answers were compiled in a triangular matrix showing species ranked by taxonomic order on both axes. From the triangular matrix we can ask whether closely-related species were mistaken for each other, *i.e.* confused, more often than distantly-related species. We tested this hypothesis with a null model approach that compared the mean taxonomic distance between confused species in the observed matrix to the distribution of mean taxonomic distances between confused species in 10,000 randomized matrices. Finally, we drew a dendrogram to represent the similarity between species with regard to the distribution of identification errors. The 20 participants who took the quiz showed substantial variation in their ability to identify species correctly. Fourteen species were correctly identified more often than expected at random, while only one was misidentified more often than expected at random. The observed mean distance between confused species was smaller than all of the mean distances from the randomized, null-model matrices, indicating that confusions are more frequent between closely related species than between distant ones.

KEY-WORDS: bioacoustic sampling, bird vocalizations, central Amazon, Dendrocolaptinae, false positives, misidentification, Thamnophilidae.

INTRODUCTION

Bioacoustic monitoring of wildlife based on autonomous recording units has seen remarkable technical progress in the last decade, both in aquatic (Sousa-Lima *et al.* 2013) and in terrestrial (Fristrup and Mennitt 2012) environments. Such progress has made it easier to obtain presence/absence data for species with conspicuous vocalizations like some insects, anurans, and a large variety of birds. Autonomous recording combines four features that make it a particularly cost-efficient sampling technique: the possibility of sampling in all directions from one observation point; relatively high detection probability when visibility is low; the possibility of simultaneously sampling many sites with moderate to low effort; and, last but not least, a permanent record of animal signals that can be easily reviewed to correct doubtful identifications. In spite of its convenient features, autonomous recording is still liable to errors, like all field-sampling techniques. Acoustic recordings may easily miss species that are present at a site (false negatives), or they may lead to identification errors, which can result in the mistaken record of a species that is actually not present at a site (false positives).

There is a large body of literature offering modeling solutions for estimating biological parameters based on data with false-negative errors (MacKenzie *et al.* 2002). False positive errors, on the other hand, have received relatively less attention, and the analytical solutions to deal with them are in an earlier stage of development (Miller *et al.* 2013). Nonetheless, the relevance of false positives is evident, especially in site-occupancy surveys, where they can lead to measurable errors in occupancy estimates even when they represent as little as 1% of detections (McClintock *et al.* 2010). Occupancy models that take false positive errors into account, in cases where some amount of identification error is expected, produce substantially different, less biased estimates of occupancy than those models that ignore false positives (Miller *et al.* 2011).

Perhaps the greatest source of false positive sampling errors in bioacoustic data is the great similarity between many species' sounds (McClintock *et al.* 2010). This similarity, compounded by other factors such as lack of visual information and various types of background noise, results in some unavoidable amount of identification error (Farmer *et al.* 2012). There are many possible causes for false-positive errors, but even when causes are unknown, it is possible to improve site-occupancy and species distribution inferences if we have some notion of which species are easier or harder to identify (Miller *et al.* 2011). Knowledge of how easy it is to mistake one species for another can also be useful in novel probabilistic methods of taxonomic classification (Somervuo *et al.* 2016).

In the present study, we asked a group of experts to identify vocalizations of 41 Amazon Forest bird species, and used their answers to quantify which species were most likely to be mistakenly identified. In doing this, we addressed three specific questions: a) To what extent are experts capable of correctly identifying bird sounds? b) Which species are more difficult to identify? and finally, c) Is the taxonomic distance between two species related to the probability of mistaking one of those species for the other?

We based our survey of expert identifications in an on-line quiz which presented users with recordings of bird species occurring in the Biological Dynamics of Forest Fragments Project (BDFFP) study area, on the southwest end of the Guiana shield region, 80 km north of the city of Manaus, Brazil (2.4°S; 59.9°W). This area is particularly fit for a study about false positives in bioacoustic sampling because it has a rich avifauna (Cohn-Haft *et al.* 1997); it has a very good reference collection of bird vocalizations (Naka *et al.* 2008); and its bird fauna is relatively well known, compared to other regions of the Amazon. The combination of these three factors facilitates the emergence of a fairly large community of experts who can identify regional birds from their vocalizations. Although the study area has about 400 bird species, this study will focus on a small subset of species to construct a bird identification quiz that represents a meaningful part of the avifauna but is short enough to engage a reasonable number of collaborating experts.

METHODS

Construction of a vocalization library

The first step of this study was to assemble a vocalization library with species from the family Thamnophilidae (antbirds) and subfamily Dendrocolaptinae (woodcreepers, family Dendrocolaptidae) occurring in the BDFFP area. We chose these two groups for four reasons: i) they are almost entirely represented by understory birds, and thus easier to hear and record; ii) most of the species in these groups are common in Amazonia, very vocal, and well known; iii) their songs are rather simple and stereotypical when compared to oscine passerines and iv) they have relatively well-resolved phylogenies (Irestedt *et al.* 2004, Moyle *et al.* 2009). The latter attribute allows us to ask if taxonomic distance between two given species bears any relationship with the probability of mistaking one of those species for the other.

The recordings used in this study were obtained from 1) the Ferraz Lab autonomous recordings database, 2) the Xeno-Canto Foundation on-line database, and 3) from the commercially available CD “voices of the Brazilian Amazon” (Naka *et al.* 2008). To minimize sound quality differences within the quiz, we individually edited recordings using software Adobe Audition 5.5 to standardize duration, background noise and signal amplitude. By doing this, we aimed to ensure that variations in identification success were determined mostly by variation in characteristics of the vocalizations. Nevertheless, in order to present quiz users with an aural experience that was somewhat faithful to that experienced in the field, we did not attempt to completely eliminate background noise and other imperfections. In the end, our quiz library contained 82 vocalizations from 41 species (13 woodcreepers and 28 antbirds), with two different vocalizations for each species. One recording of *Thamnophilus punctatus* was removed from the study after the quiz application because six observers raised doubts about the possibility of correctly identifying the vocalization.

On-line quiz

In order to quantify identification errors, we designed an on-line quiz using the software Wondershare Quiz Creator. The quiz consisted of 41 questions, selected at random from a pool of 82. Each question presented an audio recording and a sonogram, which illustrate the vocalization of one focal species. To answer each question, experts had to listen to the recording and fill a blank space with the name of the species that they believed to be featured in the recording. Since the 41 questions in every test are picked at random, the number of questions per species and the number of species heard in a single test are subject to some variation. However, random selection of questions was done without replacement, thus preventing any species from being heard more than twice in one test. To ensure that the quiz was done in one take, each user had a time limit of 30 minutes to finish answering all the questions. Since the quiz software does not check for typing mistakes, we developed a script in the R package (R Development Core Team 2013) that compares expert answers to a list of species from the study area and corrects typing mistakes. Corrections were applied only in cases where the given answer was five or less characters away from one species on the list. Answers that were more than five characters away from every species in the list were flagged for manual verification.

Quiz participants

The search for quiz participants followed an e-mail thread that started with a collaboration request, instructions to complete the on-line quiz, and a brief description of the study goals. The request was sent to a list of thirty experts, defined here as individuals with professional or graduate-level experience in identifying Amazon Forest birds by their vocalizations. Everyone on this list was personally known to us as a competent field researcher or recommended to us by ornithologists with more than 25 years of experience identifying Amazon bird vocalizations. We had a total of 20 quiz takers, which inevitably had variable skills in identifying the study species: two were professional field guides, nine were graduate students, and nine were professional ornithologists. Some participants had more experience in visual than aural identification while others knew Amazon bird vocalizations well but not necessarily the vocalizations from the study area. These sources of variability in observation skill are unavoidable and contribute to the misidentification that we want to study.

Binomial analyses of identification data

We measured the performance of each expert in identifying vocalizations by the proportion of quiz questions that he or she answered correctly. To sort performances between exceptionally good, average, or exceptionally bad, we performed a binomial test. The test is based on the null hypothesis of equal probability of getting answers right or wrong. The null scenario is equivalent to assuming that, in each question, the participant tosses an unbiased coin that has a right answer on one side and a wrong answer on the other. The binomial test quantifies the probability P of such participant obtaining a result just as extreme, or more extreme than the one obtained in the quiz. “More extreme” means “with a greater number of correct answers”, or “with a greater number of wrong answers”, depending on which end of the distribution the participant falls. We obtain P from an implementation of the Binomial distribution formula in the R core Package (R Development Core Team 2013), and apply a two-tailed approach to testing the null hypothesis. When the probability of getting a number of correct answers greater than or equal to the observed was ≤ 0.025 (*i.e.* performance lies in the upper tail of our distribution), we considered that performance exceptionally good. On the other hand, when the probability of getting a number of correct answers smaller than or equal to the observed was ≤ 0.025 (*i.e.* performance lies in the lower tail of our distribution), we considered the performance exceptionally bad and excluded the answers of the observer from subsequent steps in the analysis. Our decision to exclude responses from experts with exceptionally bad performance is an attempt to direct the subsequent part of our analysis to identification mistakes that stem from the similarity between vocalizations and not so much from the observer's lack of previous contact with the species. In all cases where $P > 0.025$, we considered that the participant had a standard performance.

As a second step in our study, we compared difficulty of identification across species (using the answers from participants with standard or exceptionally good performance). This comparison followed the same approach as the comparison between participants, with the difference that here, the number of coin tosses in the binomial distribution is the total number of times, N, that the quiz presented any expert with a vocalization of the focal species. Since quiz questions are randomly sampled, the value of N was slightly different among species (mean = 15.82, SD = 4.49). In the comparison among species, the two-tailed test based on the binomial distribution allowed us to identify which species are particularly difficult or particularly easy to identify. A value of $P \leq 0.025$ means it is highly unlikely that a species would present a result as extreme as, or more extreme than observed, under the null hypothesis that the probability of a correct identification equals 0.5.

Multinomial analysis

The binomial analyses described above looked only at whether quiz answers were right or wrong. In the multinomial part of our methods, however, we take advantage of the fact that, even though there is only one way to be right, there are many different ways of being wrong. At the most superficial level, we considered three kinds of wrong answers: blank answers, where users did not write anything or declared that they could not answer; off-site answers, where users named a species that does not occur in the study area; and plain-wrong answers, where users named a species which does occur in the study area but does not appear in the recording. From here on, in evaluating the frequency of confusions between species of the BDFFP area, we restrict our analysis to right answers and plain-wrong answers alone. Furthermore, our quantification of confusions is symmetric, *i.e.* an answer where the expert writes the name of species *b* while listening to the voice of species *a*, counts as a confusion between *a* and *b* in the same way as an answer where the expert writes the name of species *a* while listening to the voice of species *b*. The number of confusions between species *a* and *b* is the sum of confusions in both directions.

Correct and plain-wrong answers by all experts with standard and exceptionally good performance were compiled in a triangular matrix with the same list of species in rows and columns. Cells along the diagonal of this triangular matrix show the number of times each species was correctly identified; cells in the sub-diagonal show the number of confusions between the respective row and column species. We sorted species along columns and rows according to taxonomic relatedness, following the classification by Remsen *et al.* (2014). Two species in consecutive positions on the matrix are separated by one unit of taxonomic distance and are taxonomically closer than two species separated by one or more positions in the list. To investigate whether it was easier to confuse taxonomically close than taxonomically distant species, we used a null model approach (Gotelli & Graves 1996) where we compared the average distance between confused species in the observed confusion matrix (measured in positions in the ranking) to the distribution of average distances between confused species in a set of 10,000 randomized, or "null", confusion matrices.

The null model approach tests the null hypothesis that relatedness between two species has no effect on the probability of confusion, *i.e.* the observed distance does not significantly depart from the distribution of random distances. The lower the observed distance relative to the distribution of "null" distances, the easier it is to reject the null hypotheses and the stronger the support for the idea that relatedness does influence confusion. The randomization algorithm that generates the null matrices has two key restrictions: 1) the number of wrong answers per species is kept constant across random matrices; and 2) the probability that each species is picked as a wrong answer is also kept constant across randomizations. The first restriction ensures that randomizations do not change the basic difficulty of correctly identifying each species. The second restriction is a conservative choice to ensure that if observers have some species bias when offering wrong answers, that bias won't be lost in the null matrices. We experimented with other, less restrictive, algorithms and obtained qualitatively similar results.

To get a quantification and graphic presentation of the possibilities of confusion between species we generated a dendrogram based on the observed identification errors. To transform the number of confusions between two given species into a similarity measurement, we converted our confusion matrix into a matrix of Canberra distances between species (Lance and Williams 1967). The Canberra distance between species vectors $\boldsymbol{x}$ and $\boldsymbol{y}$ are given by:

$$d^{CAN}(\boldsymbol{x},\boldsymbol{y}) = \frac{n}{NZ} * \sum_{i=1}^{n} \frac{|x_i - y_i|}{|x_i| + |y_i|}$$

Where $\boldsymbol{x}$ and $\boldsymbol{y}$ are species-specific identification vectors with length equal to the total number of species, *n*, and elements representing the number of times that the vocalizations of $\boldsymbol{x}$ and $\boldsymbol{y}$, respectively, were identified as vocalization of species $i = 1, \ldots, n$.

$$\boldsymbol{x} = (x_1, x_2, \ldots, x_n)$$

$$\boldsymbol{y} = (y_1, y_2, \ldots, y_n)$$

The denominator NZ in the distance formula is the number of coordinate pairs (x_i, y_i) that are different from (0,0); within the sum, terms that are divided by zero are treated as zero. We used Canberra distances as implemented in the R stats package (R Development Core Team 2013), where multiplication by the *n*/NZ factor treats cases where both x_i and y_i are zero as missing data. This factoring is useful for ensuring that two species will not be deemed more similar only because they were never confused with a third species. With Canberra distances in hand, we represented the confusions among species in the form of a dendrogram, where our study species are positioned according to information in the confusion matrix of Figure 1. We drew the dendrogram using a Lance-Williams clustering analysis (Lance and Williams 1966) with the complete-linkage clustering method (farthest neighbors clustering). In the process of drawing our dendrogram, we tested different combinations of inter-specific distance metrics and clustering algorithms. None of the distance metrics commonly used to construct phylogenies was designed for the type of data in our confusion matrix, which has a large number of values that are equal or close to zero. In the end, we settled on the Canberra distance with a Lance-Williams clustering algorithm because this option gave us the simplest results, which could be easily related to the distribution of confusions observed in Figure 1. Our use of Canberra distances is also justified by the frequent use of this metric as a dissimilarity index on ranked lists and other strictly positive, discrete variables in computer science (Jurman *et al.* 2009).

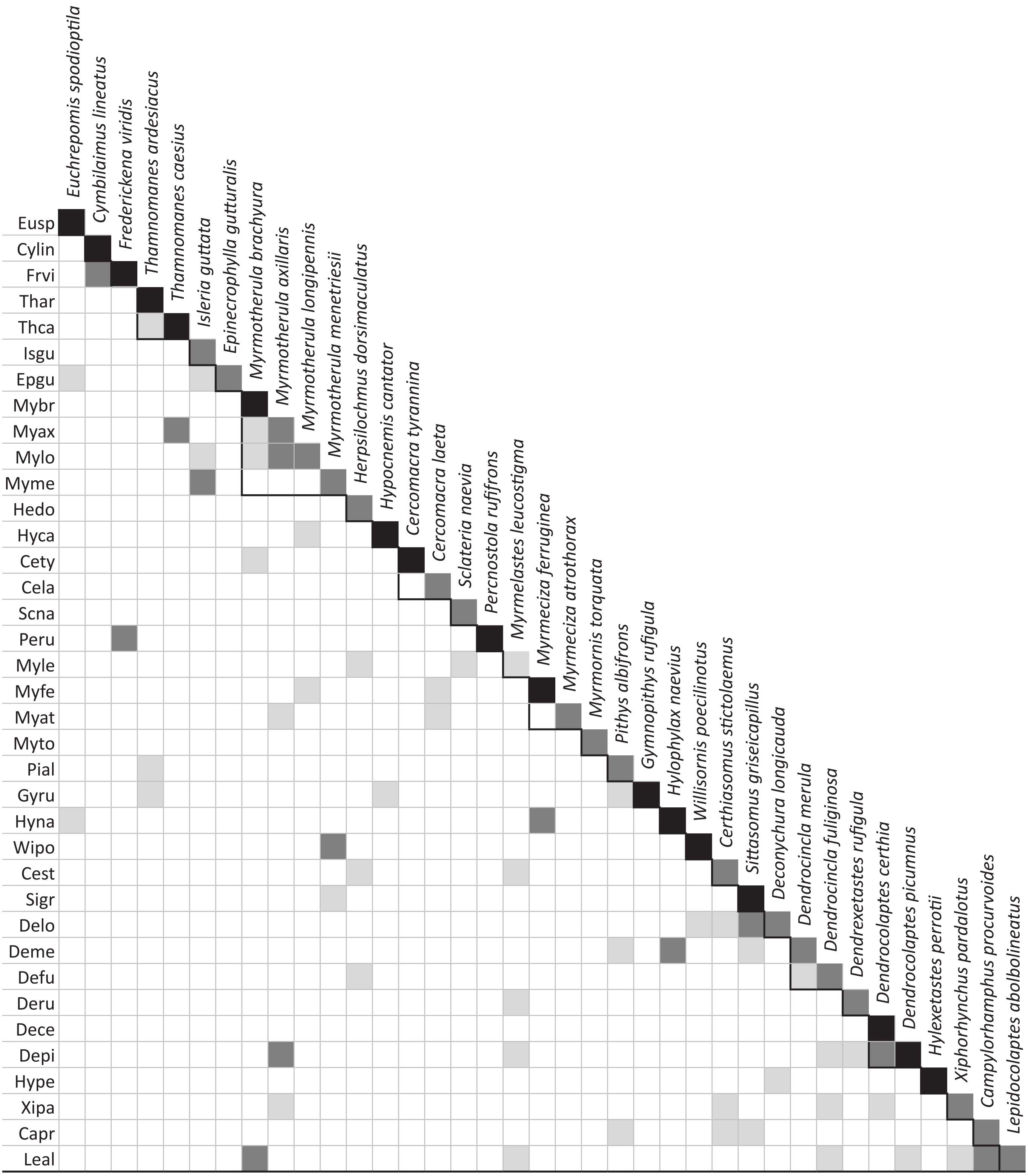

FIGURE 1. Triangular confusion matrix summarizing the quiz results, with correct answers on the diagonal and wrong answers to the left of the diagonal. Species are sorted in taxonomic order across rows and columns; codes on the left are abbreviations of the species names on the right. The color of each cell corresponds to the number of times the column species was identified as the corresponding row species: white stands for 0, light grey for 1, dark grey for values ≥ 2 and ≤ 10, and black for values > 10. Confusions between species of the same genus are outlined by a thin black line.

RESULTS

We obtained the collaboration of 20 experts, each of whom took the bird identification quiz once. The joint results from the 20 tests returned 820 answers. Out of those, 469 (57%) were correct identifications, 179 (22 %) were left blank, 128 (16%) were mistaken by species that occur in the study area and the remaining 44 answers

(5%) were mistaken by other species that do not occur in the study area. Expert performances in the test varied substantially: seven (35%) had an exceptionally good performance, and four (20%) had an exceptionally poor performance, *i.e.* they answered correctly less often than would be expected in a binomial experiment with 0.5 probability of guessing a question right. The remaining 10 participants performed at the standard level (Table 1).

Upon excluding answers from participants with an exceptionally poor performance, we summarized the results by species, as shown in Table 2. Evidently, some species are easier to identify than others: out of 41 species tested, 14 (34%) were identified correctly much more often than if the answer were determined by the toss of a fair coin (including *Cymbilaimus lineatus*, *Thamnophilus murinus* and *Thamnophilus punctatus*, which were always correctly identified by all observers). Only one species, *Myrmelastes leucostigma*, was so hard to identify that the experts got the species right less often than expected by the toss of a fair coin. For the 26 remaining species (64%) we found no evidence of difference between the outcome of the test and the results of a Binomial experiment with probability of success equal to 0.5. That is, the majority of species were neither extremely easy nor extremely hard to identify.

The null model analysis of the confusion matrix (represented in Figure 1) shows that confusions were more frequent between taxonomically closer species than between relatively distant ones. The observed mean distance between confused species of 5.8 taxonomic units was lower than every single one of the 10,000 simulated mean distances (Figure 2). The probability of obtaining a distance as low as the observed one is thus lower than 0.0001; we reject the null hypotheses with P < 0.0001. The two species that were most frequently confused were the antbirds *Willisornis poecilonotus* and *Myrmotherula menetriesii* with six confusions out of 38 times in which either species was heard (16%). The dendrogram generated from the Canberra distance matrix is consistent with the confusions found in the triangular matrix (Figure 3). Thirteen out of 18 (72%) branches on the dendrogram correspond to confusion points on the triangular matrix. Note how the antbirds *Isleria guttata* and *Myrmotherula menetriesii* stand out for being the pair of species separated by the shortest Canberra distance.

TABLE 1. Bird-voice identification results for the 20 experts involved in this study, showing the number of blank answers ("Blank"), answers with a species that does not occur in the study area ("Off-site"), and answers with a wrong species from the study area ("Plain wrong"). The column "Correct" shows the number of correct answers. "P" indicates the binomial probability of obtaining a number of correct answers as extreme or more extreme than the observed, given the total number of trials and a probability of success equal to 0.5. Rows F, J, K, L, O, R, S, and T add to 40, and not to 41 trials, because they included the *T. punctatus* recording that was removed from the analyses.

Observer	Blank	Off-site	Plain wrong	Correct	P
Observer A*	23	0	8	10	0.0007
Observer B	5	3	9	24	0.1744
Observer C**	0	0	1	40	<0.0001
Observer D	11	0	4	26	0.0586
Observer E*	3	22	7	9	0.0002
Observer F	14	4	6	16	0.1340
Observer G*	25	0	9	7	<0.0001
Observer H	16	1	5	19	0.4372
Observer I*	22	1	8	10	0.0007
Observer J**	4	3	4	29	0.0032
Observer K**	4	1	2	33	<0.0001
Observer L**	0	1	1	38	<0.0001
Observer M**	5	0	7	29	0.0057
Observer N	8	0	10	23	0.2663
Observer O**	1	1	3	35	<0.0001
Observer P	11	1	5	24	0.1744
Observer Q	11	3	4	23	0.2663
Observer R	14	0	4	22	0.3179
Observer S**	0	0	13	27	0.0192
Observer T	1	4	11	24	0.1340

* Right answer probability significantly lower than 0.5 in a two-tailed test with P = 0.05.
** Right answer probability significantly higher than 0.5 in a two-tailed test with P = 0.05.

TABLE 2. Summary of species-specific quiz results, showing the number of times each species was left in blank (“Blank”), mistaken for a species outside the study area (“Off-site”), or mistaken for a species from the study area (“Plain wrong”). Columns “Correct” and “n” show the number of correct answers and the number of times the species was heard by participants, respectively. “P” is the binomial probability of obtaining a number of correct answers as extreme, or more extreme than observed, given n attempts and a probability of success equal to 0.5.

Species	Blank	Off-site	Plain wrong	Correct	n	P
Euchrepomis spodioptila	3	1	1	12	17	0.0717
*Cymbilaimus lineatus***	1	0	0	13	14	<0.0001
Frederickena viridis	1	0	4	14	19	0.0318
*Thamnophilus murinus***	0	0	0	18	18	<0.0001
*Thamnophilus punctatus***,***	0	0	0	8	8	0.0039
Thamnomanes ardesiacus	6	0	0	16	22	0.0262
Thamnomanes caesius	7	0	3	12	22	0.4159
Isleria guttata	3	1	5	2	11	0.0327
Epinecrophylla gutturalis	4	2	1	10	17	0.3145
Myrmotherula brachyura	7	0	2	13	22	0.2617
Myrmotherula axillaris	0	0	6	8	14	0.3953
Myrmotherula longipennis	0	1	5	6	12	0.6128
Myrmotherula menetriesii	4	0	4	8	16	0.5982
Herpsilochmus dorsimaculatus	4	0	2	7	13	0.5000
Hypocnemis cantator	6	0	0	12	18	0.1189
*Cercomacra cinerascens***	2	0	0	18	20	0.0002
*Cercomacra tyrannina***	1	2	0	18	21	0.0007
Cercomacra laeta	1	0	2	8	11	0.1133
*Sclateria naevia***	0	0	1	8	9	0.0195
*Percnostola rufifrons***	0	0	2	15	17	0.0012
*Myrmelastes leucostigma**	3	0	5	1	9	0.0195
*Myrmeciza ferruginea***	6	0	0	18	24	0.0113
Myrmeciza atrothorax	6	0	1	8	15	0.5000
*Myrmornis torquata***	0	2	1	10	13	0.0461
Pithys albifrons	6	0	4	6	16	0.2272
*Gymnopithys rufigula***	2	1	2	17	22	0.0084
Hylophylax naevius	2	0	3	13	18	0.0481
Willisornis poecilinotus	5	1	5	11	22	0.5841
Certhiasomus stictolaemus	2	4	2	4	12	0.1208
*Sittasomus griseicapillus***	0	0	3	18	21	0.0007
Deconychura longicauda	4	0	3	7	14	0.6047
Dendrocincla merula	2	0	5	7	14	0.6047
Dendrocincla fuliginosa	3	1	3	8	15	0.5000
*Glyphorynchus spirurus***	1	0	0	14	15	<0.0001
Dendrexetastes rufigula	6	2	0	10	18	0.4072
*Dendrocolaptes certhia***	1	1	2	13	17	0.0245
Dendrocolaptes picumnus	3	1	3	13	20	0.1316
*Hylexetastes perrotii***	0	0	1	11	12	0.0032
Xiphorhynchus pardalotus	2	0	3	10	15	0.1508
Campylorhamphus procurvoides	0	0	1	2	3	0.5000
Lepidocolaptes albolineatus	2	1	5	5	13	0.2905

* Difficult species, with a number of correct answers lower than expected in a two-tailed test with significance level P = 0.05.

** Easy species, with a number of correct answers higher than expected in a two-tailed test with significance level P = 0.05.

*** One of the *T. punctatus* vocalizations used in the study had its identification questioned by experts and was removed from results.

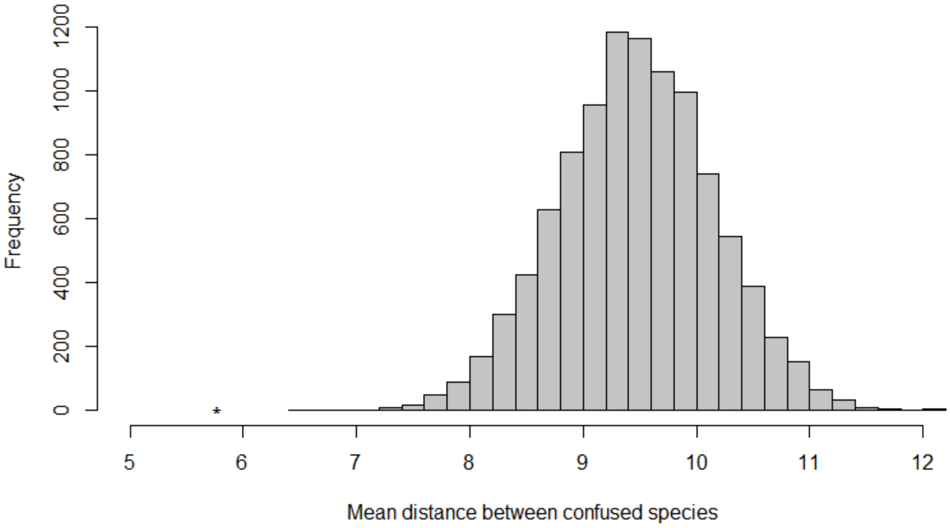

FIGURE 2. Observed mean taxonomic distance between confused species (*) and histogram of the simulated mean distances between confused species in 10,000 randomized matrices. Values on the *y-axis* indicate the number of random matrices with a mean distance between confused species equal to the corresponding value in the *x* axis.

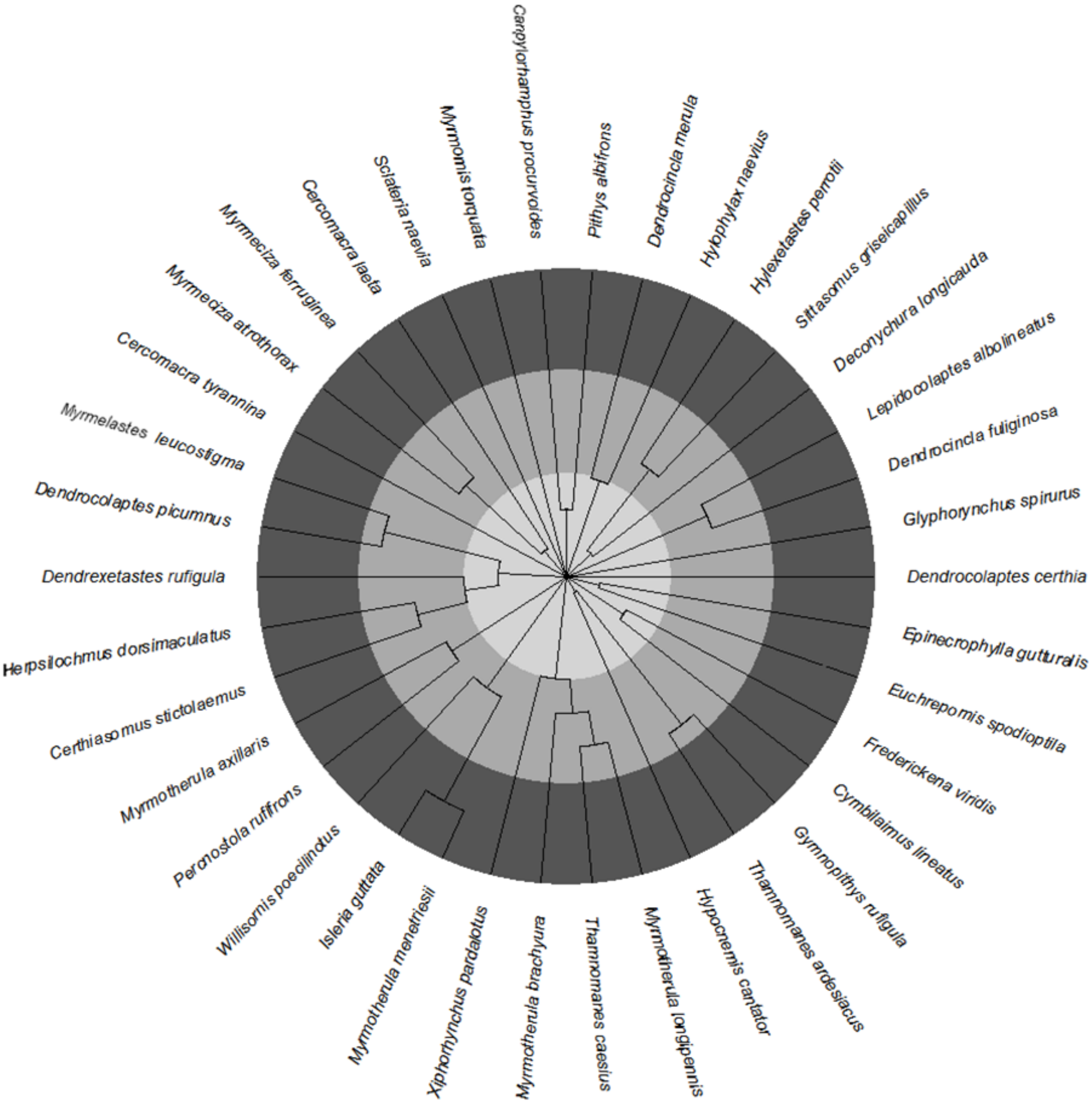

FIGURE 3. Confusion dendrogram based on the Canberra distance between species and Lance-Williams clustering algorithm. The distance from a branching point and the outer edge of the graphic is proportional to how easily observers could tell the two branches apart. Branching points in the dark gray area separate species that were frequently confused, while branching points in the light gray area separate easily distinguishable species or groups of species. For simplicity, this figure omits species that were never mistaken by other species.

DISCUSSION

Our results document the pervasiveness of errors in the identification of bird vocalizations, suggesting that such errors are inescapable and widespread in ornithological surveys (see also Lees *et al.* 2014). Even among identifications made by experts taking an on-line quiz, with the opportunity of listening to a fairly good recording while observing the respective sonogram, we found that more than 25% of identifications were wrong. Understanding how these errors happen is a key step towards lowering their frequency and improving our ability to obtain unbiased estimates of wildlife population parameters from bioacoustic data. We found considerable variation among experts in their ability to identify vocalizations, as well as substantial variation among species, in the frequency with which they were correctly identified. Although there are many possible errors, the probability of confusion between closely related species is higher than between relatively more distant ones, even when focusing on a phylogenetically restricted set of species. We acknowledge that our online quiz may have presented difficulties that are atypical of real-world processing of bioacoustics data, such as the relatively short time limit for answering questions, the lack of precise geographical information on where the recording was done, and the absence of environmental cues such as microhabitat and time of the day; nonetheless, these results are a motivation to improve ornithological training, to use sampling techniques that keep a permanent record of observations, and, most importantly, to incorporate the very real possibility of identification error in analyses of bioacoustics data.

Knowing that different experts have different backgrounds, it should come as no surprise that they performed very differently from each other in the identification quiz. Backgrounds varied in more than one way: while some experts learned the vocalizations in the field and probably relied mostly on sound for their quiz answers, others learned mostly in the lab, while processing audio recordings, and were more likely to take clues from the sonogram. There was also geographical variation in the backgrounds, with some experts having direct experience of listening to bird vocalizations from our study area and others having learnt mostly from experience in other parts of the Amazon. Experts from the latter group will be more likely to err by giving names of species that were not part of the study – especially when they are not informed about the geographic origin of the recordings. While it is unavoidable that different people will recall auditive memories differently, this problem could be minimized through the use of spaced-repetition learning (Donovan & Radosevich 1999) supported by digital tools (*e.g.* Cerqueira *et al.* 2013). Field practice will help observers memorize the voices of animals that they encounter most frequently; spaced-repetition learning, on the other hand, offers a means for adjusting the time studying each species, not according to the opportunity of encounter, but to how well the observer recalls one particular sound.

The observed variation among species with regard to ease of identification helps to sort out which species can be reliably studied based on bioacoustic data and which certainly require caution. Among the species in our study, *Cymbilaimus lineatus*, *Thamnophilus murinus* and *Thamnophilus punctatus* stand out for never having been mistaken by other species. Why would it be so? *T. murinus* and *C. lineatus* are respectively the fourth and seventh most frequently detected species among the antbirds and woodcreepers in our autonomous recordings database. The *T. punctatus'* song ends with a very peculiar rhythmic pattern, which could be the reason why it is particularly hard to confuse with other songs. These three species summarize what we believe to be two main factors facilitating correct identifications: commonness, already reported to play a role in species detection by Farmer *et al.* (2012), and peculiarity of the vocalization. On the opposite end of the difficulty spectrum, *Myrmelastes leucostigma*, stood out for being the only species with evidence for a correct identification probability lower than 0.5. *M. leucostigma*, along with the recurrently confused *Willisornis poecilonotus* and *Myrmotherula menetriesii*, may hold clues for understanding what makes a vocalization difficult to identify. Clearly, some species will be confused with each other because they sound alike—such as *W. poecilinotus* and *M. menetriesii*. However, the vocalization of *M. leucostigma* was confused with half a dozen species that don't particularly sound like each other. We don't know what caused these errors but wonder if there are acoustic traits that make a vocalization particularly difficult to memorize, regardless of its resemblance with other vocalizations. Besides the inherent difficulty of a sound and the obvious pairwise resemblance between species, it is also interesting to ask whether there are broader patterns that help one predict what are the most likely confusions. Both the dendrogram and the null model results support the reasonable idea that increasing phylogenetic relatedness increases the probability of confusion between species vocalizations. Our metric of relatedness is crude, but the final result is a contribution to understanding what types of misidentifications to expect as well as a motivation to take a detailed look at those exceptional situations where frequent confusion arises between unrelated species. This should be an incentive for keeping permanent records of bioacoustic surveys so that inevitable errors can be corrected and understood.

We see the work reported here as a first step towards understanding what are the most frequent misidentifications between species in the bioacoustic surveys of central Amazon birds. This work could be usefully expanded to a larger set of species and an online quiz where participants are informed *a priori* about the geographical context of the questions. We did not anticipate this to be a problem, but in hindsight, we believe we might be able to learn more about the possibility of misidentification if experts had a basis for excluding species that do not belong in our sample. A complementary work that could throw further light on the causes for confusion would be to quantify distance between vocalizations based not on expert answers to the quiz but on quantitative measures of the frequency and tempo of vocalizations. It would be particularly interesting to confront results from the two approaches and find out in what circumstances two vocalizations that have similar measures may be easily distinguished by the observers as well as when observers fail to discriminate sounds that are measurably different.

Knowledge of which animal sounds are most difficult to identify will contribute towards decreasing false positive errors and improving the quality of bioacoustic data. It is important to keep in mind, however, that as much as one values data quality and observer training, identification errors will never go away permanently. Whether the observer is a human being or a machine, there will be a non-negligible possibility of error. Future work should aim not only at reducing errors, but also at incorporating the possibility of errors in the analysis of bioacoustics data. Consideration of identification errors is particularly important when estimating population parameters from surveys of animal sounds. A reduction in parameter estimation bias can go a long way in advancing scientific knowledge and supporting management decisions. We hope that our results help improve the quantification of uncertainty about Amazon bird identification, and ultimately advance knowledge of their distribution and population dynamics.

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ARTICLE

Effects of intrinsic and time-specific factors on daily nest survival of birds in a semiarid area of South America (Caatinga)

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ABSTRACT: Nest predation is a determinant of reproductive success of tropical birds and its effects can vary in space, time and due to intrinsic factors of the species. In this study, we conducted a preliminary investigation on changes in the risk of nest predation on Caatinga birds due to intrinsic factors (nest type and taxonomic group) and time-specific factors (breeding season and nest abundance). We located and monitored bird nests during the breeding seasons of 2012 (n = 33 nests) and 2013 (n = 45) in a mixed landscape of anthropogenic and natural sites. We use the MARK program that uses known-fate models to calculate Daily Nest Survival Estimates (DNS) and evaluate the effect of covariates on DNS estimates. Predation was the main cause of nest loss (n = 54). In the analysis of intrinsic factors, the best model included the type of nest to explain variation in estimates. DNS declined across the breeding season for all nest types, but estimates of closed nests (between 0.996 and 0.851) were higher than those of open nests (between 0.985 and 0.629). For time-specific factors, the best models for each breeding season included the quadratic effect of nest abundance to explain the variation in DNS. There was an inverse relationship between the abundance of nests and nest predation. The high importance of predation and the effect of the type of nest showed that the reproductive success of the birds studied is due to similar factors to those found in other Neotropical environments. On the other hand, locally-specific effects, such as low reproductive success and inverse relationship between abundance and nest predation risk, demonstrate the need for further exploration of this theme within the Caatinga avifauna.

KEY-WORDS: avian, density-dependence, predation, reproductive success.

INTRODUCTION

Interactions such as predation, competition and brood parasitism may result in temporal and spatial variations in reproductive success in birds (Gates & Gysel 1978, Martin 1995, Woodworth 1999). Among these, predation is the primary cause of nest mortality (Ricklefs 1969), especially for Neotropical birds (França & Marini 2009b, Marini *et al.* 2009a, Dias & Macedo 2011), and can result in the loss of some 70% of passerine clutches (Robinson *et al.* 2000, Stutchbury & Morton 2001). The high impact of nest predation on breeding success of Neotropical birds makes this interaction an important part of the dynamics of bird populations in these environments, and knowledge of its operation is key for effective conservation (Stutchbury & Morton 2001).

Fluctuations in nest predation rates may be related to time-specific factors that vary across the breeding season, during nest development or between breeding seasons (Martin *et al.* 2000, Roos 2002, Peak *et al.* 2004, Thompson-III 2007, Wilson *et al.* 2007, França & Marini 2009b). Predation rates can also be determined by spatially varying factors, for example, between different types of habitat, variation in nest building sites and density of co-specific nests (Burhans *et al.* 2002, Roos 2002, Peak *et al.* 2004, Mahon & Martin 2006, Aguilar *et al.* 2008). Finally, predation rates may be linked to intrinsic reproductive factors such as nest type, parental behavior or even morphological and behavioral patterns inherent to taxonomic order of the prey species (Martin & Clobert 1996, Martin *et al.* 2000, Robinson *et al.* 2000, Borges & Marini 2010, Dias *et al.* 2010).

In northeastern Brazil the xeric vegetation type (Caatinga) is characterized by high seasonality, irregularity and lack of rain (Prado 2003, Silva *et al.* 2003, Leal *et al.* 2005), all of which can both regulate and restrict the breeding season for birds (Cavalcanti 2014), and result in time-dependent fluctuations in nest predation rates. Bird breeding in Caatinga seems to be scheduled to coincide with the rainy season (Nascimento *et al.* 2000, Telino-Júnior *et al.* 2005, Roos *et al.* 2006) when, over a short time period, many species simultaneously invest in nest production (Cavalcanti 2014). This temporal concentration of breeding activity generates resource availability peaks for nest predators and can result in density-dependent relationships between predator and prey (Aguilar *et al.* 2008). In addition to extrinsic factors, some intrinsic factors may be important sources of variation in nest predation rates in the Caatinga. The high local richness of bird species in Caatinga (from 70 to 145 species: Santos 2004, Farias *et al.* 2005, Olmos *et al.* 2005, Telino-Júnior *et al.* 2005, Farias 2007, Araujo & Rodrigues 2011) when compared to other semi-arid environments (*e.g.* n ≤ 25, northeastern Venezuela, Poulin *et al.* 1993; n ≤ 54, western Mexico, Del-R & Butterfield 1999; n ≤ 61, northcentral Chile, Jaksic & Lazo 1999) can result in greater variability of such intrinsic factors as nest type, breeding and social behavior, and generate particular predation patterns not found in other tropical semiarid areas.

Most studies evaluating nest predation in seasonal Neotropics have occurred in the Cerrado (*e.g.* Francisco 2006, Carvalho *et al.* 2007, Aguilar *et al.* 2008, França & Marini 2009b, Marini *et al.* 2009a, Borges & Marini 2010, Marini *et al.* 2010, Hoffmann & Rodrigues 2011, Marini *et al.* 2012). Caatinga weather conditions are more severe than those of the Cerrado, with higher rates of solar radiation, average annual temperature and potential evapotranspiration, and lower relative humidity rates and annual precipitation (Prado 2003). Avian ecology and conservation from the Caatinga are considered the least-known among Brazilian ecoregions (Marini & Garcia 2005). In view of the lack of information concerning factors influencing predation risk of bird nests in seasonal Neotropical environments, the present study aimed to test the following hypotheses: (1) closed nests are less likely to suffer predation than open nests (as has been reported in other humid and seasonal tropical environments in the Neotropics - Oniki 1979, Purcell & Verner 1999, Robinson *et al.* 2000); (2) the risk of nest predation varies between bird taxonomic Orders (Borges & Marini 2010); (3) the abundance of active nests is related to daily fluctuations in predation risk (Ackerman *et al.* 2004, Paiva 2008, Elmberg & Pöysä 2011).

METHODS

Study area

The Caatinga ecoregion occurs in northeastern Brazil at altitudes ranging from 0–600 m. The average annual temperature varies between 24 and 28°C and total annual rainfall from 250–1000 mm, with a high water deficit for most of the year (Prado 2003). Natural vegetation consists mainly of woody and herbaceous species, small and completely deciduous during the dry season (Velloso *et al.* 2002, Prado 2003). The study presented here occurred in an area of Caatinga (5°03'54''S; 37°24'03''W, 76 m a.s.l.), in the state of Rio Grande do Norte, in the *Depressão Sertaneja Setentrional* (Dry Northern Depression) region (Velloso *et al.* 2002). The study area encompasses some 400 ha, and comprises a mixed landscape of areas of native Caatinga vegetation and human-use areas with different levels and types of impacts. Nest sampling occurred in the areas disturbed by perennial or seasonal plant cultivation, areas where local beekeeping occurred and in abandoned areas of agricultural experiments.

Data sampling and analysis

We conducted active searches for bird nests at likely nesting sites to calculate the estimates of Daily Nest Survival (DNS) and daily nest abundance in the study area. Nests were searched for between March and May 2012, and between February and June 2013. Nests were also located by following individuals exhibiting behavior indicating the nearby presence of a nest. Found nests were visited at regular intervals of three and four days until they became inactive. For each nest we identified the incubator species and classified nest type (open or closed). During each monitoring event we recorded the date, nest status (active or inactive) and type of nest contents (empty, eggs or nestlings). We considered a nest successful when at least one of the nestlings survived long enough to fledge and leave the nest. Nest status was defined as preyed upon when all the eggs or nestlings disappeared from the nest before the minimum period required for hatching or nestling departure had ended, and/or when obvious signs of predation on eggs or nestlings were observed. This form of search and nest monitoring procedure is commonly used in studies estimating reproductive success (*e.g.* Johnson *et al.* 2006, França *et al.* 2009, Marini *et al.* 2012).

All data analyses were performed with the program MARK (Dinsmore *et al.* 2002). We used capture-recapture models based on known-fate models to generate the estimates of Daily Nest Survival (DNS), and evaluate the effects of temporal and intrinsic covariates on these estimates. To create models, we combined covariates considered to affect the variation in nest survival. The covariates considered were: (1) linear and quadratic effects of the breeding season on the probability of DNS (season and season^2); (2) linear and quadratic effects of nest abundance on the estimates of DNS (nest and nest^2); (3) effect of nest type, either open or closed nests (type) and; (4) effect of taxonomic Order (Columbiformes, Passeriformes and Psittaciformes) of the species under investigation. We used a method that compared a null model with a set of candidate models. We created candidate models by combining covariates thought to explain the variation in DNS. For the covariate *nest abundance*, we used our records of the number of active nests from daily monitoring. Monitoring events occurred at fixed intervals of three and four days, and during this time a pair of researchers sought new nests. Daily monitoring occurred from 4 to 6 h/day.

To select the best model among the set of candidate models, we ordered models with the Akaike Information Criterion (Burnham & Anderson 1998). Models with best fit were those with the lowest AIC and also models with ΔAICc ≤ 2, as these are considered to possess substantial support to explain part of the within-data variation (Burnham & Anderson 1998). We estimated reproductive success through the logistic function of the best model, using a period of 27 days between egg laying and nestling flight. This period is within the 24 to 28 days range of development for seven of the fully monitored nests from the study, and is similar to durations reported by other studies on Neotropical passerines (Lopes & Marini 2005a, Medeiros & Marini 2007, Duca & Marini 2011).

We conducted two analyses of candidate models to test the study hypotheses and the different data types collected in the two breeding seasons. The first analysis considered only data from the first breeding season, and evaluated the effect of intrinsic factors on estimates of DNS. This was the only season in which we sampled closed nests. The second analysis considered only open nests for the two breeding seasons, to evaluate the effect of temporally varying factors on estimates of DNS.

RESULTS

The main factor influencing reproductive success in the study area was nest predation (n = 54 predated nests and 24 successful). To test for intrinsic factors we analyzed 33 nests sampled in 2012. The candidate model with the best support for the observed variation included the covariates *reproductive period* and *nest type* (Table 1). The next models in the adjustment order were not able to explain the variance in the data (ΔAICc ≥ 3.53). The best fit model explained 70% of variance from the set of candidate models.

TABLE 1. Candidate models considered for evaluating the effect of intrinsic factors in the variation of DNS (Daily Nest Survival) estimates in the 2012 breeding season at the Caatinga, Brazil. Selection was based on Akaike Information Criterion with correction for small samples (AIC_c). The w-AIC_c is the support of each model in relation to the set of candidate models. K represents the number of parameters of each model.

Model	AIC_c	ΔAIC_c	w-AIC_c	K	Deviance
Season + type	104.44	0.00	0.70	3	98.36
Season + order + type	107.98	3.53	0.11	6	95.70
Season + order	108.76	4.32	0.08	5	98.56
Type	109.88	5.44	0.04	2	105.85
Constant	110.63	6.18	0.03	1	108.62
Order	112.55	8.10	0.01	4	104.41
Type + order	113.09	8.64	0.00	5	102.89

According to the best fitting model, the DNS for closed and open nests decreased as the breeding season progressed, but closed nests had higher values (Figure 1). In the first 10 days of the breeding season, the DNS estimates tended to decrease at a lower rate (closed nests = 0.996 to 0.992, open nests = 0.985 to 0.972) than in the last 10 days (closed nests = 0.917 to 0.851, open nests = 0.767 to 0.629; Figure 1). Closed nests had high estimates of reproductive success early in the season (69.8%), and values up to 5.3 times lower at the end of the season (13.2%). Reproductive success for open nests ranged from 30.5% at the beginning of the season and close to zero at the end (Figure 2). The difference between nest types ranged from around 56% at breeding season start to 13% at the end.

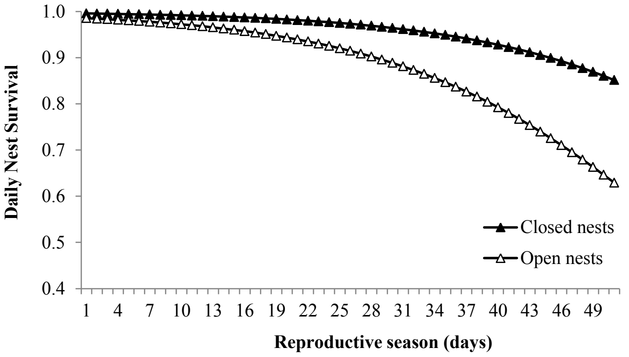

FIGURE 1. Daily Nest Survival (DNS) estimates for open and closed nests during the first breeding season (2012) at Caatinga, Brazil. Results are based on analyses of the best fitting candidate models. Linear equation of the best model: DNS = 4.286 -0.074 (breeding season) + 1.216 (type of nest).

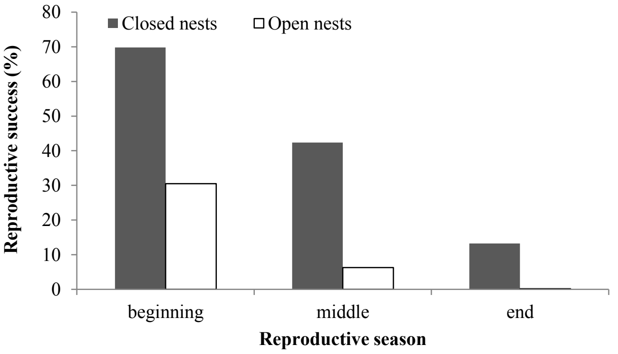

FIGURE 2. Reproductive success estimation (%) for open and closed nests according to three nesting start dates during the breeding season (beginning, middle and end), with a period of 27 days between egg laying and fledgling flight.

Evaluation of the effect of time-dependent factors was based on 24 and 45 open nests from the 2012 and 2013 breeding seasons, respectively. During the first breeding season, seven nests were successful and 17 were preyed upon. Two candidate models showed substantial support to explain the variation in DNS estimates, and the best model was that one which considered the effects of the covariate *nest abundance* (Table 2). The best model was affected by the quadratic effect of nest abundance, while in the second model ($\Delta AIC_c = 0.84$), DNS was affected by the linear effect of breeding season. The best model explained 44% of variance considered by the set of candidate models, and the two best models together explained 73% of the variation (Table 2). We present the results of the best model (nests^2) for discussion. During the 2013 breeding season 14 nests were successful and 31 were predated. In this analysis the best adjusted model was also that one which considered the quadratic effect on the nest abundance to explain variations in DNS (Table 2). The next model in the adjustment order ($\Delta AIC_c = 7.27$), and the null model ($\Delta AIC_c = 8.87$), had no support for explaining the variations in the data. The best fitted model explained 94% of variance considered by the set of candidate models (Table 2). We used the best model (nest^2) to generate the estimates of DNS.

DNS tended to increase during periods of low daily nest abundance records. During the 2012 breeding season, DNS ranged from 0.743 to 0.946 with 5 to 10 active nests per day being recorded. In the 2013 breeding season DNS ranged from 0.831 to 0.952 with 2 to 7 active nests per day being recorded (Figure 3). In periods of higher recorded nest abundance, DNS tended to decrease in the 2012 breeding season, but was more constant in 2013. During the 2012 breeding season, DNS decreased from 0.969 to 0.919, with 17 to 22 active nests recorded daily, while in 2013 DNS values oscillated between 0.977 and 0.975, with 13 to 18 active nests recorded daily (Figure 3). Reproductive success estimates for open nests

TABLE 2. Candidate models considered for evaluating the effect of covariates for time-specific variation of DNS (Daily Nest Survival) estimates for open nests during two studied breeding seasons in Caatinga, Brazil. Selection was based on Akaike Information Criterion with correction for small samples (AIC_c). The *w*-AIC_c is the support of each model in relation to the set of candidate models. K represents the number of parameters of each model.

Model	AIC_c	ΔAIC_c	*w*-AIC_c	K	Deviance
2012 Breeding season					
Nests^2	60.64	0.00	0.44	3	54.48
Season	61.48	0.83	0.29	2	57.40
Season^2	63.07	2.42	0.13	3	56.91
Nests	63.32	2.67	0.11	2	59.24
Constant	66.84	6.20	0.01	1	64.82
2013 Breeding season					
Nests^2	134.98	0.00	0.94	3	128.92
Nests	142.25	7.26	0.02	2	138.22
Constant	143.85	8.86	0.01	1	141.84
Season	144.23	9.25	0.00	2	140.20
Season^2	144.71	9.72	0.00	3	138.65

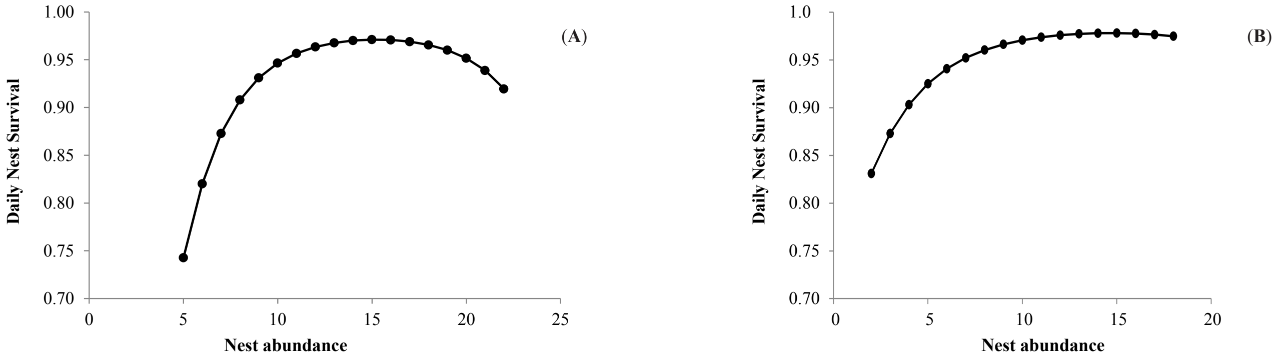

FIGURE 3. Daily Nest Survival (DNS) estimates for open nests with nest abundance considered (quadratic effect), during the 2012 (**A**) and 2013 (**B**) breeding seasons at Caatinga, Brazil. Results are based on the best model from the analysis of candidate models. Linear equation of the best models: (**A**) DNS = -1.928 + 0.715 (nests) -0.023 (nests^2) and (**B**) DNS = 0.841 + 0.403 (nests) -0.014 (nests^2).

were low (Figure 4). During the 2012 breeding season reproductive success ranged from very low to almost zero (7.4 to 0.01% of successful nests). During the 2013 breeding season reproductive success declined from the beginning and middle of the breeding season, then increased again to peak at the end of the season (15.1%).

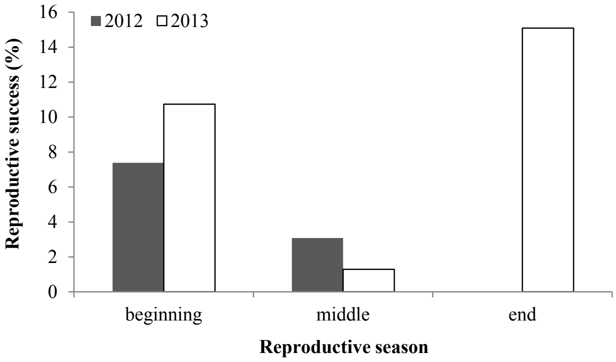

FIGURE 4. Reproductive success estimate (%) with open nests at Caatinga, Brazil, according to three nest start dates (beginning, middle and end) during the 2012 and 2013 breeding seasons, and with a period of 27 days between egg laying and nestling flight.

DISCUSSION

Predation was the main cause of nest failure during this study. This parallels observations made in Cerrado (Carvalho *et al.* 2007, Medeiros & Marini 2007, Aguilar *et al.* 2008, França & Marini 2009a, Borges & Marini 2010), Amazonia (Oniki 1979, Mullner & Linsenmair 2007) and Atlantic Forest (Duca & Marini 2005, Duca & Marini 2008). In our study closed nests had higher success, and this also has been commonly observed in both Neotropical (Oniki 1979, Robinson *et al.* 2000, Duca & Marini 2005, Duca & Marini 2008, Faria *et al.* 2008) and temperate areas (Purcell & Verner 1999). It is assumed that closed nests are under lower predation rates due to the reduced accessibility of nest contents to predators (Oniki 1979). Our data provide evidence that the characteristic feature of the semiarid Caatinga, with high unpredictability in the availability and distribution of rainfall (Prado 2003), is not a factor that changes the overall Neotropical pattern of high nest predation rates on all types of nests.

Few studies have considered the processes responsible for temporal variation in predation in Neotropical bird nests. Results presented here indicate a temporal effect of nest abundance in the Daily Nest Survival. Predator-prey interactions are commonly considered to be related to density-dependent effects (*e.g.* Gates & Gysel 1978, Oliveira *et al.* 2001, Oro *et al.* 2006), and some of these are involved during nest predation (Gates & Gysel 1978, Bêty *et al.* 2002, Roos 2002, Paiva 2008). In such studies, variation in the risk of nest predation may have arisen from a functional response by predators, so that predation frequency may be directly related to density (Gates & Gysel 1978, Roos 2002, Aguilar *et al.* 2008, Paiva 2008, Dias *et al.* 2010).

Our results have found a different effect to that commonly reported in the literature, and indicate a direct relationship between the abundance of nests and estimates of DNS. In other words, an inverse relationship between the abundance of nests and their risk of predation. This may have climatic links. The breeding season in the Caatinga is among the shortest reported for any seasonal Neotropical environment (Cavalcanti 2014), possibly due to the short rainy season and associated period of adequate food availability. In 2013 the breeding season at the current study site lasted only 87 days (active nests) (Cavalcanti 2014). It is possible that this brevity results in an avian breeding season so short, intense, widespread and temporally contiguous as to generate rapid predator satiation. In such a situation, prey consumption rates may depend simply on the intake ability and digestive capacity of individual predators (Jeschke *et al.* 2002). When satiation is achieved hunting activities decrease, lowering predation rates (Jeschke *et al.* 2002). According to this hypothesis, a rapid predator satiation process may result in the inverse relationship between the abundance and predation rate of nests, as we observed at this Caatinga site.

We recorded low levels of avian reproductive success, and a marked variation between the two study years (2012, 0.01 to 7% and 2013, 10% to 15%). Reports of reproductive success for other seasonal Neotropical areas are generally higher than those recorded (Cerrado - *Suiriri affinis* 32%, *Suiriri islerorum* 10%, Lopes & Marini 2005b; *Elaenia chiriquensis* 33%, Medeiros & Marini 2007; *Tyrannus savana* 52.5%, Marini *et al.* 2009a; *Elaenia cristata* 27.1%, Marini *et al.* 2009b; *Mimus saturninus* 54%, Rodrigues 2009). For some species, breeding success values close to those of the current study have been reported (Amazonia - *Cercomacra tyrannina* 7.1%, Robinson *et al.* 2000; Cerrado - *Volatinia jacarina* 4.7%, Carvalho *et al.* 2007; Cerrado – *S. islerorum* 16.8 and 6.7%, França & Marini 2009b). A study in Cerrado has shown that overall bird community breeding success in areas under high human impact (16.6%) may be less than those in more natural areas (29.4%) (Borges & Marini 2010). We report here the lowest reproductive success values so far encountered in the Neotropics, and this may be a consequence of the high levels of human impact on the study site vegetation, the mosaic nature of the landscape, or the unique nature of Caatinga rainfall patterns. While it is difficult to determine which of these is the dominant cause for the low breeding success observed, these results highlight the vulnerability of local Caatinga bird populations, as heavy nest predation pressure could make human-impacted vegetation fragments potentially inviable, as either population sources or sinks for the local avifauna.

This study is one of the first to establish the current patterns of variation in breeding success for Caatinga birds. The pronounced importance of predation and the effect of the type of nest demonstrated by this study show that breeding success for Caatinga birds are governed by processes similar to those found in other Neotropical environments. On the other hand, the local characteristics of inverse dependence between abundance and nest predation risk, as well as an extremely low rate of breeding success, highlight the need for attention to the unusual nature of the breeding ecology of the Caatinga avifauna.

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ARTICLE

Twenty-three years of bird monitoring reveal low extinction and colonization of species in a reserve surrounded by an extremely fragmented landscape in southern Brazil

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ABSTRACT: Human activities have modified landscapes worldwide, promoting fragmentation and isolation of forest habitats. Such landscape modifications are responsible for changes in species composition due to extinction and colonization events. Forest species dynamism is usually affected by forest fragmentation when remaining fragments are small and isolated, but forest dynamism is usually more stable when forest fragments are large and connected. In this study we verified changes in bird composition during 23 years of bird monitoring at the Mata dos Godoy State Park (PEMG). We aimed to evaluate the avian community dynamism of this reserve, as well as its effectiveness in protecting biodiversity in an extremely fragmented landscape. We reviewed historical records of bird species composition and checked for any possible misidentifications, updated the list and created an annual data set of bird species occurrence. We used this list to evaluate species persistence, species loss, and colonization over the study period. Additionally, species were classified according to their guilds in order to determine which species traits were associated with local extinction. A total of 331 bird species were recorded in PEMG over 23 years of monitoring, 17 of which were considered locally extinct or possibly extinct, and 11 were recent local colonizations. This indicates that bird composition in PEMG has been relatively stable over the years. However, local extinction was more likely for large frugivores and insectivores, which are guilds already known to be more susceptible to local extinction. Colonizations, in turn, were associated with guilds of more open habitats, like edge insectivores. We suggest that extinctions and colonizations are also potentially related to species distribution ranges and climate change. Although local extinctions occurred, PEMG still maintains a significant fraction of its historical avifauna and may potentially maintain source populations for many bird species, thus making it an important reserve for the north of Paraná.

KEY-WORDS: avifauna, Atlantic Forest, forest fragment dynamism, Protected Area, species persistence.

INTRODUCTION

Human activities, such as food and energy production, are responsible for the modification of landscapes worldwide (Foley *et al.* 2005, Sodhi & Ehrlich 2010, Haddad *et al.* 2015). These activities contribute to changes in climate regimes, loss of ecosystem services such as air and water quality and decrease in forest cover, all of which result in biodiversity loss (DeFries *et al.* 2004, Foley *et al.* 2005, Zhao *et al.* 2006, Haddad *et al.* 2015). In the Atlantic Forest Biome, a biodiversity hotspot (Myers *et al.* 2000), this scenario is alarming because only 11.4% to 16% of the original forest cover still remains (Ribeiro *et al.* 2009). Exacerbating this situation is the fact that the majority of the remaining forest fragments are smaller than 50 ha (Ribeiro *et al.* 2009) and surrounded by a matrix of anthropogenic habitats (*e.g.* plantations and urban areas) (Tabarelli *et al.* 2010).

The Atlantic Forest Biome consists of several different forest formations that have suffered different deforestation pressures (Galindo-Leal & Câmara 2003). In the north of Paraná state (southern Brazil), which is comprised by semi-deciduous forest formations, deforestation has led to the loss of approximately 98% of the original forest cover (Torezan *et al.* 2005). In this landscape scenario, however, Mata dos Godoy State Park (*Parque Estadual Mata dos Godoy* - PEMG) stands out as potentially the most important reserve since it is the largest and most well preserved forest fragment in the north of Paraná state (Anjos *et al.* 2007, 2009). Even though this reserve is immersed in an agro-mosaic matrix, much of the regional fauna of anurans (Bernarde & Anjos 1999, Machado & Bernarde 2006), reptiles (Bernarde & Machado 2006) and birds (Anjos *et al.* 1997, Anjos 2001) are well represented in PEMG. Also, PEMG contains 21 threatened species and 15 rare species of Angiosperms (Rossetto & Vieira 2013), which makes PEMG an important reserve for semi-deciduous forest formations. In fact, this protected area has become a regional conservation reference not only because of its intrinsic biological value, but also because of the development of several environmental educational programmes with local communities.

Despite its importance for regional conservation, PEMG still suffers several threats. The biggest threat to PEMG is the expansion of agriculture, which has taken place in the last seven decades, but others threats such as illegal hunting, invasive species and water pollution are also present (IAP 2002). At the landscape level, the continuation of habitat loss has led to an increase in forest fragmentation and its associated negative outcomes, such as edge effects and forest fragment isolation. These landscape modifications could have important consequences for forest fragment dynamism (Laurance 2002). According to the concept of forest fragment hyperdynamism, small and isolated areas tend to be strongly affected by the impacts of fragmentation in a short time frame and should present, for example, high species turnover (Laurance *et al.* 1998, Laurance *et al.* 2002). Conversely, large connected forest fragments tend to suffer fewer changes in the same short time frame with a weak dynamism, because it will usually harbor a higher number of persisting species (Bierregaard *et al.* 1992, 1998, 2002, Laurance 2010). Laurance (2002) suggested that forest fragmentation tends to affect the dispersion of species and individuals, leading to an increase in colonization of generalist, invasive and pathogenic species, which will usually modify biological interactions (*i.e.* through competition). These in turn will affect both species abundance and composition (Bierregaard *et al.* 1992, Laurance *et al.* 2002, Laurance 2002, 2010). However, the effects on forest dynamism will depend on the duration and strength of these and other impacts, and on the characteristics of the forest fragment (Laurance 2002, Laurance *et al.* 2002). At the moment, it is uncertain if PEMG has maintained its biodiversity over the years. Therefore, it is crucial to document how species composition has changed since PEMG became a legal reserve to assess its current and future role in the protection of biodiversity. Moreover, this will provide a better understanding of which species are more susceptible to local extinction in semi-deciduous forest formations of the Atlantic Forest.

In this study we verified if the bird community of PEMG has been maintained over the years after it was recognised as a legal reserve in 1989. Historical data sets are an important component to determine the persistence, colonization and/or local extinction of species. However, before using this type of data it is important to review the historical records of the literature to guarantee that the data does not contain dubious records (*i.e.* misidentification). Lees *et al.* (2014) suggest several ways of dealing with misidentification. For instance, one could use the distributional range of the species in question to determine if it overlaps with the dubious record, or one could possibly determine if suitable habitat for the species occurs in the area in question, or even the possibility of a mix up between very similar species (*e.g. Drymophila ferruginea* and *D. rubricollis*). We have two goals for this study, the first one to present a revised historical checklist for the birds of PEMG, where we present species occurrence data from 1993 to 2015 and check for possible misidentifications. Our second goal is to use this revised checklist to assess the potential species dynamism in this reserve during the last 23 years. Because birds are recognized as good biological indicators and capable of responding to primary and secondary causes of environmental changes (Morrison 1986, Temple & Wiens 1989, Koskimies 1989, Kushlan 1993, Piratelli *et al.* 2008), our approach will allow us to determine how effective PEMG is for the conservation of the regional biota in the north of Paraná state.

METHODS

Study area

Mata dos Godoy State Park (23°27'S; 51°15'W, PEMG, Figure 1) is the largest and best preserved forest fragment in northern Paraná state, south of Brazil (Anjos *et al.* 2007). PEMG is located in Espírito Santo District, 15 km from the center of the municipality of Londrina and over the Tropic of Capricorn. This reserve covers 656 ha and is mainly composed by pristine seasonal semi-deciduous forest (Figure 1, Torezan 2002). PEMG presents a natural variation in topography, which allows one to divide PEMG in two different regions comprised of pristine forest. One of the regions is located in the north and consists of a plateau at an altitude of approximately 600 m, while the second region is located in the south of PEMG and consists of a hillside that ranges from 600 to 470 m a.s.l. (Anjos *et al.* 2007). This difference in elevation is responsible for the widespread occurrence of bamboo vegetation in the southern part of PEMG, which results in differences in the occurrence of bird species between these two areas (see Anjos *et al.* 2007, Santana & Anjos 2010). For more details on the vegetation of PEMG see Silveira (2006) and Rossetto & Vieira (2013). This reserve also harbor an area of secondary forest in the southeast, an area of open habitats (*e.g.* pasture or initial regeneration) in the northern portion, and a reforestation area that was implemented twenty years ago (IAP 2002; Figure 1).

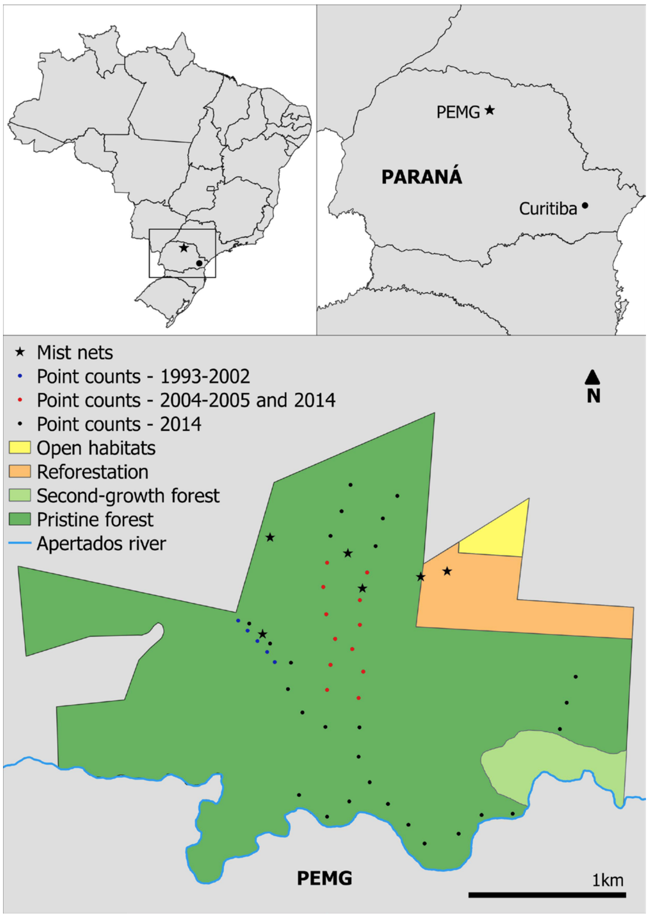

FIGURE 1. Location of Mata dos Godoy State Park (PEMG, 23°27'S; 51°15'W) in the north of Paraná state, south of Brazil.

A matrix of privately owned agricultural land surrounds the northern and western borders of PEMG, while the Apertados River borders the south and a continuous forest fragment borders the east. Considering all forest fragments surrounding PEMG up to a distance of 1 km, connected or not to PEMG, there is a mosaic of forest cover of approximately 2800 ha (Lopes *et al.* 2006). PEMG is situated in the Tibagi River basin (IAP 2002) and according to Köppen classification, the climate of the region is Cfa, subtropical humid with rainy summers, average yearly temperatures of 21°C and average maximum and minimum temperatures of 28°C and 16°C, respectively.

Data set

The historical data set was obtained using both the scientific literature and unpublished data. From the scientific literature, we compiled data on bird species using ten scientific papers published between 1997 and 2015 (Table 1). Several studies (*e.g.* Anjos & Schuchmann 1997, Anjos *et al.* 2010) were excluded from the literature review because bird data from these specific studies had already been published in one of the ten references listed in Table 1.

TABLE 1. Published bird occurrence data in PEMG, Paraná state, Brazil, and the respective period in which fieldwork was conducted.

Published papers	Period of field work
Anjos *et al.* 1997	1992–1996
Anjos & Ferreira 1998	September 1997
Anjos 2001	January–December 1996
Anjos *et al.* 2004	September–December 1997
Anjos *et al.* 2007	September–December 2001
Lopes *et al.* 2006	2003–2004
Anjos *et al.* 2011	2004–2005
Santana & Anjos 2010	2007
Bochio & Anjos 2012	2009–2010
Zaiden *et al.* 2015	2010–2011

Unpublished data, in turn, consisted of different methodologies and sampling efforts that were conducted between 1993 and 2015, these methods were: *ad libitum* searches, point counts, and bird capture with mist nets. *Ad libitum* searches by different observers were conducted in the entire area of PEMG without controlling for sampling effort. Point counts (Vielliard & Silva 1990, Bibby *et al.* 1993) were performed in PEMG during three different periods: (1) 1993–2002, (2) 2004–2005, and (3) 2014. For the first period, point counts were conducted in 1993, 1995–1999, 2001 and 2002. In each of these years, with the exception of 1996, five point counts in pristine forest were sampled twice during spring (October). In 1996, the same point counts were performed once a month from January to December (Anjos 2001). Point counts in all these years (including 1996) were placed 100 m apart and at least 50 m away from the forest edge (Figure 1). Sampling time for each point was 20 minutes, and the radius of detection was unlimited. For the second time period, point counts were conducted every season in 2004 and 2005. In this case, six point counts along two trails were placed 200 m apart, giving a total of 12 points (Figure 1). Point counts were sampled for 15 minutes with a detection radius ≤100 m (Anjos *et al.* 2011). Data from spring and summer from this second time period were published in Anjos *et al.* (2011, 2015), but for the present study we have also incorporated unpublished records from autumn and winter. The third point count sampling period occurred from September to December 2014. In this case, 39 point counts (with 15 min sampling time and a detection radius ≤50 m) were placed along 13 trails, each trail consisted of three point counts at 200 m intervals (Figure 1). Each point count was sampled four times during the sampling period. In all of the three-time periods, bird sampling was conducted early in the morning and started with species vocal activity. Sampling ended approximately 3 h later.

Mist nets were placed in six different locations in PEMG between February and October 2015 (Figure 1), with a total sampling effort of 10,332 h.m^2. Mist nets procedures followed Roos (2010).

Bird nomenclature and systematic classification are in accordance with the list of Brazilian birds reviewed and updated by the *Comitê Brasileiro de Registros Ornitológicos* (Piacentini *et al.* 2015). The conservation status of each species was based on IUCN (2015), ICMBio (2014) and Mikich & Bérnils (2004) at the global, national and regional levels, respectively. We used Bencke *et al.* (2006) to classify species as endemic to the Atlantic Forest.

Data analysis

The data set was organized on an annual basis and bird records were divided into two larger time periods, before and after 2005 (Appendix I). We only considered presence and absence data because sampling effort among studies, from the scientific literature or unpublished data, were not standardized, making quantitative comparisons unfeasible. Based on this list, we carefully reviewed questionable records (*e.g.* misidentifications) in order to eliminate "false presences". This procedure allowed for the correct evaluation of local species persistence in PEMG (Lees *et al.* 2014) according to the categories presented below.

We categorized bird species as: 1) "forest persistent", forest bird species that were recorded regularly in the entire study period; 2) "non-forest persistent", species that inhabit non-forest habitats and were recorded regularly in the entire study period; 3) "forest persistent and declining", forest species that were recorded regularly up to 2005, but were only recorded in one or two years after 2005; 4) "possibly extinct", forest species that were regularly recorded until 2005, but were not recorded thereafter; 5) "extinct", forest species that were regularly recorded until 2000, but not afterwards, or species that are easily detectable (*e.g. Odontophorus capueira*) but were recorded only in the first years of monitoring (1993–1996); 6) "frequent migrants", migrant species in the south of Brazil that were present during most of the studied years; 7) "occasional migrants", migrant species that were occasionally found during the study period; 8) "colonizer", species that were found in consecutive years in the study area after 2005 and not before; 9) "sporadic species", species for which PEMG harbor unsuitable habitat (*e.g.* Ardeidae) and that had few and infrequent records during the entire study period; 10) "indeterminate", species with few and infrequent records during the entire study period and for which PEMG harbor suitable habitat for the specie. For the last case we were unable to classify the species as persistent, extinct or colonizer. Classification into forest, non-forest and migrant species follows Sick (1997), del Hoyo *et al.* (2015) and our personal observations in the study area. For species that were mentioned in the literature as both forest and non-forest, we used the habitat that was described as preferred for the species.

The Sørensen Index of Similarity (Magurran 1988) was used to analyse variation in species composition over time. We used this index to calculate how similar the two time periods were (before 2005 and after 2005). The following formula was used to calculate the Sørensen Index of Similarity: $Ss = 2j / (a + b)$; where j corresponds to the number of species common to both periods (before 2005 and after 2005), a represents the number of species present before 2005 and b the number of species present after 2005 (Magurran 1988). For this analysis we first pooled the species in the categories "extinct", "possibly extinct", "forest persistent", "non-forest persistent", "forest persistent and declining" and "colonizer". We then excluded "colonizer" species in order to verify only the effects of extinctions over the periods.

In order to evaluate if certain traits made the species more prone to extinction, species were grouped according to their guilds. Species were classified using a combination of food resources explored by the species and habitat choices, which were mainly based on Willis (1979), Ribon *et al.* (2003), Giraudo *et al.* (2008) and our own field observations. Species were classified as: carnivores (CA); carrion eaters (CE); large frugivores (LF); small frugivores (SF); seedeaters (SE); nectarivores (NE); ground insectivores (GI); understory insectivores (UI); trunk and twig insectivores (TI); sub-canopy and canopy insectivores (SCI); aerial insectivores (AI); edge insectivores (EI); nocturnal insectivores (NI); ground omnivores (GO); understory omnivores (UO); sub-canopy and canopy omnivores (SCO); edge omnivores (EO); aquatic omnivores (AO); and piscivorous (PI).

To visualize which guilds increased or decreased in number of species during the last 23 years in PEMG, we plotted a graph with the number of species in each guild that were present before and after 2005. For this analysis, we excluded the following categories: "frequent migrant", "occasional migrant", "sporadic species" and "indeterminate". We considered a species to be declining and in risk of future extinction when it presented a decline in occurrence records after 2005. We used this data to determine the future tendency in the number of species for each guild. Future tendency of a guild was defined as the number of species present after 2005, subtracting the number of species in the category "forest persistent and declining" (Figure 2).

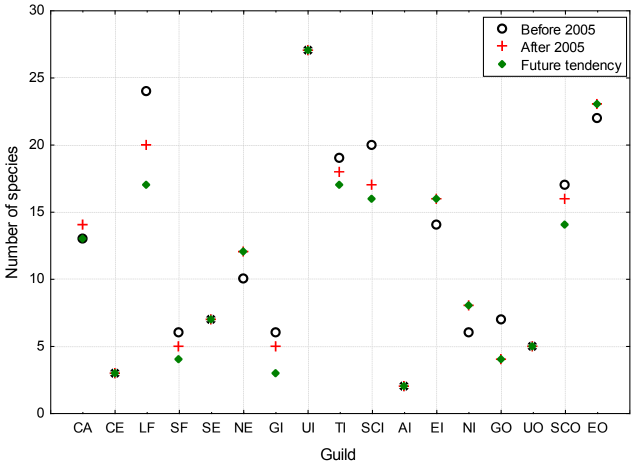

FIGURE 2. Number of species before and after 2005 for each bird guild in Mata dos Godoy State Park (PEMG), Paraná state, Brazil. Only the following categories were considered: "extinct", "possibly extinct", "colonizer", "persistent and declining" and "persistent". For the latter category, both forest and non-forest bird species were considered. Species that presented a decline in occurrence records after 2005 were considered to be declining and in risk of future extinction and this data were used to determine the future tendency in the number of species for each guild. Guild: CA – carnivores; LF – large frugivores; SF – small frugivores; SE – seedeaters; NE – nectarivores; GI – ground insectivores; TI – trunk and twig insectivores; SCI – sub-canopy and canopy insectivores; EI – edge insectivores; NI – nocturnal insectivores; GO – ground omnivores; SCO – sub-canopy and canopy omnivores; EO – edge omnivores.

RESULTS

A total of 331 bird species were recorded during 23 years of bird monitoring in PEMG (Appendix I). Thirteen species found in the literature review were not included in this list of 331 bird species, either because their ranges did not include northern Paraná, or because they were recorded only once and could represent dubious records (Appendix II). Of the 331 species with confirmed presence in PEMG, 74 species are endemic to the Atlantic Forest, while 13 species are considered threatened either at the global, national or regional levels (Appendix I). Furthermore, 19 species are considered "Near threatened" at global and regional levels, and five species are considered as "Data deficient" in the Paraná state.

Bird community composition before and after 2005 was very similar (93%; Ss = 0.932). When colonizer species were excluded, bird species similarity between the two time periods increased (95%, Ss = 0.957), as expected. Therefore, PEMG presented a stable avifauna during the 23 years of bird monitoring. However, the number of species that went extinct promoted a higher dissimilarity (5%) between the two time periods than the number of species that later colonized PEMG (2%). This stability was expected because 191 out of the 331 species, that were originally found in PEMG, were considered as persistent (150 forest persistent, 30 non-forest persistent and 11 forest persistent and declining), while only 12 species were considered locally extinct, five species as possibly extinct and 11 species were considered to be recent colonizations, according to our criteria (Table 2). For the remaining species, 42 species were considered migrants (30 frequent and 12 occasional) and 70 were recorded only once or twice during the monitoring period (37 classified as sporadic and 33 as indeterminate; Appendix I).

A total of 28 bird species (~10%) were considered either as locally extinct, possibly extinct or persistent and declining. Moreover, of the 13 species considered threatened at global, national or regional levels recorded in PEMG during the entire monitoring period, seven are already locally extinct or possibly extinct and three others are considered to be declining (Table 2). Three species considered near threatened at regional and global levels were also considered locally extinct in PEMG. However, two species, *Myiothlypis flaveola* and *Nyctiphrynus ocellatus*, which are threatened bird species at the regional level, were considered to have recently colonized PEMG. If we exclude the species that went locally extinct, PEMG currently harbor 319 bird species (68 endemic to Atlantic Forest), out of which eight are threatened species, 16 near threatened and five data deficient for the Paraná state (Appendix I).

The most representative guilds, considering the total number of bird species originally recorded at PEMG (331), were edge omnivores (n = 36, 10.9%), understory insectivores (n = 31, 9.4%), sub-canopy and canopy insectivores (n = 30, 9.0%), edge insectivores (n = 28, 8.4%), large frugivores (n = 26, 7.8%), sub-canopy and canopy omnivores (n = 23, 6.9%), trunk and twig insectivores (n = 22, 6.6%) and carnivores (n = 22, 6.6%) (Appendix I). In general, insectivores were highly representative with 149 species (45.0%), followed by omnivores (84, 25.4%) and frugivores (35, 10.6%).

The two guilds with the highest number of species going locally extinct were large frugivores (33.3%, n = 4) and ground omnivores (16.6%, n = 2) (Table 3). Possibly extinct species were mainly represented by sub-canopy and canopy insectivores (40%, n = 2). Large frugivores had the highest number of forest bird species that are declining (27.2%, n = 3), followed by ground insectivores (18.2%, n = 2). Colonizers, on the other hand, were well represented by the insectivores and omnivores guilds (Table 3).

Large frugivores are expected to have a higher number of future local extinctions because of the decline in the number of species occurrence for this category (Figure 2). Small frugivores, ground insectivores, ground omnivores, trunk and twig insectivores, as well as sub-canopy and canopy insectivores were guilds that had a high number of species at risk of local extinction. Conversely, edge insectivores, edge omnivores, nocturnal insectivores and nectarivores tended to maintain local populations and may even see increases in the number of species in the future.

TABLE 2. Species considered extinct, possibly extinct, declining and recent colonisers in PEMG, Paraná state, Brazil. Local Status: EX – extinct; PE – possibly extinct; D – forest persistent and declining; C – colonizer. Conservation Status: VU – vulnerable; EN – endangered; CR – critically endangered; NT – near threatened; DD – data deficient; PR – regional level (Mikich & Bérnils 2004); BR – national level (ICMBio 2014); GL – global level (IUCN 2015). Guild: CA – carnivores; LF – large frugivores; SF – small frugivores; SE – seedeaters; NE – nectarivores; GI – ground insectivores; TI – trunk and twig insectivores; SCI – sub-canopy and canopy insectivores; EI – edge insectivores; NI – nocturnal insectivores; GO – ground omnivores; SCO – sub-canopy and canopy omnivores; EO – edge omnivores. Endemic species (E) follows Bencke *et al.* (2006).

Species	Local status	Conservation status	Guild
Crypturellus undulatus (Temminck, 1815)	EX	CR-PR	GO
Aburria jacutinga (Spix, 1825) E	EX	EN-GL; EN-BR; EN-PR	LF
Crax fasciolata Spix, 1825	EX	VU-GL; CR-PR	LF
Odontophorus capueira (Spix, 1825) E	EX		GO
Pulsatrix perspicillata (Latham, 1790)	EX	VU-BR; DD-PR	CA
Chamaeza ruficauda (Cabanis & Heine, 1859) E	EX		GI
Manacus manacus (Linnaeus, 1766)	EX		SF
Lipaugus lanioides (Lesson, 1844) E	EX	NT-GL; NT-PR	LF
Procnias nudicollis (Vieillot, 1817) E	EX	VU-GL	LF
Phylloscartes eximius (Temminck, 1822) E	EX	NT-GL	SCI
Tiaris fuliginosus (Wied, 1830)	EX		SE
Piranga flava (Vieillot, 1822)	EX	NT-PR	SCO
Tinamus solitarius (Vieillot, 1819) E	PE	NT-GL; VU-PR	GO
Campephilus melanoleucos (Gmelin, 1788)	PE		TI
Piprites chloris (Temminck, 1822)	PE		SCI
Hylophilus poicilotis Temminck, 1822 E	PE		EI
Polioptila lactea Sharpe, 1885 E	PE	NT-GL; EN-PR	SCI
Patagioenas plumbea (Vieillot, 1818)	D		LF
Strix hylophila Temminck, 1825 E	D	NT-GL	CA
Pteroglossus aracari (Linnaeus, 1758)	D	VU-PR	SCO
Piculus aurulentus (Temminck, 1821) E	D	NT-GL	TI
Primolius maracana (Vieillot, 1816)	D	NT-GL; EN-PR	LF
Triclaria malachitacea (Spix, 1824) E	D	NT-GL; VU-PR	LF
Grallaria varia (Boddaert, 1783)	D		GI
Hylopezus nattereri (Pinto, 1937) E	D		GI
Heliobletus contaminatus Berlepsch, 1885 E	D		SCI
Oxyruncus cristatus Swainson, 1821	D		SCO
Euphonia pectoralis (Latham, 1801) E	D		SF
Leptodon cayanensis (Latham, 1790)	C		CA
Buteo brachyurus Vieillot, 1816	C		CA
Nyctiphrynus ocellatus (Tschudi, 1844)	C	EN-PR	NI
Hydropsalis parvula (Gould, 1837)	C		NI
Amazilia versicolor (Vieillot, 1818)	C		NE
Amazilia lactea (Lesson, 1832)	C		NE
Myiarchus ferox (Gmelin, 1789)	C		EI
Myiarchus tyrannulus (Statius Muller, 1776)	C		EI
Myiothlypis flaveola Baird, 1865	C	VU-PR	EI
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)	C		EO
Haplospiza unicolor Cabanis, 1851 E	C		SE

TABLE 3. Representation of guilds (%) in each category in PEMG, Paraná state, Brazil. Each column corresponds to 100% of the respective category. Guilds are as follows: CA – carnivores; CE – carrion eaters; LF – large frugivores; SF – small frugivores; SE – seedeaters; NE – nectarivores; GI – ground insectivores; UI – understory insectivores; TI – trunk and twig insectivores; SCI – sub-canopy and canopy insectivores; AI – aerial insectivores; EI – edge insectivores; NI – nocturnal insectivores; GO – ground omnivores; UO – understory omnivores; SCO – sub-canopy and canopy omnivores; EO – edge omnivores; AO – aquatic omnivores; and PI – piscivorous.

Guild	Extinct (100% = 12)	Possibly extinct (100% = 5)	Forest persistent declining (100% = 11)	Forest persistent (100% = 150)	Non-forest persistent (100% = 30)	Colonizer (100% = 11)
CA	8.3	-	9.1	4.7	13.3	18.2
CE	-	-	-	2.0	-	-
LF	33.3	-	27.2	11.3	-	-
SF	8.3	-	9.1	2.7	-	-
SE	8.3	-	-	1.3	13.3	9.1
NE	-	-	-	6.7	-	18.2
GI	8.3	-	18.2	1.3	3.3	-
UI	-	-	-	18.0	-	9.1
TI	-	20.0	9.1	10.7	3.3	-
SCI	8.3	40.0	9.1	10.7	-	-
AI	-	-	-	-	6.7	-
EI	-	20.0	-	2.7	30.0	18.2
NI	-	-	-	3.3	3.3	18.2
GO	16.7	20.0	-	2.0	3.3	-
UO	-	-	-	3.3	-	-
SCO	8.3	-	18.2	9.3	-	-
EO	-	-	-	10.0	23.3	9.1
AO	-	-	-	-	-	-
PI	-	-	-	-	-	-

DISCUSSION

Over the 23 years of bird monitoring, PEMG presented low species turnover and a high number of bird species persisting over this time period. Local extinction of bird species, as well as colonization of novel bird species, did occur in PEMG during this time period, but at low numbers. We argue that some features of PEMG contributed to its relative stability, these being high number of bird species, large core area, and functional connectivity with other forest fragments (Laurance 2002, Haddad *et al.* 2015), especially in the eastern area of PEMG, which borders a large forest fragment (Lopes *et al.* 2006). The high number of species in PEMG, in turn, could be explained by the natural heterogeneity of the pristine vegetation encountered in PEMG. This natural heterogeneity is probably the result of topographic variation (plateau vs. hillside), which allows for the coexistence of species with different ecological requirements in this reserve (Anjos *et al.* 2007, Santana & Anjos 2010).

However, PEMG is surrounded by a human dominated landscape that has changed dramatically during the last 23 years. Agriculture (mainly soya beans) has expanded over the years at the northern and western borders of PEMG, compromising the buffer zone of the reserve, especially during the turn of the century. The buffer zone that existed 23 years ago in the west portion of the reserve is completely absent nowadays (L. Anjos, pers. obs.). Other local threats have been detected over the 23 years of monitoring, like illegal hunting activities and the presence of domestic species (*e.g.* cats and dogs) in the study area (IAP 2002), threats that are known to have important impacts on biodiversity and community dynamics (Wright 2005, Galetti & Sazima 2006, Campos *et al.* 2007). The synergic effects of these threats could affect bird composition in the PEMG in terms of both local extinctions and colonizations (Laurance 2010).

Extinctions

Extinctions in the PEMG were biased towards specific bird groups. This was expected because some biological features are known to be better predictors of bird sensitivity to fragmented landscapes (*e.g.* Henle *et al.* 2004, Anjos 2006). For example, body size and feeding habits (Pizo 2001, Ribon *et al.* 2003), dispersal capacity (Sekercioglu *et al.* 2002, Lees & Peres 2009) and geographical distribution (Kattan *et al.* 1994, Anjos *et al.* 2010). In our study, large frugivores had the highest rate of extinction (33.3% of total extinctions) and higher number of species expected to decline in the future. Ground omnivores and ground insectivores followed in terms of the number of species that went locally extinct or presented a tendency of future decline. These three guilds frequently show high sensitivity to habitat fragmentation (Thiollay 1992, Ribon *et al.* 2003, Franz *et al.* 2010, Loures-Ribeiro *et al.* 2011, Stratford & Stouffer 2015) due to certain biological features that increase their susceptibility to local extinction. Large frugivores, for example, present low population densities and recruitment, and need large living areas to feed on specific resource (Pizo 2001). Ground insectivores, in turn, appear to be sensitive to microhabitat changes (*e.g.* in leaf litter depth and vegetation structure), which frequently occur in disturbed and fragmented habitats (Stratford & Stouffer 2013, 2015). Further, large frugivores and ground omnivores are frequently hunted due to their large body size (Strahl & Grajal 1991, Pizo 2001), and terrestrial birds are more susceptible to predation by domestic species (*e.g.* dogs and cats).

Other guilds that declined and had a high number of species that went "possibly extinct" were sub-canopy and canopy insectivores and sub-canopy and canopy omnivores, which are guilds that are usually not cited as being prone to local extinction due to fragmentation (Bregman *et al.* 2014). Anjos (2006) studied the sensitivity of bird species in the fragmented landscape of PEMG, and found that some particular species in the aforementioned guilds (*e.g. Piprites chloris* and *Oxyruncus cristatus*) presented high local sensitivity to the effects of fragmentation. However, understory insectivorous - a guild that usually declines after forest fragmentation and forest isolation (Stouffer & Bierregaard 1995, Sekercioglu *et al.* 2002, Powell *et al.* 2015) - persisted in stable numbers in PEMG. A possible explanation could be the fact that we considered terrestrial species as "ground insectivores" instead of grouping them as "understory insectivores". We think it is important to consider where in the understory these insectivore bird species forage, because microhabitats in the understory should differ in their response towards fragmentation.

The extinction pattern found for PEMG follows a widespread global pattern in tropical fragmented landscapes, with higher extinction risk and/or declines in insectivores and large frugivores (reviewed in Bregman *et al.* 2014). However, other guilds like sub-canopy and canopy omnivores were susceptible to local extinction or decline in PEMG, a pattern of species loss that does not conform to the usual widespread pattern of global species loss in tropical fragmented landscapes (Bregman *et al.* 2014). Extinctions or decline in other guilds that are usually not affected by fragmentation could be related to particularities of the area in question, such as history, time of isolation, connectivity with other forest areas and surrounding matrix (Sigel *et al.* 2010).

PEMG, for example, lies over the Tropic of Capricorn, a transitional region between Tropical and Subtropical regions and lies at the northern limit for several bird species with a more southern distribution in Brazil. Likewise, it is at the southern limit for the distribution of several bird species with a more northern distribution in Brazil. This peculiarity could explain some of the patterns of extinctions and declines. Species at the border of their distribution have higher probability of going extinct because of the limited rescue effect (Anjos *et al.* 2010) and/or because species may be at their ecological and physiological limits (Kattan *et al.* 1994). PEMG is at the distributional range limit of nine bird species considered as either locally extinct or possibly extinct, and seven bird species considered to be declining. It is noticeable that species with a more southern distribution were more affected (12 species, *e.g. Heliobletus contaminatus*, *Lipaugus lanioides* and *Polioptila lactea*) than species with a more northern distribution (4 species, *e.g. Campephilus melanoleucus* and *Crypturellus undulatus*).

A possible factor responsible for the extinction bias towards bird species with a more southern distributional range is the drastic deforestation that occurred in Paraná state between 1890 and 1990 (Gubert-Filho 2010). Deforestation in Paraná was severe for both semi-deciduous forests (that prevails in northern Paraná) and araucaria forests (that occurs more to the south), eliminating the connectivity that once existed between this two forest formations. Enclaves of *Araucaria* Forest that were close to PEMG did occur in the past (Torezan 2002), but these have been eliminated or have become isolated from the core *Araucaria* Forest present in the south of Brazil. Thus, bird species highly associated to *Araucaria* Forest that occur in PEMG could be disappearing or declining due to the lack of suitable habitats and absence of landscape connectivity that could allow a rescue effect. This could be the case for species like *H. contaminatus*, *Piculus aurulentus* and *Strix hylophila*.

Climate change could also be a contributing factor to the decline of bird species with a more southern distributional range. Changes in temperature and precipitation levels can have direct and indirect effects on bird populations (Crick 2004). Direct effects consist, for example, in shifts in the reproduction period of several bird species (Crick 2004), while indirect effects are changes in bird resources like plants and insects (Bale *et al.* 2002), particularly those with restricted climatic ranges or adapted to lower temperatures (Butterfield & Coulson 1997). Therefore, birds as well as plants and insects associated to colder habitats (as *Araucaria* Forest) could have declined in PEMG due to the elevation of temperatures in this region (Walther *et al.* 2002). For example, *H. contaminatus* has a specialized bill (Whitney & Pacheco 1994) and a foraging strategy that involves searching arthropods in substrates (*e.g.* moss and lichen) that are more common in colder regions (Parrini *et al.* 2009).

Colonizations

Birds species with a more northern distributional range made up the majority of the 11 colonizing species. For example, *N. ocellatus*, *Amazilia lactea*, *Myiarchus tyrannulus*, *M. flaveola*, and *Thlypopsis sordida.* Some of these species are clearly associated with open areas, like *Cerrado* (*e.g. M. tyrannulus* and *M. flaveola*) (Sick 1997). The elevation of temperature in the region in the last decades (Walther *et al.* 2002), together with forest fragmentation that generates more open habitats for species typical of *Cerrado*, could explain why bird species with a more northern distributional range and of drier habitats are expanding into this more moist region. An emblematic case is *M. flaveola*, considered a threatened species in Paraná, which used to have only a few records in the north of the state (Mikich & Bérnils 2004) but seems to be currently expanding to novel areas (see WikiAves.com.br for current records in Paraná state).

The guilds with the highest number of species to have colonized PEMG were edge insectivores, edge omnivorous, nectarivores and nocturnal insectivores. Bird species from these guilds are mainly associated with more open areas. PEMG is inserted in a fragmented landscape where edge effect is favored, which could explain why guilds associated with open habitats were the ones with the highest number of colonizing species (Thiollay 1992, Franz *et al.* 2010). To reinforce this point, as mentioned above, in the beginning of 2000 there was a deforestation of the buffer zone, which probably increased edge effect in one of the most preserved areas of the reserve.

Two carnivore species, *Buteo brachyurus* and *Leptodon cayanensis*, were considered as colonizers according to our criteria. These species can be easily detected in the field because they constantly vocalize (mainly in the breeding season) and are commonly found on thermals with vultures (Ferguson-Lees & Christie 2001, G. Willrich, pers. obs.). This fact indicates that their absence before 2005 is not a consequence of under-sampling, but could be a possible turnover of predators in PEMG. Forest fragmentation can lead to changes in the composition of raptors without an actual change in the number of raptor species (Jullien & Thiollay 1996). Thus, habitat loss (promoted by agriculture expansion in the region) together with hunting activities, both of which are considered to be the main threats to populations of large raptors (Thiollay 1985, Bildstein *et al.* 1998, ICMBio 2008), could have gradually eliminated large raptors from the landscape, favouring smaller raptors species that can tolerate more fragmented habitats, such as the species mentioned above.

Data limitations

There is little information on the avifauna of northern Paraná state before the colonization and expansion of human activities. For instance, naturalists did not visit the region close to the municipality of Londrina in the 19th century. However, Peter W. Wetscot in the 1930s made an important account about the capture of a single Harpy Eagle (*Harpia harpyja*) individual near the municipality of Londrina (Scherer-Neto & Straube 1995). This record suggests that the avifauna in northern Paraná was originally much richer in species number. Some groups, like great raptors (Accipitridae, *e.g. Spizaetus ornatus*), were never recorded in PEMG or the region, and their presence can only be inferred by the use of distributional maps. This indicates that the avifauna present in PEMG, as well as the number of species locally extinct, could in fact be underestimated because of the lack of information on species distributions prior to the creation of the reserve (Lees & Pimm 2015).

The "indeterminate" species (species with few and infrequent records), which were recorded only in the first years of monitoring could in fact have been common in the past, but our time frame captured the presence of these species when they were at the end of their decline. For example, records of *Sclerurus scansor* and the "Near threatened" *Phylloscartes sylviolus* and *P. paulista* could have been the last ones in PEMG. The maintenance of bird monitoring in PEMG can provide more information to assess the local status of such species in the future.

Future bird monitoring in PEMG should adopt a standardized method so that different time periods can be appropriately compared. For example, if point counts in PEMG had a standardized protocol (*e.g.* the same location, sampling time and radius of detection), we would have been able to use multivariate methods such as NMDS to compare bird abundance and composition along different time periods. We argue that it is important to sample the same points and use the same sampling procedures used in 2014. The reason is the number of trails used and because points are distributed both in the plateau and in the altitudinal gradient of the reserve. We also advocate for the increase in the use of mist net and ringing, as initiated in 2015, so that population sizes could be estimated for several species over the years. The evaluation of the data obtained by these methodologies will allow a better comprehension of species declining tendencies in the future.

Implications for protected areas

The dynamism encountered for this bird community over the years was weak, which indicates that most bird species were able to persist/occupy PEMG after it was declared a legal reserve. If we consider the avifauna list of Scherer-Neto *et al.* (2011), PEMG harbors almost 45% of all bird species present in Paraná state, and together with the small species dynamism over the years, the role of PEMG for the conservation of biodiversity in northern Paraná is undeniable. Like many other protected areas, PEMG is under constant pressure. For example, a recent plan to build an airport in the vicinity of PEMG was rejected due to the efforts of the Instituto Ambiental do Paraná (IAP) and a local NGO (MAE). However, other development projects such as the implementation of industries next to PEMG are still under discussion.

Furthermore, in a new concept of conservation called "biodiversity-friendly landscapes", which aims to create a more functional and connected landscape that conciliates human necessities and biodiversity conservation (Melo *et al.* 2013), PEMG could act as a source for many bird populations that could expand to surrounding areas of less preserved forest fragments or new restoration areas (Brancalion *et al.* 2013). Together with the use of ecological corridors and restoration areas that increase connectivity within this highly fragmented landscape, it is possible to increase rescue effects among bird populations of nearby forest fragments, thus increasing the chances of maintaining current biodiversity in the long run.

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APPENDIX I

Species recorded to PEMG in 23 years of monitoring. Nomenclature of species follows Piacentini *et al.* (2015) and endemic species (E) of Atlantic Forest follows Bencke *et al.* (2006).
Literature review and unpublished data before 2005 (in parenthesis the period of sampling): 1) Anjos *et al.* 1997 (1993–1996); 2) Anjos & Ferreira 1998 (1997); 3) Anjos 2001 (1996); 4) Anjos *et al.* 2004 (1997); 5) Anjos field works (1993, 1995–1999); 6) Anjos field works (2001–2002); 7) Anjos *et al.* 2007 (2001); 8) Lopes *et al.* 2006 (2003–2004); 9) Anjos *et al.* 2011 and unpublished data (2004–2005).
Literature review and unpublished data after 2005 (in parenthesis the period of sampling): 10) Santana & Anjos 2010 (2007); 11) Bochio & Anjos 2012 (2009–2010); 12) Bochio field works (2009–2010); 13) Oliveira field works (2009–2015); 14) Muzi field works (2010–2012); 15) Zaiden *et al.* 2015 (2011); 16) Rosa field works (2009–2015); 17) Calsavara field works (2013–2015); Willrich field works (2014–2015); Mist nets (2015).
Local Status: FP – forest persistent; NFP – non-forest persistent; D – forest persistent and declining; PE – possibly extinct; EX – extinct; FM – frequent migrant; OF – occasional migrant; C – colonizer; S – sporadic species; I – indeterminate.
Conservation Status: VU – vulnerable; EN – endangered; CR – critically endangered; NT – near threatened; DD – data deficient; PR – regional level (Mikich & Bérnils 2004); BR – national level (ICMBio 2014); GL – global level (IUCN 2015).
Guilds: CA – carnivores; CE – carrion eaters; LF – large frugivores; SF – small frugivores; SE – seedeaters; NE – nectarivores; GI – ground insectivores; UI – understory insectivores; TI – trunk and twig insectivores; SCI – sub-canopy and canopy insectivores; AI – aerial insectivores; EI – edge insectivores; NI – nocturnal insectivores; GO – ground omnivores; UO – understory omnivores; SCO – sub-canopy and canopy omnivores; EO – edge omnivores; AO – aquatic omnivores and PI – piscivorous.

Family/species	Before 2005									After 2005										Local Status	Conservation Status	Guild
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
Tinamidade																						
Tinamus solitarius (Vieillot, 1819) E	X		X	X	X	X	X		X											PE	NT-GL; VU-PR	GO
Crypturellus obsoletus (Temminck, 1815)	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		GO
Crypturellus undulatus (Temminck, 1815)	X		X		X															EX	CR-PR	GO
Crypturellus parvirostris (Wagler, 1827)	X		X		X		X		X		X	X	X			X		X		FP		GO
Crypturellus tataupa (Temminck, 1815)	X		X	X	X		X		X		X	X	X	X		X	X	X		FP		GO
Rhynchotus rufescens (Temminck, 1815)													X			X		X		S		GO
Nothura maculosa (Temminck, 1815)	X												X	X				X		NFP		GO
Anatidae																						
Dendrocygna viduata (Linnaeus, 1766)	X																			S		AO
Cracidae																						
Penelope superciliaris Temminck, 1815	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		LF
Aburria jacutinga (Spix, 1825) E	X		X																	EX	EN-GL; EN-BR; EN-PR	LF
Crax fasciolata Spix, 1825	X		X																	EX	VU-GL; CR-PR	LF
Odontophoridae																						
Odontophorus capueira (Spix, 1825) E	X																			EX		GO
Ardeidae																						
Nycticorax nycticorax (Linnaeus, 1758)													X					X		S		AO

Family/species	**Before 2005**									**After 2005**										**Local Status**	**Conservation Status**	**Guild**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**			
Butorides striata (Linnaeus, 1758)													X							S		AO
Bubulcus ibis (Linnaeus, 1758	X																	X		S		GO
Ardea cocoi Linnaeus, 1766																X				S		AO
Ardea alba Linnaeus, 1758																X				S		AO
Syrigma sibilatrix (Temminck, 1824)																		X		S		GO
Egretta thula (Molina, 1782)																X				S		AO
Threskiornithidae																						
Mesembrinibis cayennensis (Gmelin, 1789)																		X		S	NT-PR	AO
Theristicus caudatus (Boddaert, 1783)													X							S		GO
Cathartidae																						
Cathartes aura (Linnaeus, 1758)	X												X			X		X		FP		CE
Coragyps atratus (Bechstein, 1793)	X												X			X	X	X		FP		CE
Sarcoramphus papa (Linnaeus, 1758)	X															X	X	X		FP		CE
Accipitridae																						
Leptodon cayanensis (Latham, 1790)													X					X		C		CA
Elanoides forficatus (Linnaeus, 1758)	X												X			X		X		FM		AI
Elanus leucurus (Vieillot, 1818)	X												X			X				NFP		CA
Harpagus diodon (Temminck, 1823)	X																			OM		CA
Accipiter striatus Vieillot, 1808	X						X						X							FP		CA
Ictinia plumbea (Gmelin, 1788)	X				X	X	X		X				X			X		X		FM		AI
Heterospizias meridionalis (Latham, 1790)																		X		S		CA
Rupornis magnirostris (Gmelin, 1788)	X						X		X				X			X	X	X		FP		CA
Geranoaetus albicaudatus (Vieillot, 1816)													X							S		CA
Buteo nitidus (Latham, 1790)	X																			I		CA
Buteo brachyurus Vieillot, 1816													X	X				X		C		CA
Aramidae																						
Aramus guarauna (Linnaeus, 1766)																		X		S		AO
Rallidae																						
Aramides saracura (Spix, 1825) E	X				X		X		X		X	X	X					X		FP		GI
Laterallus melanophaius (Vieillot, 1819)	X																			I		GI
Pardirallus nigricans (Vieillot, 1819)																		X		I		GI
Charadriidae																						
Vanellus chilensis (Molina, 1782)	X												X			X		X		NFP		GI

Family/species	**Before 2005**									**After 2005**										**Local Status**	**Conservation Status**	**Guild**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**			
Columbidae																						
Columbina talpacoti (Temminck, 1810)	X												X			X	X	X		FP		SE
Columbina squammata (Lesson, 1831)	X												X			X				FP		SE
Columbina picui (Temminck, 1813)	X												X			X		X		NFP		SE
Claravis pretiosa (Ferrari-Perez, 1886)	X						X		X		X	X			X			X		FP		LF
Patagioenas picazuro (Temminck, 1813)	X		X	X	X	X	X		X		X	X	X		X	X	X	X		FP		EO
Patagioenas cayennensis (Bonnaterre, 1792)	X		X	X	X	X	X		X		X	X	X		X	X		X		FP		LF
Patagioenas plumbea (Vieillot, 1818)	X		X												X					D		LF
Zenaida auriculata (Des Murs, 1847)	X												X			X	X	X		NFP		EO
Leptotila verreauxi Bonaparte, 1855	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		LF
Leptotila rufaxilla (Richard & Bernard, 1792)	X		X	X	X		X		X		X	X	X	X	X	X		X		FP		LF
Geotrygon montana (Linnaeus, 1758)	X		X	X	X	X	X		X		X	X	X	X	X	X		X		FP		LF
Cuculidae																						
Piaya cayana (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		SCI
Coccyzus melacoryphus Vieillot, 1817	X			X					X		X	X	X					X		FM		EI
Coccyzus americanus (Linnaeus, 1758)	X			X		X	X		X											OM		SCO
Coccyzus euleri Cabanis, 1873	X					X	X													OM	DD-PR	SCI
Crotophaga ani Linnaeus, 1758	X		X										X			X		X		NFP		EI
Guira guira (Gmelin, 1788)	X												X			X	X	X		NFP		EI
Tapera naevia (Linnaeus, 1766)	X				X	X					X	X		X		X	X	X		FP		EI
Dromococcyx pavoninus Pelzeln, 1870	X								X		X	X	X	X		X		X		FP		UI
Tytonidae																						
Tyto furcata (Temminck, 1827)	X												X			X		X		FP		CA
Strigidae																						
Megascops choliba (Vieillot, 1817)	X						X						X	X		X		X		FP		NI
Pulsatrix perspicillata (Latham, 1790)	X		X		X															EX	VU-BR; DD-PR	CA
Pulsatrix koeniswaldiana (Bertoni & Bertoni, 1901) E	X		X	X	X	X							X			X		X		FP		CA
Bubo virginanus (Gmelin, 1788)	X																			S		CA
Strix hylophila Temminck, 1825 E	X		X		X											X				D	NT-GL	CA
Strix virgata (Cassin, 1849)																		X		I	DD-PR	CA
Glacidium brasilianum (Gmelin, 1788)	X		X	X	X		X		X				X			X		X		FP		NI
Athene cunicularia (Molina, 1782)	X												X			X		X		NFP		NI

Family/species	**Before 2005**									**After 2005**										**Local Status**	**Conservation Status**	**Guild**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**			
Nyctibiidae																						
Nyctibius aethereus (Wied, 1820)	X																			I	EN-BR; DD-PR	NI
Nyctibius griseus (Gmelin, 1789)	X												X			X		X		FP		NI
Caprimulgidae																						
Nyctiphrynus ocellatus (Tschudi, 1844)													X			X		X		C	EN-PR	NI
Antrostomus rufus (Boddaert, 1783)	X															X				FP		NI
Lurocalis semitorquatus (Gmelin, 1789)	X		X										X					X		FM		NI
Nyctidromus albicollis (Gmelin, 1789)	X											X	X			X		X		FP		NI
Hydropsalis parvula (Gould, 1837)																X		X		C		NI
Hydropsalis torquata (Gmelin, 1789)													X							S		NI
Podager nacunda (Vieillot, 1817)	X												X					X		FM		NI
Chordeiles minor (Forster, 1771)	X																			OM	DD-PR	NI
Chordeiles acutipennis (Hermann, 1783)	X																			OM		NI
Apodidae																						
Cypseloides fumigatus (Streubel, 1848)													X							S		AI
Streptoprocne zonaris (Shaw, 1796)	X												X							S		AI
Chaetura cinereiventris Sclater, 1862	X																	X		OM		AI
Chaetura meridionalis Hellmayr, 1907	X												X			X		X		FM		AI
Trochilidae																						
Phaethornis squalidus (Temminck, 1822) E													X							I		NE
Phaethornis pretrei (Lesson & Delattre, 1839)	X												X							FP		NE
Phaethornis eurynome (Lesson, 1832) E	X		X		X	X	X		X				X	X		X		X		FP		NE
Eupetomena macroura (Gmelin, 1788)	X												X			X	X			FP		NE
Florisuga fusca (Vieillot, 1817) E	X																	X		FP		NE
Colibri serrirostris(Vieillot, 1816)	X																			I		NE
Anthracothorax nigricollis (Vieillot, 1817)	X		X	X									X			X				FP		NE
Stephanoxis lalandi (Vieillot, 1818) E	X															X				I		NE
Chlorostilbon lucidus (Shaw, 1812)	X			X			X		X				X	X				X		FP		NE
Thalurania glaucopis (Gmelin, 1788) E	X			X	X	X	X		X				X	X				X		FP		NE
Hylocharis sapphirina (Gmelin, 1788)	X																			I		NE
Hylocharis cyanus (Vieillot, 1818)		X																		I		NE
Hylocharis chrysura (Shaw, 1812)	X												X	X		X		X		FP		NE
Leucochloris albicollis (Vieillot, 1818) E	X												X							OM		NE

Family/species	**Before 2005**									**After 2005**										**Local Status**	**Conservation Status**	**Guild**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**			
Amazilia versicolor (Vieillot, 1818)													X	X				X		C		NE
Amazilia fimbriata (Gmelin, 1788)	X															X		X		FP		NE
Amazilia lactea (Lesson, 1832)													X	X		X				C		NE
Trogonidae																						
Trogon surrucura Vieillot, 1817 E	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		SCO
Trogon rufus Gmelin, 1788	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		SCO
Alcedinidae																						
Megaceryle torquata (Linnaeus, 1766)																		X		I		PI
Chloroceryle amazona (Latham, 1790)																		X		I		PI
Momotidae																						
Baryphthengus ruficapillus (Vieillot, 1818) E	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X	X	FP		UI
Galbulidae																						
Galbula ruficauda Cuvier, 1816	X																			I	NT-PR	EI
Bucconidae																						
Notharchus swainsoni (Gray, 1846) E	X		X										X					X		FP		SCO
Nystalus chacuru(Vieillot, 1816)	X																			S		EO
Nonnula rubecula (Spix, 1824)	X			X			X				X	X	X	X		X	X	X	X	FP		UI
Ramphastidae																						
Ramphastos dicolorus Linnaeus, 1766 E	X		X	X	X		X		X		X	X	X	X	X	X	X	X		FP		SCO
Selenidera maculirostris (Lichtenstein, 1823) E	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		SCO
Pteroglossus bailloni (Vieillot, 1819) E	X		X		X		X				X	X	X	X	X			X		FP	NT-GL	SCO
Pteroglossus aracari (Linnaeus, 1758)	X		X	X	X	X	X				X				X					D	VU-PR	SCO
Pteroglossus castanotis Gould, 1834																X		X		I		SCO
Picidae																						
Picumnus cirratus Temminck, 1825											X			X						I		TI
Picumnus temminckii Lafresnaye, 1845 E	X		X	X	X	X	X		X				X	X		X	X	X		FP		TI
Picumnus nebulosus Sundevall, 1866	X																			I	NT-GL	TI
Melanerpes candidus (Otto, 1796)	X												X			X	X	X		FP		TI
Melanerpes flavifrons (Vieillot, 1818) E	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		TI
Veniliornis spilogaster (Wagler, 1827) E	X		X	X	X	X	X		X		X	X	X	X				X		FP		TI
Piculus aurulentus (Temminck, 1821) E	X			X	X	X							X							D	NT-GL	TI
Colaptes melanochloros (Gmelin, 1788)	X		X	X	X	X					X	X	X	X		X		X		NFP		TI
Colaptes campestris (Vieillot, 1818)	X												X			X		X		FP		TI

Family/species	Before 2005									After 2005										Local Status	Conservation Status	Guild
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
Celeus flavescens (Gmelin, 1788)	X		X	X	X						X	X		X		X	X	X		FP		TI
Dryocopus lineatus (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		TI
Campephiluss robustus (Lichtenstein, 1818) E	X			X	X						X	X	X			X		X		FP		TI
Campephilus melanoleucos (Gmelin, 1788)			X	X	X	X														PE		TI
Falconidae																						
Caracara plancus (Miller, 1777)	X						X				X	X	X			X		X		NFP		CA
Milvago chimachima (Vieillot, 1816)	X												X			X		X		NFP		CA
Herpetotheres cachinnans (Linnaeus, 1758)	X		X	X	X	X	X		X							X		X		FP		CA
Micrastur ruficollis (Vieillot, 1817)	X		X		X	X	X						X			X		X		FP		CA
Micrastur semitorquatus (Vieillot, 1817)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		CA
Falco sparverius Linnaeus, 1758	X												X			X		X		NFP		AI
Falco femoralis Temminck, 1822	X												X							NFP		CA
Falco peregrinus Tunstall, 1771													X					X		OM		CA
Psittacidae																						
Primolius maracana (Vieillot, 1816)	X			X	X	X	X				X				X					D	NT-GL; EN-PR	LF
Psittacara leucophthalmus (Statius Muller, 1776)	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		LF
Aratinga auricapillus (Kuhl, 1820)	X		X		X	X	X		X		X	X	X	X	X	X	X	X		FP	NT-GL	LF
Eupsittula aurea (Gmelin, 1788)	X																			S		LF
Pyrrhura frontalis (Vieillot, 1817) E	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		LF
Forpus xanthopterygius (Spix, 1824)	X		X		X								X			X		X		FP		EO
Brotogeris tirica (Gmelin, 1788) E	X		X		X	X	X		X		X	X	X		X	X		X		FP		LF
Pionopsitta pileata (Scopoli, 1769) E	X		X	X	X	X	X		X		X	X	X		X	X		X		FP		LF
Pionus maximiliani (Kuhl, 1820)	X		X	X	X	X	X		X		X	X	X	X	X	X	X	X		FP		LF
Amazona aestiva (Linnaeus, 1758)	X		X	X	X	X	X		X		X	X	X	X	X	X		X		FP		LF
Triclaria malachitacea (Spix, 1824) E	X		X	X	X	X	X				X				X					D	NT-GL; VU-PR	LF
Thamnophilidae																						
Dysithamnus mentalis (Temminck, 1823)	X		X	X	X	X	X	X	X		X	X	X	X		X		X	X	FP		UI
Herpsilochmus rufimarginatus (Temminck, 1822)	X		X	X	X	X	X	X	X		X	X	X			X		X		FP		SCI
Thamnophilus doliatus (Linnaeus, 1764)	X					X							X			X				FP		EI
Thamnophilus ruficapillus Vieillot, 1816	X												X			X		X		NFP		EI
Thamnophilus caerulescens Vieillot, 1816	X		X	X	X	X	X	X	X		X	X	X			X		X		FP		UI
Hypoedaleus guttatus (Vieillot, 1816) E	X		X	X	X	X	X	X	X		X	X	X	X		X	X	X		FP		SCI
Mackenziaena leachii (Such, 1825) E						X	X		X											I		UI

Family/species	**Before 2005**									**After 2005**										**Local Status**	**Conservation Status**	**Guild**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**			
Mackenziaena severa (Lichtenstein, 1823) E	X			X	X	X	X	X	X	X	X	X	X	X		X		X		FP		UI
Pyriglena leucoptera (Vieillot, 1818) E	X		X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	FP		UI
Drymophila rubricollis (Bertoni, 1901) E	X			X			X			X			X					X		FP		UI
Drymophila malura (Temminck, 1825) E	X		X	X	X		X			X			X							FP		UI
Conopophagidae																						
Conopophaga lineata (Wied, 1831) E	X		X	X	X	X	X		X	X	X	X	X			X	X	X	X	FP		UI
Grallariidae																						
Grallaria varia (Boddaert, 1783)	X		X	X	X		X		X				X							D		GI
Hylopezus nattereri (Pinto, 1937) E							X			X			X							D		GI
Rhinocryptidae																						
Eleoscytalopus indigoticus (Wied, 1831) E	X		X	X	X		X				X	X	X	X			X	X		FP		UI
Psilorhamphus guttatus (Ménétriès, 1835) E	X		X	X	X		X						X					X		FP	NT-PR	UI
Formicariidae																						
Chamaeza campanisona (Lichtenstein, 1823)	X		X	X	X	X	X		X		X	X	X					X		FP		GI
Chamaeza ruficauda (Cabanis & Heine, 1859) E	X																			EX		GI
Scleruridae																						
Sclerurus scansor (Ménétriès, 1835) E	X		X																	I		GI
Dendrocolaptidae																						
Dendrocincla turdina (Lichtenstein, 1820) E	X		X	X	X	X	X		X		X	X	X	X		X	X	X	X	FP		TI
Sittasomus griseicapillus (Vieillot, 1818)	X		X	X	X	X	X		X		X	X	X	X		X	X	X	X	FP		TI
Xiphorhynchus fuscus (Vieillot, 1818) E	X		X	X	X	X	X		X		X	X	X	X		X		X	X	FP		TI
Campylorhamphus falcularius (Vieillot, 1822) E							X				X	X	X	X		X		X		FP		TI
Lepidocolaptes angustirostris (Vieillot, 1818)				X	X	X	X											X		S	NT-PR	TI
Dendrocolaptes platyrostris Spix, 1825	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		TI
Xiphocolaptes albicollis (Vieillot, 1818)	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		TI
Xenopidae																						
Xenops rutilans Temminck, 1821	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		TI
Furnariidae																						
Furnarius rufus (Gmelin, 1788)	X												X			X		X		NFP		EO
Lochmias nematura (Lichtenstein, 1823)							X						X			X		X		FP		UI
Clibanornis dendrocolaptoides (Pelzeln, 1859)E			X																	I	NT-GL	UI
Automolus leucophthalmus (Wied, 1821) E	X		X		X		X		X	X	X	X	X	X		X	X	X	X	FP		UI
Anabacerthia lichtensteini (Cabanis & Heine, 1859) E			X	X	X	X	X		X		X	X	X	X		X		X		FP		SCI

Family/species	Before 2005									After 2005										Local Status	Conservation Status	Guild
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
Philydor rufum (Vieillot, 1818)	X		X	X	X	X	X		X				X	X		X	X	X		FP		SCI
Heliobletus contaminatus Pelzeln, 1859 E	X		X		X	X	X			X										D		SCI
Syndactyla rufosuperciliata (Lafresnaye, 1832)	X		X		X				X				X			X		X		FP		UI
Synallaxis ruficapilla Vieillot, 1819 E	X		X	X	X	X	X		X	X	X	X	X	X		X	X	X	X	FP		UI
Synallaxis cinerascens Temminck, 1823	X		X	X	X		X			X	X	X	X	X		X	X	X		FP		UI
Synallaxis frontalis Pelzeln, 1859	X		X		X						X	X	X			X	X	X		NFP		EI
Synallaxis spixi Sclater, 1856	X		X	X	X						X	X	X			X		X		NFP		EI
Cranioleuca obsoleta (Reichenbach, 1853) E			X	X	X	X	X		X	X	X	X	X					X		FP		TI
Pipridae																						
Pipra fasciicauda Hellmayr, 1906	X		X		X		X				X	X	X	X						FP		SF
Manacus manacus (Linnaeus, 1766)	X		X		X															EX		SF
Chiroxiphia caudata (Shaw & Nodder, 1793) E	X		X	X	X	X	X		X		X	X	X	X		X	X	X	X	FP		SF
Oxyruncidae																						
Oxyruncus cristatus Swainson, 1821	X		X	X	X						X	X								D		SCO
Onychorhynchidae																						
Myiobius barbatus (Gmelin, 1789)	X																			I		UI
Tityridae																						
Schiffornis virescens (Lafresnaye, 1838) E	X				X						X	X	X			X				FP		UO
Tityra inquisitor (Lichtenstein, 1823)	X		X		X		X		X		X	X	X	X		X				FP		LF
Tityra cayana (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		LF
Pachyramphus viridis (Vieillot, 1816)	X		X										X			X				FM		SCI
Pachyramphus castaneus (Jardine & Selby, 1827)	X		X	X	X	X	X		X				X			X		X		FP		SCI
Pachyramphus polychopterus (Vieillot, 1818)	X					X	X				X	X	X	X		X		X		FM		SCI
Pachyramphus validus (Lichtenstein, 1823)	X		X		X	X	X						X	X		X		X		FM		SCI
Contigidae																						
Phibalura flavirostris Vieillot, 1816	X																			I	NT-GL; NT-PR	SCO
Pyroderus scutatus (Shaw, 1792) E														X						I	NT-PR	LF
Lipaugus lanioides (Lesson, 1844) E	X																			EX	NT-GL; NT-PR	LF
Procnias nudicollis (Vieillot, 1817) E					X															EX	VU-GL	LF
Pipritidae																						
Piprites chloris (Temminck, 1822)	X		X	X	X		X													PE		SCI
Platyrinchidae																						
Platyrinchus mystaceus Vieillot, 1818	X			X	X		X		X	X	X	X	X	X		X	X	X	X	FP		UI

Family/species	**Before 2005**									**After 2005**										**Local Status**	**Conservation Status**	**Guild**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**			
Rhynchocyclidae																						
Mionectes rufiventris Cabanis, 1846 E	X		X	X	X	X	X						X							FP		UO
Leptopogon amaurocephalus Tschudi, 1846	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		UI
Corythopis delalandi (Lesson, 1830)	X						X		X	X	X	X	X	X		X	X	X	X	FP		UI
Phylloscartes eximius (Temminck, 1822) E	X		X		X															EX	NT-GL	SCI
Phylloscartes ventralis (Temminck, 1824)	X		X	X	X	X	X				X	X				X	X			FP		SCI
Phylloscartes paulista Ihering & Ihering, 1907 E					X															I	NT-GL; NT-PR	SCI
Phylloscartes sylviolus (Cabanis & Heine, 1859) E	X																			I	NT-GL; DD-PR	SCI
Tolmomyias sulphurescens (Spix, 1825)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		SCI
Todirostrum cinereum (Linnaeus, 1766)	X						X						X			X		X		FP		EI
Poecilotriccus plumbeiceps (Lafresnaye, 1846)	X		X	X	X	X	X			X			X			X		X		FP		UI
Myiornis auricularis (Vieillot, 1818) E	X		X	X	X	X	X		X	X			X			X	X	X		FP		SCI
Hemitriccus diops (Temminck, 1822) E							X			X			X			X		X		FP		UI
Hemitriccus obsoletus (Miranda-Ribeiro, 1906) E	X						X				X	X	X							FP	DD-PR	UI
Hemitriccus margaritaceiventer (d'Orbigny & Lafresnaye, 1837)	X															X				S		EI
Tyrannidae																						
Hirundinea ferruginea (Gmelin, 1788)													X							S		EI
Euscarthmus meloryphus Wied, 1831	X																	X		S		EI
Tyranniscus burmeisteri (Cabanis & Heine, 1859)	X				X				X		X	X						X		FP	DD-PR	SCI
Camptostoma obsoletum (Temminck, 1824)	X		X	X	X	X	X		X		X	X	X			X		X		FP		SCO
Elaenia flavogaster (Thunberg, 1822)	X												X					X		FP		EO
Elaenia parvirostris Pelzeln, 1868	X												X	X		X		X		FM		EO
Elaenia mesoleuca (Deppe, 1830)	X		X				X									X				FM		EO
Elaenia chiriquensis Lawrence, 1865																		X		OM		EO
Elaenia obscura (d'Orbigny & Lafresnaye, 1837)																		X		I		EO
Myiopagis caniceps (Swainson, 1835)	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		SCI
Myiopagis viridicata (Vieillot, 1817)	X		X										X			X		X		FP		SCI
Capsiempis flaveola (Lichtenstein, 1823)	X		X	X	X		X			X			X			X		X		FP		UI
Phyllomyias virescens (Temminck, 1824) **E**																		X		I		SCI
Serpophaga subcristata (Vieillot, 1817)	X												X			X		X		NFP		EI
Legatus leucophaius (Vieillot, 1818)											X	X	X	X		X		X		FM		SCI
Myiarchus swainsoni Cabanis & Heine, 1859	X				X	X	X		X			X	X			X		X		FM		SCI
Myiarchus ferox (Gmelin, 1789)													X			X		X		C		EI

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Myiarchus tyrannulus (Statius Muller, 1776)													X			X		X		C		EI
Sirystes sibilator (Vieillot, 1818)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		SCI
Pitangus sulphuratus (Linnaeus, 1766)	X		X		X		X		X		X	X	X			X		X		FP		EO
Machetornis rixosa (Vieillot, 1819)	X												X			X		X		NFP		EI
Myiodynastes maculatus (Statius Muller, 1776)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FM		EO
Megarynchus pitangua (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		EO
Myiozetetes similis (Spix, 1825)	X		X	X	X		X						X			X		X		FP		EO
Tyrannus melancholicus Vieillot, 1819	X		X		X								X			X		X		FM		EI
Tyrannus savana Daudin, 1802	X												X			X		X		FM		EO
Empidonomus varius (Vieillot, 1818)	X						X						X			X		X		FM		EO
Colonia colonus (Vieillot, 1818)	X		X	X	X	X			X				X			X		X		FP		SCI
Myiophobus fasciatus (Statius Muller, 1776)	X		X	X									X	X		X		X		FM		EI
Pyrocephalus rubinus (Boddaert, 1783)	X												X			X				FM		EI
Arundinicola leucocephala (Linnaeus, 1764)	X																			S		EI
Cnemotriccus fuscatus (Wied, 1831)	X									X	X	X	X			X		X		FM		EI
Lathrotriccus euleri (Cabanis, 1868)	X		X		X	X	X		X	X	X	X	X	X		X		X	X	FM		UI
Contopus cinereus (Spix, 1825)	X												X					X		FP		SCI
Knipolegus cyanirostris (Vieillot, 1818)	X																	X		FP		EI
Satrapa icterophrys (Vieillot, 1818)	X																			S		EI
Muscipipra vetula (Lichtenstein, 1823) E	X																			S		SCI
Vireonidae																						
Cyclarhis gujanensis (Gmelin, 1789)	X		X	X	X	X	X		X		X	X	X			X	X	X		FP		SCO
Hylophilus poicilotis Temminck, 1822 E	X						X													PE		EI
Vireo chivi (Vieillot, 1817)	X						X		X				X			X		X		FM		SCO
Corvidae																						
Cyanocorax chrysops (Vieillot, 1818)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		EO
Hirundinidae																						
Pygochelidon cyanoleuca (Vieillot, 1817)	X												X	X		X		X		NFP		AI
Alopochelidon fucata (Temminck, 1822)	X																			OM		AI
Stelgidopteryx ruficollis (Vieillot, 1817)	X												X	X		X		X		FM		AI
Progne tapera (Vieillot, 1817)	X												X			X		X		FM		AI
Progne chalybea (Gmelin, 1789)	X												X					X		FM		AI
Tachycineta leucorrhoa (Vieillot, 1817)	X																	X		FM		AI

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Hirundo rustica Linnaeus, 1758	X																			OM		AI
Petrochelidon pyrrhonota (Vieillot, 1817)	X																			OM		AI
Troglodytidae																						
Troglodytes musculus Naumann, 1823	X		X				X				X	X	X			X	X	X		NFP		EI
Polioptilidae																						
Polioptila lactea Sharpe, 1885 E	X		X	X	X		X													PE	NT-GL; EN-PR	SCI
Turdidae																						
Turdus leucomelas Vieillot, 1818	X		X	X	X	X	X		X		X	X	X	X		X	X	X	X	FP		EO
Turdus rufiventris Vieillot, 1818	X		X		X	X	X		X		X	X	X			X	X	X	X	FP		EO
Turdus amaurochalinus Cabanis, 1850	X		X	X		X	X		X		X	X	X			X		X		FP		EO
Turdus subalaris (Seebohm, 1887) E						X	X					X	X	X		X	X	X		FM		UO
Turdus albicollis Vieillot, 1818	X		X		X		X		X		X	X	X	X			X	X	X	FP		UO
Mimidae																						
Mimus saturninus (Lichtenstein, 1823)	X												X			X		X		NFP		EO
Motacillidae																						
Anthus lutescens Pucheran, 1855	X												X			X		X		NFP		EO
Passerellidae																						
Zonotrichia capensis (Statius Muller, 1776)	X						X						X			X		X		NFP		SE
Ammodramus humeralis (Bosc, 1792)	X												X			X		X		NFP		EO
Arremon semitorquatus Swainson, 1838 E													X							I		SE
Arremon flavirostris Swainson, 1838													X							S		SE
Parulidae																						
Setophaga pitiayumi (Vieillot, 1817)	X		X	X	X	X	X				X	X	X	X		X	X	X		FP		SCI
Geothlypis aequinoctialis (Gmelin, 1789)	X												X			X		X		NFP		EI
Basileuterus culicivorus (Deppe, 1830)	X		X	X	X	X	X		X		X	X	X			X	X	X	X	FP		UI
Myiothlypis flaveola Baird, 1865									X				X	X		X	X	X		C	VU-PR	EI
Myiothlypis leucoblephara (Vieillot, 1817) E	X		X	X	X		X				X	X	X			X	X	X	X	FP		UI
Icteridae																						
Cacicus chrysopterus (Vigors, 1825)													X							I		SCO
Cacicus haemorrhous (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X	X		X	X	X		FP		SCO
Icterus pyrrhopterus (Vieillot, 1819)	X												X							FP		EO
Gnorimopsar chopi (Vieillot, 1819)	X																			S		EO
Molothrus oryzivorus (Gmelin, 1788)	X																			S		EO

Family/species	Before 2005									After 2005										Local Status	Conservation Status	Guild
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
Molothrus bonariensis (Gmelin, 1789)	X												X			X		X		NFP		EO
Sturnella superciliaris (Bonaparte, 1850)	X												X			X				NFP		EO
Thraupidae																						
Pipraeidea melanonota (Vieillot, 1819)	X			X	X	X	X		X				X	X		X		X		FP		SCO
Cissopis leverianus (Gmelin, 1788)	X		X	X	X	X	X						X			X		X		FP		LF
Tangara seledon (Statius Muller, 1776) E	X																			I		SCO
Tangara sayaca (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X			X		X		FP		EO
Tangara preciosa (Cabanis, 1850)	X												X	X						FP		EO
Tangara cayana (Linnaeus, 1766)	X																			I	NT-PR	EO
Nemosia pileata (Boddaert, 1783)	X												X			X		X		FP		SCO
Conirostrum speciosum (Temminck, 1824)	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		SCO
Sicalis flaveola (Linnaeus, 1766)																X		X		S		SE
Haplospiza unicolor Cabanis, 1851 E													X					X		C		SE
Hemithraupis guira (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X	X		X		X		FP		SCO
Volatinia jacarina (Linnaeus, 1766)	X												X	X		X		X		FM		SE
Trichothraupis melanops (Vieillot, 1818)	X		X	X	X	X	X		X		X	X	X	X		X	X	X	X	FP		UO
Coryphospingus cucullatus (Statius Muller, 1776)	X												X	X		X		X		NFP		SE
Tachyphonus coronatus (Vieillot, 1822) E	X		X	X	X	X	X				X	X	X			X		X		FP		EO
Ramphocelus carbo (Pallas, 1764)	X																			S		EO
Tersina viridis (Illiger, 1811)	X						X		X				X	X		X		X		FM		SF
Dacnis cayana (Linnaeus, 1766)	X						X		X		X	X	X	X		X		X		FP		SCO
Coereba flaveola (Linnaeus, 1758)	X												X			X		X		FP		NE
Tiaris fuliginosus (Wied, 1830)	X																			EX		SE
Sporophila lineola (Linnaeus, 1758)													X							S		SE
Sporophila collaris (Boddaert, 1783)	X																			S		SE
Sporophila caerulescens (Vieillot, 1823)	X															X		X		NFP		SE
Saltator similis d'Orbigny & Lafresnaye, 1837	X		X		X	X	X		X		X	X	X	X		X		X	X	FP		EO
Saltator fuliginosus (Daudin, 1800) E	X		X	X	X	X	X		X		X	X	X				X	X		FP		LF
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)													X			X				C		EO
Pyrrhocoma ruficeps (Strickland, 1844) E	X				X		X						X	X		X		X		FP		UI
Cardinalidae																						
Piranga flava (Vieillot, 1822)	X																			EX	NT-PR	SCO
Habia rubica (Vieillot, 1819)	X		X	X	X	X	X		X			X	X			X	X	X		FP		UO

Family/species	Before 2005									After 2005										Local Status	Conservation Status	Guild
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19			
Amaurospiza moesta (Hartlaub, 1853) E													X							I	NT-GL	SE
Cyanoloxia brissonii (Lichtenstein, 1823)	X																			I		SE
Fringillidae																						
Spinus magellanicus (Vieillot, 1805)	X																			S		SE
Euphonia chlorotica (Linnaeus, 1766)	X		X	X	X	X	X		X		X	X	X			X	X	X		FP		SF
Euphonia violacea (Linnaeus, 1758)	X		X	X	X						X	X	X			X		X		FP		SF
Euphonia cyanocephala (Vieillot, 1818)	X		X						X				X			X		X		FM		SF
Euphonia pectoralis (Latham, 1801)E	X			X	X		X				X	X								D		SF
Chlorophonia cyanea (Thunberg, 1822)	X																	X		I		SF
Estrildidae																						
Estrilda astrild (Linnaeus, 1758)	X																	X		S		SE
Passeridae																						
Passer domesticus (Linnaeus, 1758)	X																			S		EO

APPENDIX II

Species found in literature review and not included in the final list (Appendix I), since they were recorded only once and could represent dubious records or because their distributional ranges do not include northern Paraná state. Nomenclature of species follows Piacentini *et al.* (2015).

Species	Literature
Trogon viridis Linnaeus, 1766	Anjos *et al.* 1997, Anjos 2001
Cyanerpes cyaneus (Linnaeus, 1766)	Anjos *et al.* 1997
Attila rufus (Vieillot, 1819)	Anjos *et al.* 1997
Dysithamnus stictothorax (Temminck, 1823)	Anjos *et al.* 1997, Anjos *et al.* 2004
Drymophila ferruginea (Temminck, 1822)	Anjos *et al.* 1997, Anjos *et al.* 2004
Hemitriccus nidipendulus (Wied, 1831)	Anjos *et al.* 1997
Phylloscartes oustaleti (Sclater, 1887)	Anjos *et al.* 1997
Saltatricola atricollis (Vieillot, 1817)	Anjos *et al.* 1997
Aramides cajaneus (Statius Muller, 1776)	Anjos *et al.* 2007
Anabacerthia amaurotis (Temminck, 1823)	Anjos *et al.* 2007
Patagioenas maculosa (Temminck, 1813)	Bochio & Anjos 2012
Cichlocolaptes leucophrus (Jardine & Selby, 1830)	Bochio & Anjos 2012
Campylorhamphus trochilirostris (Lischtenstein, 1820)	Bochio & Anjos 2012

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Use of urban areas by two emblematic and threatened birds in the central Andes of Colombia

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ABSTRACT: The Turquoise Dacnis (*Dacnis hartlaubi*) and the Cerulean Warbler (*Setophaga cerulea*) are categorized as "vulnerable" at global scale. Habitat loss and degradation following rapid agricultural expansion and urban development are the main causes of their declines. In this note we present the first documented records of these species in urban green areas in South America. Our observations were undertaken between 2007–2014 during surveys of the avifauna of Armenia City in the central Andes of Colombia. We recorded Turquoise Dacnis on 19 occasions and Cerulean Warbler on 10. Most records were solitary males foraging in *Cecropia angustifolia* and *Inga ornata* trees, and some were associated with mixed species flocks. Both species used forest patches, parks and areas with scattered trees. Our observations suggest that cities may provide passage and/or wintering areas for these threatened species.

KEY-WORDS: Cerulean Warbler, conservation, threatened species, Turquoise Dacnis, Urbanization.

The Turquoise Dacnis, *Dacnis hartlaubi* (Sclater, 1855), is a Colombian endemic species with a disjunct distribution in the Andean mountains (Hilty & Brown 1986, Botero & Verhelst 2001). It inhabits low montane forest, secondary forests, and shade coffee agroecosystems between 1350 and 2200 m a.s.l. (Botero & Verhelst 2001, Cortés-Herrera *et al.* 2014, BirdLife International 2016a). The Cerulean Warbler, *Setophaga cerulea* (Wilson, 1810), is a Neotropical migrant, breeding in southern Canada and the United States, and migrating to Central America and northern South America during the winter (Restall *et al.* 2007, Colorado *et al.* 2014). In the wintering areas, the Cerulean Warbler occurs in low montane forest, traditional shade coffee agroecosystems, secondary forests, and scrubland habitats between 500 to 2000 m a.s.l. (Hilty & Brown 1986, Colorado *et al.* 2014, BirdLife International 2016b). The Cerulean Warbler and the Turquoise Dacnis are emblematic species used to promote bird friendly coffee shade plantations and habitat conservation for biodiversity, especially for migratory birds (Komar 2006, Sánchez-Clavijo *et al.* 2009). Notwithstanding, these two species are listed as "vulnerable" worldwide because of their small range (Turquoise Dacnis) and dramatic population declines as a result of habitat loss, degradation and fragmentation, following agricultural and urban expansion (Renjifo *et al.* 2014, BirdLife International 2016a, b); although in some cases they can be tolerant to some habitat modification (BirdLife International 2016a). However, there are no records of these species using parks and urban green areas in the Neotropics. In this note, we report their occurrence and regular use of small forest patches immersed in urban areas of the metropolitan area in a Neotropical city.

Armenia, the capital of the Quindío Department, is a city of 115 km^2 with a population of 372,344 people (DNP 2014a, b). It is located in the central Andes of Colombia at 1350-1550 m a.s.l., with an annual mean precipitation of 2163 mm, a mean temperature of 21.8°C and a relative humidity ranging between 76 and 81% (IDEAM 2014). The city was devastated by an earthquake (25 January 1999), but it has been expanding dramatically over the past ten years, causing a loss of 83 ha of forest area (Nieto *et al.* 2009). Currently, Armenia is a modern city characterized by large buildings that contrast with small houses and green areas. However, this city has an unusual pattern of landscape configuration due to the presence of corridors of natural vegetation through the urban area (Figure 1), showing a strong connectivity pattern with its surrounding landscape. The urbanized area covers 997 ha, of which 314 ha are natural protected areas inside and around the city (Figure 1), which preserve 122 streams and 322 forest patches of native vegetation that serve as both a refuge and facilitating connectivity for biodiversity (Nieto *et al.* 2009). These areas also include coffee agroecosystems and linear patches of secondary forest dominated by *Guadua angustifolia*. There are other green areas within the city that include lawns, urban parks, and gardens (Table 1).

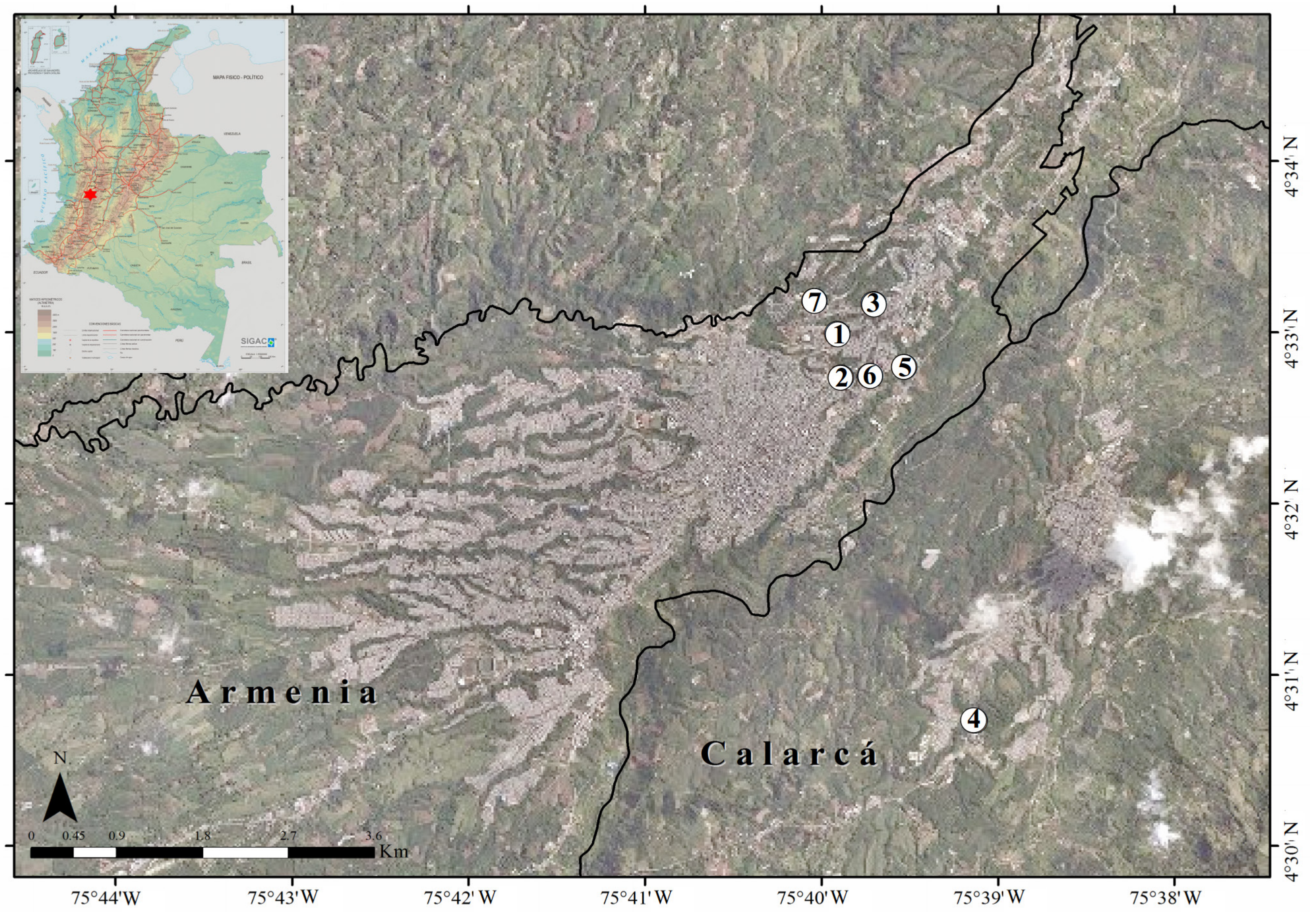

FIGURE 1. Map of the metropolitan area of Armenia city, Colombia, showing the corridors of native vegetation across the city and the surrounding landscape. Numbers indicate the sites where the Cerulean Warbler and Turquoise Dacnis were recorded (see details in Table 1).

During surveys of the avifauna and some birding trips in the urban parks and natural corridors of the Armenia city carried out between 2007 and 2014, we observed multiple individuals of both Turquoise Dacnis and Cerulean Warbler. Photos and video sequences to document these records were taken with Nikon D90 and Panasonic Fz70 cameras. We followed the birds and recorded the time, locality, habitat, behavior activity (*e.g.* perched, foraging, flying), the number of birds, sex, height relative to the ground level, and the tree species.

A total of 19 records of Turquoise Dacnis were recorded at six localities in the urban area of Armenia city (Table 1). This species was detected in the morning (06:00 to 09:30 h), either solitary (only males) or in pairs. It was seen in secondary forest, forest edges, shade-coffee plantations, and parks with dispersed trees (Table 1). Sometimes the males perched on the top of a tree and later flew to forest patches. Males were observed throughout the year, but more frequently in the transition between wet to dry season (October to January and May to July).

When males and females were together, they did not stay for more than 30 min in the same area, moving actively in the canopy or making long flights (30–150 m) using street trees as stepping stones to cross the highway. Male and female foraged together at midstorey levels in the canopy, searching and gleaning insects on the foliage of *Nectandra reticulata*, *Cecropia angustifolia*, *Inga ornata*, *Coussapoa villosa*, *Escallonia pendula, G. angustifolia*, and *Albizia carbonaria*, or hanging upside down on the leaves. Males were seen joining mixed species feeding flocks of insectivorous birds twice in the middle of the year (Table 1). The birds also searched for nectar resources such as *I. ornata*, *A. carbonaria*, and *Erythrina rubrinervia*, or eating the mature fruits of *Zanthoxylum rhoifolium* (Figure 2) and especially *C. angustifolia*. On one occasion a male was seen pecking the fruits of *N. reticulata*.

FIGURE 2. The Turquoise Dacnis and the Cerulean Warbler in urban forest patches of Armenia city, Colombia. (**A**) A male Turquoise Dacnis eating fruits of *Zanthoxylum rhoifolium* at Parque de la Vida; (**B**) A male Cerulean Warbler foraging for insects on the foliage at midstorey levels at *Jardín Botánico de la Universidad del Quindío*. Photos: Oscar H. Marín-Gómez.

We obtained 10 detections of Cerulean Warbler in four localities of Armenia city, mainly from November to January, principally single males, and 50% of the records were birds joining mixed species flocks (Table 1). They were solitary males foraging actively on the foliage of *I. ornata* at middle to canopy levels in the morning (Figure 2). This species was observed moving between vegetation patches, but apparently prefers forest patches and does not use parks or areas with scattered trees. Only once a solitary male was seen flying from the forest to a shade-coffee plantation. When a pair was observed, they foraged together with mixed-species flocks of insectivorous birds at the forest edge (Table 1).

This note is the first documented report for the Turquoise Dacnis and the Cerulean Warbler in the Neotropics using frequently natural small forest patches immersed in urban areas, principally as foraging sites or stepping stones to move among native forest patches. Both species have been observed in seven localities of continuous forest near shade-coffee plantations in Quindío (Arbeláez-Cortés *et al.* 2011, O. Marín-Gómez, pers. obs.) but they are uncommon in this department; and they had not been recorded previously in the urban area of Armenia (Marín-Gómez 2005).

Our results are congruent with the foraging strategies and behaviors previously published for both species, particularly the use of shade-coffee plantations as foraging areas and the habit of joining mixed flocks (Munves 1975, Botero & Verhelst 2001, Colorado *et al.* 2014). The obtained data also indicated that *C. angustifolia* and *I. ornata* are key food sources for insectivorous and nectarivorous birds, as they are abundant in the forest patches of the Colombian coffee region. *Inga ornata* is a tree frequently used in shade coffee plantations and yields a high food supply of nectar and insects for birds (Marín-Gómez 2007), and *C. angustifolia* is one of the most abundant pioneer species during forest regeneration, which is visited by a high number of frugivorous species.

We did not find preceding occurrences for these two species within urban areas (except one record of Turquoise Dacnis in the Jardín Botánico de Pereira), neither on eBird, excluding our own records (http://ebird.org/, accessed 2 February 2016), or in the recent reviews of the conservation status for species both from Colombia (Colorado *et al.* 2014, Cortés-Herrera *et al.* 2014) and the Americas in general (BirdLife International 2016a, b). Although in some cases these species have been reported as tolerant to habitat transformation, there is little evidence supporting this information (BirdLife International 2016a).

TABLE 1. Description of the localities and records of Turquoise Dacnis and Cerulean Warbler in the urban area of Armenia city, Colombia.

Locality	Area description	Species	Date	Time (h)	Observations/remarks
1. Calle 9 Norte, Barrio Profesionales. (4°32'59.6''N; 75° 39'56.4''W)	Small linear patch (2 ha) of second grown forest at 1522 m a.s.l., dominated by *Guadua angustifolia*, *Cecropia angustifolia*, *Albizia carbonaria*, *Inga ornata*, and *Eucalyptus globulus*, reaching 12 m height. This forest is immersed in an urban area with buildings of three to seven floors.	Turquoise Dacnis	24 Oct 2011	06:30–07:00	An adult male foraging inside the foliage of a *Nectandra reticulata* tree, and picking mature fruits. Later it flew to a *C. angustifolia* tree and ate some fruits during 2 min.
			01 Nov 2011	07:25–07:28	A male eating fruits of *C. angustifolia*.
			15 Nov 2011	07:30–07:40	An adult female foraging hung upside down and eating *C. angustifolia* fruits.
			17 Nov 2011	07:00–07:05	A male perched and preening on the top (~20 m) of *G. angustifolia*.
			29 Feb 2012	07:25–07:35	A pair was perched in a top of *G. angustifolia*, then they flew in the same way to another forest patch crossing the highway.
			31 Mar 2012	07:15–07:40	A pair foraging in an *I. ornata* tree. The female was gleaning on foliage, the male visited the flowers and fed the nectar legitimately -making contact with the reproductive structures. Then the female was searching insects in the inflorescences.
			11 May 2012	08:15–08:30	A male foraging in the foliage of a *N. reticulata* tree with a Red-eyed Vireo (*Vireo olivaceus*).
			12 May 2012	06:55–07:00	A male perched on a tree top.
2. Centro Deportivo Nueva Cecilia. (4°32'43.45''N; 75°39'53.35''W)	A green area with pastures for soccer and tennis fields, with some dispersed trees and a small secondary forest of 4 ha at 1499 m a.s.l., where *G. angustifolia*, *C. angustifolia*, and *E. globulus* dominate and reach 15 m height.	Cerulean Warbler	11 Jan 2013	09:40–09:50	A male foraging on foliage of *I. ornata* joined a flock of insectivorous birds as Red-faced Spinetail (*Cranioleuca erythrops*), Tropical Parula (*Setophaga pitiayumi*), Red-eyed Vireo, Golden Tanager (*Tangara arthus*), and Golden-faced Tyrannulet (*Zimmerius chrysops*).
		Turquoise Dacnis	10 Jan 2014	10:30–10:50	A male on the top of *C. angustifolia,* a female hung upside down leaves foraging insects.
			03 Feb 2014	08:20–08:30	A male searching nectar in flowers of *Erythrina rubrinervia*.
			06 Jun 2014	09:25–09:35	A male foraging on flowers of *E. globulus*.
3. Jardín Botánico de la Universidad del Quindío. (4°33'10.29''N; 75°39'41.6''W)	The largest green area (15 ha) immersed in the urban area at 1530 m a.s.l. The vegetation is characterized by secondary forest, abandoned coffee shade plantations, pastures, gardens, and shrubs. The canopy reaches 20 m height and is dominated by *G. angustifolia*, *C. angustifolia*, *Nectandra* spp., and *Ficus* spp. The campus is surrounded by building between 3 to 30 floors.	Turquoise Dacnis	18 Jul 2013	08:00–08:10	A male foraging on the foliage and inflorescences of *A. carbonaria*, together with Bay-headed Tanager (*Tangara gyrola*), and Blue-gray Tanager (*Thraupis episcopus*).
		Cerulean Warbler	01 Sep 2011	12:15–12:25	A pair foraging in the understory with Yellow-throated Vireo (*Vireo flavifrons*), Slate-throated Whitestar (*Myioborus miniatus*), and Golden-faced Tyrannulet. The male was searching on *Piper* sp. leaves, whereas the female was foraging on the top of a *Pinus patula*.
			14 Dec 2011	09:35-09:38	A male moving within the foliage of *G. angustifolia*.
			19 Feb 2012	16:50-16:55	A male foraging hung upside down on *I. ornata* leaves.

Locality	Area description	Species	Date	Time (h)	Observations/remarks
4. Jardín Botánico del Quindío, Calarcá. (4°30'44.3"N; 75°39'7.7"W)	A sub-Andean forest surrounded by coffee shade and sun plantations in the periurban area of Calarcá. This fragment has 13 ha at 1490 m a.s.l. *G. angustifolia*, *Coussapoa villosa*, *Ochroma pyramidale*, *Heliocarpus popayanensis*, *Solanum sycophanta*, *Croton magdalenensis*, *Anacardium excelsum*, *Nectandra* spp., *Persea* spp., and *Ocotea* spp. are dominant, and the canopy reaches 25 m height.	Turquoise Dacnis	17 Nov 2007	08:00–09:00	A male searching insects at midstorey level of a *C. villosa* tree.
			22 Jan 2011	09:00–09:02	A male foraging on the foliage of a *Escallonia pendula* tree.
		Cerulean Warbler	07 Jan 2007	10:30–10:40	A female foraging in the canopy foliage with Rufous-naped Greenlet (*Hylophilus semibrunneus*) and Blackburnian Warbler (*Setophaga fusca*), seen from an observation tower at 30 m to the ground.
			15 Nov 2009	09:00–09:05	A solitary male perched in the canopy.
			10 Jan 2010	08:35–08:40	A male flying from the forest to a shade coffee area, then it perched on the top of a *I. ornata* tree.
5. Parque de la Vida, Armenia. (4°32'48.24"N; 75°39'32.2"W)	A park with open green areas, dispersed tall trees, and a small second grown forest of 5 ha at 1522 m a.s.l.	Turquoise Dacnis	15 Jun 2013	09:35–09:50	A male eating fruits on the top of a *Zanthoxylum rhoifolium* tree with another frugivorous birds, such as Blue-necked Tanager (*Tangara cyanicollis*), Palm Tanager (*Thraupis palmarum*), Blue-gray Tanager, Green Honeycreeper (*Chlorophanes spiza*), and Black-billed Thrush (*Turdus ignobilis*).
			14 Oct 2013	07:19–07:23	A male gleaning on the foliage of *I. ornata*.
			16 Mar 2014	06:40–06:50	A male foraging on the top of *Z. rhoifolium*.
			12 Apr 2014	06:50–07:10	A male and a female foraging fruits and foliage of *Z. rhoifolium*.
		Cerulean Warbler	13 Oct 2014	09:00–09:08	A male foraging insects on foliage.
6. Parque Fundadores, Armenia. (4°32'45.76''N; 75°39'43.34''W)	A small urban park (1 ha) at 1524 m a.s.l., with tall trees (15 m) as *Araucaria* sp., *A. excelsum*, *C. angustifolia*, and *A. carbonaria*.	Turquoise Dacnis	12 Dec 2014	08:10–08:15	A male was perched on the top of a palm; later, it flew crossing the street towards trees in the Parque de la Vida.
7. Urbanización Mercedes del Norte, Armenia. (4°33'10.68''N; 75°40'2.44''W)	A periurban secondary forest surrounding the Hojas Anchas stream, dominated by *G. angustifolia* patches. This area has an extension of 6 ha at 1469 m a.s.l.	Cerulean Warbler	11 Nov 2008	10:15–10:30	A male joined a mixed flock at midstorey levels, with insectivorous birds as Golden-crowned Warbler (*Basileuterus culicivorus*), Golden Tanager, Montane Foliage-gleaner (*Anabacerthia striaticollis*), Streak-headed Woodcreeper (*Lepidocolaptes souleyetii*), Slate-throated Whitestar, Tropical Parula, Blackburnian Warbler, and Black-and-white Warbler (*Mnioltita varia*).
			04 Dec 2009	10:30–10:45	A male foraging joint to a mixed flock in an abandoned shade coffee plantation.

An interesting observation is the apparent sexual segregation in the habitat use of the Turquoise Dacnis. We only detected pairs and females in corridors of native vegetation in the periurban area (Figure 1), meanwhile males were seen adventuring to explore small patches and street trees. Previously, Hilty & Brown (1986) hypothesized a pattern of altitudinal segregation in which the females of the Turquoise Dacnis might be observed at higher elevations. The females have a dull and cryptic plumage that hinders its detection, which could be an explanation for that hypothesis. However, our observations suggest the presence of pairs during the wet (April to May) and the dry seasons (December; Table 1), showing no evidence to support the altitudinal segregation.

Although urbanization generally results in a loss of biodiversity and habitat, some cities can serve as a refuge for some native fauna and even for threatened species (Ives *et al.* 2016). However, urbanization has had profound effects on the diversity and density of species (Chace & Walsh 2006, Aronson *et al.* 2014), and the impacts on bird biodiversity can vary depending on demographic and socioeconomic characteristics of urban areas (Strohbach *et al.* 2009). In the case of Armenia, the fast urban expansion and building construction, boosted some years after the last strong earthquake, probably have had negative impacts on bird species, which are still unknown and need to be quantified. Urban sprawl, the extraction of wood and bamboo from natural forests, the construction of taller buildings resulting in collisions (Nieto *et al.* 2009), and predation by cats are some factors negatively affecting bird survival in urban areas (Chace & Walsh 2006). As noted by Ives *et al.* (2016) the presence of a population in a particular site is not necessarily an indication of its long-term viability in that location, but it can offer potential opportunities for conservation.

The lack of interest in studying urban birds in Latin America, particularly in Colombia, along with the scarce knowledge about their ecology and conservation (Ortega-Álvarez & MacGregor-Fors 2011, Delgado & Correa 2013), may explain the absence of records of these two species in cities, which have probably remained undetected for years. In the case of Armenia, the presence of both species could be facilitated by preserving natural forest habitats within the city, which are connected with a network of forest corridors, urban green areas, and the surrounding landscape (Figure 1). These areas are a refuge for about 190 forest bird species (O. Marín-Gómez, pers. obs.) and support mixed species bird flocks of which the Turquoise Dacnis and Cerulean Warbler form part. We highlight the importance of designating natural forest present within an urban area as green spaces aiming to protect biodiversity, as a conservation tool and urban planning, especially in regions where surrounding agricultural practices have removed most of the natural vegetation. Further research could be oriented to monitoring the bird populations in natural forest in contrast of those found in the urban core. Furthermore, a larger, follow-up study of other forest-dependent birds within the urban gradient in opposition to agricultural matrix would be very enlightening.

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ARTICLE

Birds from the Pirizal region, Pantanal of Poconé, Mato Grosso, Brazil

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ABSTRACT: Pantanal is the world largest inland wetland and is internationally renowned by its high species diversity, but low level of endemism. Extensive areas of the Pantanal have never been subject to adequate sampling, and we still have much to learn about the composition and distribution of the biota found in this threatened biogeographic province. In this paper we present the results of a long term inventory conducted in Pirizal region since 1999. We recorded 343 bird species, 54.8% of them documented with specimens. A significant Amazonian influence was observed in the composition of the bird community sampled. Only two threatened species were recorded: *Penelope ochrogaster* and *Anodorhynchus hyacinthinus*. Noteworthy records include *Ictinia mississippiensis*, *Attila phoenicurus*, *Empidonax alnorum*, *Myiothlypis leucophrys*, *Dolichonyx oryzivorus* and *Catharus fuscescens.*

KEY-WORDS: avifauna, inventory, Neotropical, wetland.

INTRODUCTION

Pantanal is the world largest inland wetland, covering about 160,000 km² of southwestern Brazil, eastern Bolivia and northeastern Paraguay, extending from 16° to 21°S and from 55° to 58'W (Junk *et al.* 2006, Mercante *et al.* 2011). The annual flood pulse of the Rio Paraguay dictates important ecological process in the entire floodplain (Junk *et al.* 1989), influencing the life cycle of their wildlife (Alho *et al.* 2000, Harris *et al.* 2005). Local small differences in the topography, and consequently in the hydrological regime, creates a complex mosaic of permanently flooded, seasonally flooded and non-flooded areas, creating high habitat heterogeneity (Junk *et al.* 1989, Nunes-da-Cunha & Junk 2001, Junk *et al.* 2006, Girard 2011). The high habitat heterogeneity results in a huge biodiversity, largely influenced by neighboring biogeographic provinces, namely the Cerrado, Chaco, Chiquitano Dry Forests, Amazonia and Atlantic Forest (Brown 1986, Nunes & Tomas 2004). Nevertheless, in spite of such high species richness, Pantanal lacks endemic birds (Tubelis & Tomas 2003).

The difficult access to many parts of the Pantanal, especially when it is flooded, associated with its harsh field conditions (*e.g.* maximum daily temperature frequently exceed 40°C, hordes of mosquitoes and ticks, flooded habitats), resulted in a small number of biological inventories and, consequently, this wetland is full of collecting gaps. The biodiversity of Pantanal is still poorly known, even for birds, which are generally acknowledged as the best-sampled group among vertebrates.

The most reliable checklist ever published for the Pantanal is that of Tubelis & Tomas (2003), which recorded 463 bird species for the wetland. Several subsequent studies recorded new species for the Pantanal (*e.g.* Vasconcelos *et al.* 2008, Antas & Palo-Jr. 2009, Girard 2011) and an updated checklist for the floodplain was recently published by Nunes (2011). Nevertheless, this updated checklist is careless, incorporating several questionable or erroneous records to the Pantanal (pers. obs.) and, therefore, it will not be considered further in this paper.

The necessity of additional and intensive biological inventories in the Pantanal has been emphasized by Brown (1986), who, in a classic paper about the local zoogeography, concluded that a better understanding of the Pantanal fauna would only emerge after decades of regular and detailed inventories. However, Pantanal is under eminent threat and this is the definitive moment for decision making (Neves 2009). Replacement of the traditional low density extensive cattle ranching by intensive cattle raising, introduction of exotic grasses, deforestation, poaching and gold mining (and the resulting mercury contamination) are examples of growing anthropic activities in the region (Silva *et al.* 2001, Harris *et al.* 2006, Alho 2008, 2011). Even worse threatens are the economic/development projects that have been, or are being planned to be implemented and that will affect the flood cycle of the entire Pantanal, such as reservoirs for hydroelectric power plants in the catchment area and the extension of the Paraguay-Paraná waterway (Lourival *et al.* 1999, Silva *et al.* 2001, Alho 2008, Neves 2009, Alho 2011). Other potential sources of threat are the planned installation of industrial, metallurgical and gas-chemical plants in the Pantanal or in its catchment area (Neves 2009). Therefore, given the scarcity of basic information about the local biodiversity, as well as to the growing threats suffered by the Pantanal, this paper presents the results of a long term inventory conducted in the northern portion of this wetland.

METHODS

Study area

This study was conducted in the subregion known as Pantanal of Poconé, state of Mato Grosso, southwestern Brazil (Silva & Abdon 1998). Our fieldwork was conducted near to Pirizal (16°14'09"S; 56°22'50"W), a small district of the municipality of Nossa Senhora do Livramento that gives name to the whole region we sampled. The district of Pirizal lies in the border between the Pantanal and the Cerrado, in the transition zone between these two important Brazilian biogeographic provinces. Pirizal region has a low human density and is difficulty to access when the Pantanal is flooded. Consequently, local landscape is comparatively well preserved (Pinho & Nogueira 2003).

Fieldwork was based in the Fazenda Retiro Novo (16°22'01"S; 56°17'58"W), one of the best-studied sites from the ornithological point of view in the entire Pantanal (*e.g.* Pinho & Nogueira 2003, Pinho *et al.* 2006, 2009, in press, Pinho & Marini 2012, 2014, Bernardon *et al.* 2014). Our fieldwork also included frequent visits to nearby farms, including the Fazenda Aparecida (16°22'22"S; 56°19'26"W), Fazenda Aterrado (16°16'20"S; 56°20'59"W) and Fazenda Campo Alegre (16°20'45"S; 56°21'23"W). We also conducted limited fieldwork in the Rio Piraim, where we visited a locality known as Moquém (16°23'38"S; 56°15'51"W), and in a bamboo dominated forest patch near to Pirizal (16°13'52"S; 56°23'01"W). The study area is about 30,000 ha and all localities sampled are inside the Pantanal floodplain, in the municipalities of Nossa Senhora do Livramento and Poconé. A map of the study area, which is located between the right bank of Rio Piraim and the left bank of Rio Bento Gomes, can be seen in Pinho *et al.* (2006).

Local climate is Aw according to the Köppen's climate classification system, what means a tropical climate with dry winter (Alvares *et al.* 2014). Two marked seasons can be identified, a dry one from May to September, and a wet one from October to April (Pinho & Marini 2012). Mean annual rainfall from 1999 to 2002 was 1159 mm, mean annual temperature was 25.8°C, mean annual low temperature was 20.9°C and mean annual maximum temperature was 32.5°C (Pinho & Marini 2012).

Floods in the northern Pantanal are rather shallow when compared with floods in its southern portion, reaching up to 2 m depth, but presenting strong interannual variation (Nunes-da-Cunha & Junk 2004, Girard 2011). The flood cycle can be simplistically divided into three distinct periods (Pinho & Marini 2012): 1) flooded (January–April), run-off (May–August) and low water (September–December). Note that there is a time lag between the onset of rains and flooding.

Pantanal is very plain, and elevations of the sampled localities are ~120–125 m a.s.l., with marked changes in vegetation observed within very short distances due to topography and, consequently, to the degree of flooding. Local vegetation is a complex mosaic of distinct phytophysiognomies, including deciduous, semideciduous and evergreen forests, open savannas and natural grasslands, all of them seasonally flooded, with the only exception of the deciduous/semideciduous forests. Permanent marshes, riparian forests, and dense bamboo dominated forest patches are also found.

Four main forest types are found in the region, and are briefly described here. Cordilheira are semi-deciduous to deciduous forests with high floristic affinities with the Cerrado; located in the higher areas, this forest type never floods. Cambarazal is an evergreen forest dominated by *Vochysia divergens* (Vochysiaceae), seasonally flooded. Landi is a low and dense forest located in the lower areas, seasonally flooded. Carvoal is an open deciduous forest dominated by *Callistene fasciculata* (Vochysiaceae) and that never floods. Further descriptions of these four forest types can be found in Pinho & Marini (2012). Detailed information about the local vegetation can also be found elsewhere (Nascimento & Nunes-da-Cunha 1989, Nunes-da-Cunha & Junk 1999, 2001, Nunes-da-Cunha *et al.* 2007).

Sampling

We conducted standard samplings in the four main forest types found in the study area: cordilheira, cambarazal, landi (three replicates in each) and carvoal (two replicates). Mean ± SD size of each forest patch are as follow: cordilheira (12.1 ± 0.2 ha), cambarazal (28.8 ± 2.7 ha), landi (14.9 ± 3.0 ha) and carvoal (27.9 ± 3.8 ha).

Birds from the 11 forest patches described above were sampled through point counts and mist-netting from September 1999 to August 2001, as detailed in Pinho & Marini (2012). Additional sampling in the study area were conducted non-systematically and with multiple purposes until October 2015, especially during studies focusing on the breeding biology (*e.g.* Rubio & Pinho 2008, Evangelista *et al.* 2010, Nóbrega & Pinho 2010, Bernardon *et al.* 2014, Pinho & Marini 2014), diet (Silva & Rúbio 2007, Gaiotti & Pinho 2013), and the spatial patterns of diversity of birds (Signor & Pinho 2011). Therefore, we sampled all habitat types found in the study area to some extent in addition to the standard sampling, but the exact sampling effort conducted is difficult to determine.

We tried as much as possible to document the records obtained with specimens. Birds were collected with fireguns, airguns or mist nets, prepared as study skins and deposited in the ornithological collections of the Universidade Federal de Mato Grosso, Cuiabá (UFMT), Universidade Federal de Minas Gerais, Belo Horizonte (DZUFMG), and Universidade Federal de Viçosa, Florestal (CAF).

Taxonomy and systematic follow the 4th edition of Howard and Moore Checklist (Dickinson & Remsen-Jr. 2013, Dickinson & Christidis 2014). Subspecies were indicated only when indispensable, especially in those circumstances where the taxonomic treatment adopted here differs from those adopted by the Brazilian Ornithological Records Committee (http://www.cbro.org.br). We highlighted those species considered threatened at national (MMA 2014) and global levels (BirdLife International 2015).

RESULTS

We recorded 343 bird species distributed in 63 families, with 178 (51.9%) non-passerine species and 165 (48.1%) passerine species (Appendix I). The most species-rich family was Tyrannidae (40 species), followed by Thraupidae (27), Accipitridae (17) and Trochilidae (15). We collected 510 specimens, 365 of which are housed in UFMT, 134 in DZUFMG and 11 in CAF. We personally checked all specimens housed in the above cited institutions on February and September 2015, but found that some of the specimens listed in the accession book of the UFMT are missing, as indicated in the Appendix I. Specimens collected belong to 188 species, what corresponds to 54.8% of the bird fauna found in Pirizal.

We recorded 22 bird species not included in the list of bird species of the Pantanal compiled by Tubelis & Tomas (2003), namely: *Patagioenas speciosa*, *Ictinia mississippiensis*, *Strix huhula*, *Chelidoptera tenebrosa*, *Celeus flavus*, *Primolius maracana*, *Neopelma pallescens*, *Xenopsaris albinucha*, *Pachyramphus validus*, *P. marginatus*, *Platyrinchus mystaceus*, *Myiornis ecaudatus*, *Elaenia parvirostris*, *E. albiceps*, *Capsiempis flaveola*, *Attila phoenicurus*, *Empidonax alnorum*, *Myiothlypis leucophrys*, *Pipraeidea melanonota*, *Catharus fuscescens*, *Turdus fumigatus*, and *T. albicollis*.

The bird fauna found in Pirizal is largely composed by wide ranging species, the majority of them widely distributed across the open formation of central South America. Fifteen taxa are typical to the Amazonia (Silva 1996): *Eurypyga helias*, *Coccycua minuta*, *Zebrilus undulatus*, *Strix h. huhula*, *Trogon melanurus*, *Celeus f. flavus, Tityra semifasciata*, *Myiornis ecaudatus*, *Hemitriccus striaticollis*, *Attila bolivianus*, *Hypocnemoides maculicauda*, *Pyriglena leuconota*, *Hylophilus pectoralis*, *Cacicus cela* and *Turdus fumigatus*. None of the species recorded is typical to the Atlantic Forest (Silva 1996).

Five species are endemic to the Cerrado (Silva & Bates 2002): *Penelope ochrogaster*, *Antilophia galeata*, *Herpsilochmus longirostris*, *Myiothlypis leucophrys* and *Saltatricula atricollis*. Some species typical to the Chaco, such as *Ortalis canicollis*, *Celeus lugubris*, and *Xiphocolaptes major*, are widespread in the Pantanal and, therefore, cannot be considered as endemic to the Chaco.

Only two species recorded are considered threatened to some extent. *Penelope ochrogaster* is considered "vulnerable" at national and global levels, while *Anodorhynchus hyacinthinus* is considered "vulnerable" at global level. Noteworthy records are discussed below.

DISCUSSION

Species richness

The number of species recorded by us is one of the largest ever recorded in a single locality in the Pantanal, being exceeded only by those recorded in RPPN SESC Pantanal, municipality of Barão de Melgaço, where 371 species have been recorded during a long term inventory that is taking place since 1998 (Antas & Palo-Jr. 2009, Ubaid & Antas 2013). It is important to highlight that the area of the RPPN SESC Pantanal (106,782 ha) is much larger than the area sampled by us. Short-term inventories conducted in other sites in Pantanal revealed considerably lower species richness. For example, an inventory conducted in the Fazenda Nhumirim (4310 ha) revealed 272 species (Nunes *et al.* 2005). A more detailed inventory conducted in the Fazenda Santa Emília (2700 ha) revealed 273 species (Pivatto *et al.* 2008).

The high species richness recorded in Pirizal, as well as those recorded in RPPN SESC Pantanal, is probably usual for a large area located in the Pantanal border, being the result of the large sampling effort conducted in these two areas. This large sampling effort allowed us to detect regionally rare (*e.g. Ciccaba huhula* and *Zebrilus undulatus*), vagrant (*e.g. Pipraeidea melanonota*) and transient (*e.g. Attila phoenicurus*, *Empidonax alnorum* and *Dolichonyx oryzivorus*) species that demonstrates the importance of long-term inventories.

Records of new species

Although this paper added almost two dozen species to the list compiled by Tubelis & Tomas (2003), we must stress that this list is outdated and that several of these species have already been recorded in the Pantanal by previous authors (*e.g.* Vasconcelos *et al.* 2008, Antas & Palo-Jr. 2009, Ubaid & Antas 2013). The large number of species recorded by us for the first time in the Pantanal is probably attributable to 1) the scarcity of previous bird inventories in the floodplain; 2) the large sampling effort conducted here; and 3) the short distance of the Pirizal region to the Pantanal border and the consequent biogeographic influence from the adjacent Cerrado. We suspect that the proximity of the study area to the Cerrado enables that small populations of species apparently intolerant to the seasonal flooding (*e.g. Suiriri suiriri affinis*, *Saltatricula atricollis*) are maintained in the Pirizal region due to the constant arrival of dispersers from the adjacent Cerrado.

Pantanal is remarkable not only by its high bird species richness. The extreme rarity or even the lack of records of several very common and omnipresent species in the adjacent Cerrado (Lopes *et al.* 2009, pers. obs.) is also remarkable. Some examples are *Forpus xanthopterygius*, *Pygochelidon cyanoleuca*, *Tangara cayana*, *Dacnis cayana* and *Sporophila nigricollis*. Reasons for those absences are unknown, but they probably have something to do with the flooding regime of the Pantanal.

Noteworthy records

We included in the following section those species of conservationist and biogeographic interest.

Penelope spp. – *Penelope ochrogaster* is by far the most common species of guan in the Pirizal region, being frequently found in the landi, cambará and cordilheira forests. When the Pantanal is flooded, this species is most frequently found in cordilheira forests. *Penelope superciliaris* is a rare species in the region, known from very few records.

Ictinia mississippiensis – there are only five records of this species to the study area, generally of three or fewer birds. One remarkable exception was a flock of more than one hundred birds seen and photographed on the first week of October 2015 perched in a cordilheira forest, where they have apparently overnighted. Records of the species for the state of Mato Grosso are summarized by Lopes *et al.* (2009).

Anodorhynchus hyacinthinus – local population of this macaw increased considerably during the last two decades. It was of ~14 birds on 1996/1997, reaching ~50 birds on 2014/2015. Its nests are invariably built on cavities excavated in the trunk of *Sterculia apetala*, but it occasionally uses cavities on *Enterolobium contorsiliquum.*

Pachyramphus marginatus – a rare species in cambará forests, the tallest and most humid forest found in the study area. The congeneric *P. polychopterus* is much more common in the study area, being found in drier savannas, woodlands and forest borders. The northern border of the Pantanal represents the southern range limit for the species (Ridgely & Tudor 2009), that has two subspecies, the nominotypical one, which is restricted to the eastern Brazilian Atlantic Forest, and *P. m. nanus*, which is restricted to the Amazonia (Dickinson & Christidis 2014).

Myiornis ecaudatus – a fairly common species in cambará forests. This is a predominantly Amazonian species (Silva 1996), which has the northern Pantanal border as its southern range limit (Ridgely & Tudor 2009).

Attila phoenicurus – a transient species in the Pantanal, which breeds in the southeastern Brazilian Atlantic Forest and winters in the Amazonia (Chesser 1994, Ridgely & Tudor 1994). Two birds were mist-netted on 26 March 1999 in a landi forest. Another bird was mist-netted on October 2001. The species has also been mist-netted in the SESC Pantanal on 21 March 2011 (Ubaid & Antas 2013).

Empidonax alnorum – three species of the genus *Empidonax* are found in South America, all of them uncommon to fairly common boreal migrants (Ridgely & Tudor 2009). Identification in the hand, without the help of vocalizations, is difficult but feasible with considerable effort (Pyle 1997). A single unsexed specimen (UFMT 0644) collected on an uncertain date of 2000 is the only record of the species for the study area. Identification of this specimen was based on a careful inspection of the specimen, whose body measurements and wing morphology perfectly coincided with values presented by Pyle (1997) for *E. alnorum*, including "Formula I" and "Formula R". Unfortunately, the specimen is poorly prepared and labelled, and we have no additional information to provide about this important record.

Thamnophilus pelzelni – although Tubelis & Tomas (2003) considered all members of the *T. punctatus* complex recorded in the Pantanal as belonging to *T. sticturus*, birds recorded in the Pirizal region are referable to *T. pelzelni,* the species that is widely distributed in the Cerrado. *Thamnophilus sticturus* also occurs in the Pantanal, but is restricted to its western portion, in areas under influence of Chiquitano Dry Forests (Vasconcelos & Hoffmann 2006).

Myiothlypis leucophrys – a single specimen (UFMT 0236) collected in the poorly sampled seasonally flooded riparian forest of Rio Piraim on September 2002 is the only record of the species for the study area. This specimen represents the first record of the species for the Pantanal.

Dolichonyx oryzivorus – a single bird was mist-netted in a seasonally flooded grassland on 25 May 2001. This bird was banded and released. This is a Neartic long-distance migrant, which breeds in North America and winters in wet grasslands from northeastern Bolivia to northern Argentina, including the Pantanal (Ridgely & Tudor 2009), from where few records are available (Tubelis & Tomas 2003). The record presented here is an abnormally late one, because return migration starts in March to early April, with breeding season in North America from May to July (Fraga 2011). Extreme dates for the species in Paraguay are 20 September and 24 April (Guyra Paraguay 2005).

Catharus fuscescens – a single bird (UFMT 0201) collected on 6 November 2011 is the only record for the study area. Additional specimens in the UFMT are a bird collected in the municipality of Juína, Mato Grosso, on 24 November 2006 and seven other specimens collected in the municipalities of Comodoro, state of Mato Grosso, and Chupinguaia, state of Rondônia, all of them on the second half of January 2011. All records of the species listed here are well in accordance with what is known about the winter range of the species (Heckscher *et al.* 2011).

Turdus fumigatus – we referred the single specimen of the *T. fumigatus/hauxwelli* complex obtained in a cambarazal as belonging to this species after comparing it with unquestionable specimens of *T. fumigatus* obtained in Belém region, northern Brazil. This species has also been recorded in the RPPN SESC Pantanal by Antas & Palo-Jr. (2009), but the specimen collected in this site by V. Cavarzere and F. Ubaid on 19 October 2011 (MZUSP 91872) closely approaches *T. hauxwelli* from the morphological point of view. It is well known that the taxonomy of the *T. fumigatus/hauxwelli* complex is exceedingly difficult and needs further investigation, with some authors suggesting that these two species hybridize in Mato Grosso (Naumburg 1930, Hellmayr 1934, Gyldenstolpe 1945, Snow 1985). Nevertheless, this hypothesis needs to be confirmed, because the morphological variation observed in this complex was difficult to appreciate at that time due to the existence of an undescribed species, the cryptic *T. sanchezorum* (O'Neill *et al.* 2011). Taxonomy of this complex needs further investigation.

Turdus albicollis – the single bird collected in the study area (UFMT 3334) belongs to the subspecies found in southwestern Brazil, Paraguay and Argentina, *T. a. paraguayensis* (Naumburg 1930, Hellmayr 1934). This subspecies seems to be very rare in the state.

Some species found in the study area are locally tied to bamboo patches, even though they are not considered as bamboo specialists (Parker-III *et al.* 1996). These species are *Formicivora grisea*, *F. melanogaster*, *Synallaxis scutata*, *Myiobius barbatus* and *Platyrinchus mystaceus*. Some true bamboo specialist birds were collected by us in the Pantanal of Cáceres, including *Drymophila devillei* and *Amaurospiza moesta* (Lopes *et al.* 2011). Although bamboo patches are well known as an important contribution for Neotropical birds diversity (Cockle & Areta 2013), no study to date has focused on the importance of this microhabitat in the Pantanal region.

Identification mistakes and corrections

We have mistakenly included in previous papers and unpublished thesis the records of some species that does not occur in the Pirizal region. We identified these mistakes after a complete revision of the specimens housed in the ornithological collection of UFMT that took place on February and September 2015. These mistakes originated from mislabeled specimens or from confusion with similar looking species that occur in the region. We are now taking the opportunity to correct them.

Dendrocygna bicolor – recorded by Pinho (2005), it is a typographical error that led the species to be mistakenly included in the species list.

Pipile cujubi – recorded by Pinho (2005), Pinho & Marini 2012, Pinho *et al.* (in press), it is a nomenclatural mistake with the congeneric *P. cumanensis grayi*, which is the species found in the study area.

Geotrygon montana – recorded by Pinho (2005), it is an identification mistake of a dove observed in flight, maybe a species of *Leptotila*.

Phaethornis ruber – recorded by Pinho (2005), Signor & Pinho (2010, 2011), Pinho & Marini (2012) and Pinho *et al.* (in press). Records of the species for the Pirizal originated from misidentified specimens of *P. nattereri.* Furthermore, it is highly unlikely that three small species of hermits co-occur in a same site.

Hylocharis cyanus – recorded by Pinho (2005), Pinho & Marini (2012) and Pinho *et al.* (in press), it is an identification mistake of the male *Chlorostilbon lucidus*.

Glaucidium minutissimum – recorded by Pinho (2005) and Pinho & Marini (2012), it is double mistake. First, it is a nomenclatural confusion with the Amazonian taxon *G. hardy*, which is the taxon found in Mato Grosso. Second, it is a misidentification of specimens of *G. brasilianum* with the crown predominantly dotted, not streaked whitish, a diagnostic character that appeared in some old field guides (Dunning 1987). We never heard the voice of *G. hardy* in the study area, and given that *Glaucidium* is a genus with high chromatic variability and lack of good morphological diagnostic characters (Vielliard 1989, König & Weick 2008), we preferred to keep in our list only *G. brasilianum*, a species heard daily in the study area.

Trogon surrucura – recorded by Pinho (2005), it is a typographical error that led the species to be mistakenly included in the species list.

Nystalus maculatus striatipectus – recorded by Pinho (2005), who considered this taxon as an independent species following Silva (1991). The taxon found in Pirizal is *N. m. maculatus*, which is widely distributed throughout the Cerrado and the Caatinga. Tubelis & Tomas (2003) also inadvertently considered the taxon *striatipectus* as the only one of the complex to occur in the Pantanal, but *striatipectus* is restricted to the southwestern border of the Pantanal (Silva 1991).

Celeus flavescens – recorded by Pinho (2005) and Pinho *et al.* (in press), it is a misidentification of the morphologically variable *C. lugubris.*

Neopelma sulphureiventer – recorded by Pinho (2005), Pinho & Marini (2012) and Pinho *et al.* (in press), it is a misidentification of the congeneric *N. pallescens.*

Platyrinchus platyrhynchos – There is a specimen (UFMT 0653) collected on uncertain date on 2003 and labelled as being obtained in the study area. This specimen is much probably mislabeled and we believe that it was obtained somewhere in the northern portion of Mato Grosso.

Elaenia cristata – recorded by Pinho (2005), Signor & Pinho (2010, 2011), Pinho & Marini (2012) and Pinho *et al.* (in press). Members of the genus *Elaenia* are very difficult to identify by morphological features, and some species cannot be identified in the field, even by experienced observers. We adopted here a very conservative approach, which was to include in our list only those species documented with specimens or well known to occur in the Pantanal and easily identifiable by voice. We adopted this approach after reviewing all members of the genus housed in UFMT and finding several misidentified specimens. There are records of this species in SESC Pantanal (Antas & Palo-Jr. 2009).

Elaenia obscura – recorded by Pinho (2005), Pinho & Marini (2012) and Pinho *et al.* (in press). There is no confident record of this species for the state of Mato Grosso (Boute & Carlos 2007, Ridgely & Tudor 2009). See also above for *E. cristata*.

Elaenia mesoleuca – recorded by Pinho (2005), Pinho & Marini (2012) and Pinho *et al.* (in press). There is no confident record of this species for the state of Mato Grosso (Boute & Carlos 2007, Ridgely & Tudor 2009). See above for *E. cristata.*

Suiriri islerorum –recorded by Signor & Pinho (2010, 2011). It is a misidentification of *Suiriri suiriri affinis* (see figure 3H of Signor & Pinho 2010). Note that the nomenclature of the genus *Suiriri* adopted by Dickinson & Christidis (2014) differs from that proposed by Kirwan *et al.* (2014).

Myiozetetes similis – recorded by Pinho (2005), Pinho & Marini (2012), Signor & Pinho (2011) and Pinho *et al.* (in press). After checking specimens in the UFMT collection, we are not sure about the occurrence of the species in the study area, because it has been frequently misidentified with the similar looking *M. cayanensis*, which is very common in the region. Although voices of these species are quite different, we suspect that some observed or mist-netted specimens of *M. cayanensis* have been misidentified as *M. similis*. The ornithological collection of UFMT houses no specimen of *M. similis,* but there are records of the species, which seems to be rare in Mato Grosso, for SESC Pantanal (Antas & Palo-Jr. 2009).

Sporophila bouvronides – recorded by Pinho (2005), it is a typographical error for *S. bouvreuil*.

Arremon taciturnus – recorded by Pinho (2005), Pinho & Marini (2012) and Pinho *et al.* (in press), it is a nomenclatural confusion with *A. flavirostris.*

CONCLUSION

In this study we demonstrated that the Pirizal region harbor a huge species diversity, especially if considering that this is a predominantly non-forested site, which requires conservation efforts. We concluded that long-term inventories can result in the record of several species not previously known to occur in a comparatively well sampled region, such as the northern portion of the Pantanal (Tubelis & Tomas 2003). Given that bird inventories in the Pantanal are mostly restricted to its border or near to large cities and main roads, further inventories are still necessary on extensive regions of this wetland, especially on its central, western and northwestern portions. These regions are far from roads and big cities and, consequently, are very difficult to access, especially when the Pantanal is flooded. Without serious sampling efforts in these regions, our knowledge about the Pantanal bird fauna and its distribution will keep on far from adequate. Long-term inventories are also a great opportunity for checking our field observations and the identification of collected specimens, what can result in the correction of some identification errors. Unfortunately, this is infrequently done in the literature, resulting in the perpetuation of errors (Willis 2003). We finally would like to highlight the necessity of a complete update to the list of bird species of the Pantanal upland, incorporating not only the new records obtained in this floodplain, but also checking the identification and validity of all records available.

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APPENDIX I

Bird species recorded in the Pirizal region, municipalities of Poconé and Nossa Senhora do Livramento, Pantanal of Poconé, Mato Grosso, Brazil. Specimens listed in the accession book, but not found on their respective collections on September 2015, are highlighted in italics. Accession numbers of all specimens collected are presented, as well as other evidentiary information, which was coded as: H – heard; P – photograph, V – visually observed; - no specimen available.

Taxon	**English name**	**Specimens**	**Evidentiary information**
ORDER RHEIFORMES			
Family Rheidae			
Rhea americana (Linnaeus, 1758)	Greater Rhea	-	H,V
ORDER TINAMIFORMES			
Family Tinamidae			
Crypturellus undulatus (Temminck, 1815)	Undulated Tinamou	DZUFMG 5058–5065	H,S,V
Crypturellus parvirostris (Wagler, 1827)	Small-billed Tinamou	UFMT 2795	H,V
Rhynchotus rufescens (Temminck, 1815)	Red-winged Tinamou	-	H,V
ORDER ANSERIFORMES			
Family Anhimidae			
Chauna torquata (Oken, 1816)	Southern Screamer	-	H,P,V
Family Anatidae			
Dendrocygna viduata (Linnaeus, 1766)	White-faced Whistling-duck	-	H,P,V
Dendrocygna autumnalis (Linnaeus, 1758)	Black-bellied Whistling-duck	UFMT 3428, 3457	H,V
Amazonetta brasiliensis (J.F. Gmelin, 1789)	Brazilian Teal	UFMT 3233, 3372	H,P,V
Cairina moschata (Linnaeus, 1758)	Muscovy Duck	-	P,V
ORDER GALLIFORMES			
Family Cracidae			
Penelope ochrogaster von Pelzeln, 1870	Chestnut-bellied Guan	UFMT 0247, 2866, 2869	H,P,V
Pipile cumanensis grayi (von Pelzeln, 1870)	Blue-throated Piping Guan	UFMT 2588	H,P,V
Ortalis canicollis (Wagler, 1830)	Chaco Chachalaca	DZUFMG 5098, 5099; UFMT 0246, 0263, 2597, 2867	H,P,V
Crax fasciolata von Spix, 1825	Bare-faced Curassow	UFMT 2221	H,P,V
ORDER COLUMBIFORMES			
Family Columbidae			
Patagioenas speciosa (J.F. Gmelin, 1789)	Scaled Pigeon	-	H,P,V
Patagioenas picazuro (Temminck, 1813)	Picazuro Pigeon	-	H,V
Patagioenas cayennensis (Bonnaterre, 1792)	Pale-vented Pigeon	-	H,P,V
Leptotila verreauxi Bonaparte, 1855	White-tipped Dove	DZUFMG 5041; UFMT 0182, 0243, *0282*, 0298, 3212, 3472	H,P,V
Leptotila rufaxilla (Richard & Bernard, 1792)	Gray-fronted Dove	-	H,V,
Columbina squammata (Lesson, 1831)	Scaled Dove	UFMT 3350	H,P,V
Columbina minuta (Linnaeus, 1766)	Plain-breasted Ground-dove	-	H,V
Columbina talpacoti (Temminck, 1810)	Ruddy Ground-dove	UFMT 0229, 0261	H,P,V
Columbina picui (Temminck, 1813)	Picui Ground-dove	-	H,V
Claravis pretiosa (Ferrari-Pérez, 1886)	Blue Ground-dove	-	V
Uropelia campestris (von Spix, 1825)	Long-tailed Ground-dove	DZUFMG 5149–5152	V
ORDER EURYPYGIFORMES			
Family Eurypygidae			
Eurypyga helias (Pallas, 1781)	Sunbittern	DZUFMG 5069; UFMT 0224	H,P,V

Taxon	English name	Specimens	Evidentiary information
ORDER CAPRIMULGIFORMES			
Family Nyctibiidae			
Nyctibius grandis (J.F. Gmelin, 1789)	Great Potoo	UFMT 2586	H,V
Nyctibius griseus (J.F. Gmelin, 1789)	Common Potoo	UFMT 3227	H,V
Family Caprimulgidae			
Chordeiles nacunda (Vieillot, 1817)	Nacunda Nighthawk	-	P,V
Chordeiles pusillus Gould, 1861	Least Nighthawk	-	H,V
Nyctiprogne leucopyga (von Spix, 1825)	Band-tailed Nighthawk	-	H,P,V
Nyctidromus albicollis (J.F. Gmelin, 1789)	Pauraque	UFMT *0765*, 3344	H,P,V
Setopagis parvula (Gould, 1837)	Little Nightjar	-	H,V
Hydropsalis torquata (J.F. Gmelin, 1789)	Scissor-tailed Nightjar	-	H,V
Antrostomus rufus (Boddaert, 1783)	Rufous Nightjar	-	H,V
Family Apodidae			
Chaetura meridionalis Hellmayr, 1907	Sick's Swift	-	H,V
Family Trochilidae			
Glaucis hirsutus (J.F. Gmelin, 1788)	Rufous-breasted Hermit	-	P,V
Phaethornis nattereri von Berlepsch, 1887	Cinnamon-throated Hermit	DZUFMG 5103; UFMT 3216	H,P,V
Phaethornis subochraceus Todd, 1915	Buff-belllied Hermit	-	V
Phaethornis pretrei (Lesson & Delattre, 1839)	Planalto Hermit	-	H,V
Polytmus guainumbi (Pallas, 1764)	White-tailed Goldenthroat	UFMT 0661, 3379	V
Chrysolampis mosquitus (Linnaeus, 1758)	Ruby-topaz Hummingbird	-	V
Anthracothorax nigricollis (Vieillot, 1817)	Black-throated Mango	UFMT 0273	V
Chlorostilbon lucidus (Shaw, 1812)	Glittering-bellied Emerald	-	H,V
Eupetomena macroura (J.F. Gmelin, 1788)	Swallow-tailed Hummingbird	-	H,V
Thalurania furcata (J.F. Gmelin, 1788)	Fork-tailed Woodnymph	UFMT 0371, 0372, 3342	P,V
Amazilia versicolor (Vieillot, 1818)	Versicolored Emerald	-	H,V
Amazilia fimbriata (J.F. Gmelin, 1788)	Glittering-throated Emerald	UFMT 0764, 3345, 3349, 3375	P,V
Hylocharis chrysura (Shaw, 1812)	Gilded Hummingbird	-	P,V
Heliomaster furcifer (Shaw, 1812)	Blue-tufted Starthroat	-	V
Calliphlox amethystina (Boddaert, 1783)	Amethyst Woodstar	-	V
ORDER CUCULIFORMES			
Family Cuculidae			
Crotophaga major J.F. Gmelin, 1788	Greater Ani	DZUFMG 5057	H,P,V
Crotophaga ani Linnaeus, 1758	Smooth-billed Ani	DZUFMG 5056; UFMT 0241, 0631, 3341, 3397	H,P,V
Guira guira (J.F. Gmelin, 1788)	Guira Cuckoo	UFMT 3337, 3404	H,P,V
Tapera naevia (Linnaeus, 1766)	Striped Cuckoo	-	H,V
Coccycua minuta (Vieillot, 1817)	Little Cuckoo	-	V
Piaya cayana (Linnaeus, 1766)	Squirrel Cuckoo	-	H,P,V
Coccyzus americanus (Linnaeus, 1758)	Yellow-billed Cuckoo	-	V
Coccyzus melacoryphus Vieillot, 1817	Dark-billed Cuckoo	-	V
ORDER GRUIFORMES			
Family Rallidae			
Aramides cajaneus (Statius Muller, 1776)	Gray-necked Wood-rail	UFMT 3335, 3358	H,P,V
Neocrex erythrops (P.L. Sclater, 1867)	Paint-billed Crake	-	V
Porzana albicollis (Vieillot, 1819)	Ash-throated Crake	-	H,V

Taxon	**English name**	**Specimens**	**Evidentiary information**
Porphyrio martinicus (Linnaeus, 1766)	Purple Gallinule	-	V
Porphyrio flavirostris (J.F. Gmelin, 1789)	Azure Gallinule	-	V
Family Heliornithidae			
Heliornis fulica (Boddaert, 1783)	Sungrebe	-	V
Family Aramidae			
Aramus guarauna (Linnaeus, 1766)	Limpkin	-	H,P,V
ORDER PELECANIFORMES			
Family Ciconiidae			
Mycteria americana Linnaeus, 1758	Wood Stork	-	P,V
Ciconia maguari (J.F. Gmelin, 1789)	Maguari Stork	-	P,V
Jabiru mycteria (M.H.C. Lichtenstein, 1819)	Jabiru	-	P,V
Family Ardeidae			
Tigrisoma lineatum (Boddaert, 1783)	Rufescent Tiger-heron	DZUFMG 5146; UFMT 3370, 3429, 3432	H,P,V
Cochlearius cochlearius (Linnaeus, 1766)	Boat-billed Heron	-	V
Zebrilus undulatus (J.F. Gmelin, 1789)	Zigzag Heron	-	V
Ixobrychus exilis (J.F. Gmelin, 1789)	Least Bittern	DZUFMG 5089	V
Nycticorax nycticorax (Linnaeus, 1758)	Black-crowned Night-heron	-	V
Butorides striata (Linnaeus, 1758)	Striated Heron	DZUFMG 5042, UFMT 3485	H,P,V
Bubulcus ibis (Linnaeus, 1758)	Cattle Egret	-	P,V
Ardea cocoi Linnaeus, 1766	Cocoi Heron	-	P,V
Ardea alba Linnaeus, 1758	Great Egret	-	P,V
Syrigma sibilatrix (Temminck, 1824)	Whistling Heron	UFMT 3423, 3459	H,P,V
Pilherodius pileatus (Boddaert, 1783)	Capped Heron	-	P,V
Egretta caerulea (Linnaeus, 1758)	Little Blue Heron	UFMT 2154	P,V
Egretta thula (Molina, 1782)	Snowy Egret	-	P,V
Family Threskiornithidae			
Platalea ajaja Linnaeus, 1758	Roseate Spoonbill	DZUFMG 5111; UFMT 2590	P,V
Theristicus caerulescens (Vieillot, 1817)	Plumbeous Ibis	UFMT 3456	H,P,V
Theristicus caudatus (Boddaert, 1783)	Buff-necked Ibis	DZUFMG 5144	H,P,V
Mesembrinibis cayennensis (J.F. Gmelin, 1789)	Green Ibis	-	H,P,V
Phimosus infuscatus (M.H.C. Lichtenstein, 1823)	Bare-faced Ibis	UFMT 3421	P,V
Family Phalacrocoracidae			
Phalacrocorax brasilianus (J.F. Gmelin, 1789)	Neotropic Cormorant	-	V
Family Anhingidae			
Anhinga anhinga (Linnaeus, 1766)	Anhinga	-	V
ORDER CHARADRIIFORMES			
Family Recurvirostridae		-	
Himantopus himantopus melanurus Vieillot, 1817	White-backed Stilt	UFMT 0364	P,V
Family Charadriidae			
Charadrius collaris Vieillot, 1818	Collared Plover	DZUFMG 5053	V
Vanellus chilensis (Molina, 1782)	Southern Lapwing	UFMT 2578, 3128, 3401	H,V
Vanellus cayanus (Latham, 1790)	Pied Lapwing	UFMT 3438	P,V
Family Jacanidae			
Jacana jacana (Linnaeus, 1766)	Wattled Jacana	UFMT 0202, 3213, 3217, 3359	H,P,V

Taxon	**English name**	**Specimens**	**Evidentiary information**
Family Scolopacidae			
Calidris melanotos (Vieillot, 1819)	Pectoral Sandpiper	-	V
Gallinago paraguaiae (Vieillot, 1816)	South American Snipe	-	H,V
Actitis macularius (Linnaeus, 1766)	Spotted Sandpiper	-	V
Tringa solitaria A. Wilson, 1813	Solitary Sandpiper	-	P,V
Tringa flavipes (J.F. Gmelin, 1789)	Lesser Yellowlegs	-	V
Family Laridae			
Rynchops niger Linnaeus, 1758	Black Skimmer	-	P,V
Sternula superciliaris (Vieillot, 1819)	Yellow-billed Tern	-	P,V
Phaetusa simplex (J.F. Gmelin, 1789)	Large-billed Tern	-	H,P,V
ORDER ACCIPITRIFORMES			
Family Cathartidae			
Cathartes aura (Linnaeus, 1758)	Turkey Vulture	-	V
Cathartes burrovianus Cassin, 1845	Lesser Yellow-headed Vulture	-	V
Coragyps atratus (Bechstein, 1793)	Black Vulture	-	V
Sarcoramphus papa (Linnaeus, 1758)	King Vulture	-	V
Family Pandionidae			
Pandion haliaetus (Linnaeus, 1758)	Osprey	-	V
Family Accipitridae			
Elanus leucurus (Vieillot, 1818)	White-tailed Kite	-	V
Gampsonyx swainsonii Vigors, 1825	Pearl Kite	-	V
Elanoides forficatus (Linnaeus, 1758)	Swallow-tailed Kite	UFMT 2595	V
Spizaetus melanoleucus (Vieillot, 1816)	Black-and-white Hawk-eagle	-	H,V
Accipiter striatus Vieillot, 1808	Sharp-shinned Hawk	-	V
Accipiter bicolor (Vieillot, 1817)	Bicolored Hawk	-	H,V
Busarellus nigricollis (Latham, 1790)	Black-collared Hawk	UFMT 0248, 0250, 0267	H,P,V
Geranospiza caerulescens (Vieillot, 1817)	Crane Hawk	UFMT 3232	V
Ictinia mississippiensis (A. Wilson, 1811)	Mississippi Kite	-	V
Ictinia plumbea (J.F. Gmelin, 1788)	Plumbeous Kite	DZUFMG 5087; UFMT 0245, 2160	H,V
Rostrhamus sociabilis (Vieillot, 1817)	Snail Kite	UFMT 3413, 3419	H,V
Rupornis magnirostris (J.F. Gmelin, 1788)	Roadside Hawk	DZUFMG 5119; UFMT 0216, 0481, 0876, 2579, 2583, 2879, 3274, 3347, 3368, 3402	H,P,V
Buteogallus meridionalis (Latham, 1790)	Savanna Hawk	UFMT 2584, 2589, 2596, 2875, 3382, 3415	H,P,V
Buteogallus urubitinga (J.F. Gmelin, 1788)	Great Black-hawk	UFMT 2591	H,P,V
Geranoaetus albicaudatus (Vieillot, 1816)	White-tailed Hawk	-	V
Buteo nitidus (Latham, 1790)	Gray Hawk	UFMT 2872	H,V
Buteo albonotatus Kaup, 1847	Zone-tailed Hawk	-	V
ORDER STRIGIFORMES			
Family Tytonidae			
Tyto alba (Scopoli, 1769)	Barn Owl	-	H,V
Family Strigidae			
Glaucidium brasilianum (J.F. Gmelin, 1788)	Ferruginous Pygmy-owl	DZUFMG 5031, 5074; UFMT 0299	H,V
Athene cunicularia (Molina, 1782)	Burrowing Owl	-	H,V

Taxon	**English name**	**Specimens**	**Evidentiary information**
Megascops choliba (Vieillot, 1817)	Tropical Screech-owl	UFMT 0768, 0798	H,V
Pulsatrix perspicillata (Latham, 1790)	Spectacled Owl	-	H,V
Bubo virginianus (J.F. Gmelin, 1788)	Great Horned Owl	UFMT 2146	H,V
Ciccaba huhula (Daudin, 1800)	Black-banded Owl	DZUFMG 5030	V
ORDER TROGONIFORMES			
Family Trogonidae			
Trogon melanurus Swainson, 1838	Black-tailed Trogon	UFMT 0634	H,V
Trogon curucui Linnaeus, 1766	Blue-crowned Trogon	DZUFMG 5040; UFMT 0635	H,V
ORDER PICIFORMES			
Family Galbulidae			
Galbula ruficauda Cuvier, 1816	Rufous-tailed Jacamar	UFMT 0288, 0289, 0293	H,P,V
Family Bucconidae			
Nystalus chacuru (Vieillot, 1816)	White-eared Puffbird	-	H,V
Nystalus maculatus (J.F. Gmelin, 1788)	Spot-backed Puffbird	-	H,V
Monasa nigrifrons (von Spix, 1824)	Black-fronted Nunbird	CAF 0205; DZUFMG 5093; UFMT 3186, 3187, 3338	H,V
Chelidoptera tenebrosa (Pallas, 1782)	Swallow-wing	-	V
Family Picidae			
Picumnus albosquamatus d'Orbigny, 1840	White-wedged Piculet	DZUFMG 5107-5110; UFMT 0904	H,V
Dryocopus lineatus (Linnaeus, 1766)	Lineated Woodpecker	UFMT 3416	H,P,V
Celeus flavus (Statius Muller, 1776)	Cream-colored Woodpecker	-	P,V
Celeus lugubris (Malherbe, 1851)	Pale-crested Woodpecker	DZUFMG 5049, 5050; UFMT 0271, 3363	H,P,V
Piculus chrysochloros (Vieillot, 1818)	Golden-green Woodpecker	-	V
Colaptes melanochloros (J.F. Gmelin, 1788)	Green-barred Woodpecker	UFMT 3210	H,P,V
Colaptes campestris (Vieillot, 1818)	Campo Flicker	DZUFMG 5054; UFMT 0757, 2587	H,V
Campephilus melanoleucos (J.F. Gmelin, 1788)	Crimson-crested Woodpecker	UFMT 0184, 0682, 0683	H,V
Melanerpes candidus (Otto, 1796)	White Woodpecker	UFMT 3433, 3441	H,V
Veniliornis mixtus (Boddaert, 1783)	Checkered Woodpecker	DZUFMG 5106; UFMT 0497	V
Veniliornis passerinus (Linnaeus, 1766)	Little Woodpecker	DZUFMG 5153; UFMT 0214, 0486, 3425	H,V
Family Ramphastidae			
Ramphastos toco Statius Muller, 1776	Toco Toucan	UFMT 0212, 0503, 2580	H,P,V
Pteroglossus castanotis Gould, 1834	Chestnut-eared Aracari	DZUFMG 5035; UFMT 2014, 3277, 3405	H,P,V
ORDER CORACIIFORMES			
Family Momotidae			
Momotus momota (Linnaeus, 1766)	Blue-crowned Motmot	-	H,P,V
Family Alcedinidae			
Megaceryle torquata (Linnaeus, 1766)	Ringed Kingfisher	UFMT 2581	H,P,V
Chloroceryle amazona (Latham, 1790)	Amazon Kingfisher	-	H,P,V
Chloroceryle aenea (Pallas, 1764)	American Pygmy Kingfisher	UFMT 0213, 0281, 0691, 0770, 0964, 3262	P,V
Chloroceryle americana (J.F. Gmelin, 1788)	Green Kingfisher	UFMT 3197, 3376	H,P,V
Chloroceryle inda (Linnaeus, 1766)	Green-and-rufous Kingfisher	UFMT 0287, 0633	P,V

Taxon	**English name**	**Specimens**	**Evidentiary information**
ORDER CARIAMIFORMES			
Family Cariamidae			
Cariama cristata (Linnaeus, 1766)	Red-legged Seriema	-	H,P,V
ORDER FALCONIFORMES			
Family Falconidae			
Herpetotheres cachinnans (Linnaeus, 1758)	Laughing Falcon	-	H,P,V
Micrastur semitorquatus (Vieillot, 1817)	Collared Forest-falcon	UFMT 0314	H,V
Caracara plancus (J.F. Miller, 1777)	Southern Caracara	-	H,P,V
Milvago chimachima (Vieillot, 1816)	Yellow-headed Caracara	-	H,V
Falco sparverius Linnaeus, 1758	American Kestrel	-	H,V
Falco rufigularis Daudin, 1800	Bat Falcon	-	V
Falco femoralis Temminck, 1822	Aplomado Falcon	UFMT 3406	H,V
ORDER PSITTACIFORMES			
Family Psittacidae			
Myiopsitta monachus (Boddaert, 1783)	Monk Parakeet	-	H,V
Brotogeris chiriri (Vieillot, 1818)	Yellow-chevroned Parakeet	UFMT 0183	H,P,V
Amazona aestiva (Linnaeus, 1758)	Blue-fronted Parrot	UFMT 3399, 3403	H,P,V
Amazona amazonica (Linnaeus, 1766)	Orange-winged Parrot	-	H,V
Anodorhynchus hyacinthinus (Latham, 1790)	Hyacinth Macaw	-	H,P,V
Eupsittula aurea (J.F. Gmelin, 1788)	Nanday Parakeet	UFMT 0891	H,P,V
Aratinga nenday (Vieillot, 1823)	Peach-fronted Parakeet	-	H,V
Primolius auricollis (Cassin, 1853)	Yellow-collared Macaw	CAF 0222	H,P,V
Primolius maracana (Vieillot, 1816)	Blue-winged Macaw	-	H,V
Ara ararauna (Linnaeus, 1758)	Blue-and-yellow Macaw	-	H,V
Ara chloropterus G.R. Gray, 1859	Red-and-green Macaw	-	H,V
Diopsittaca nobilis (Linnaeus, 1758)	Red-shouldered Macaw	DZUFMG 5068; UFMT 0501, 0769, 3238, 3276, 3295, 3309, 3333	H,P,V
Psittacara acuticaudatus (Vieillot, 1818)	Blue-crowned Parakeet	CAF 0224; UFMT 3418, 3422	H,V
Psittacara leucophthalmus (Statius Muller, 1776)	White-eyed Parakeet	-	H,V
ORDER PASSERIFORMES			
Family Pipridae			
Neopelma pallescens (Lafresnaye, 1853)	Pale-bellied Tyrant-manakin	DZUFMG 5097; UFMT 0196, 0491, 0639	H,P,V
Pipra fasciicauda Hellmayr, 1906	Band-tailed Manakin	UFMT 0258, 0651	P,V
Antilophia galeata (M.H.C. Lichtenstein, 1823)	Helmeted Manakin	UFMT 0640	H,P,V
Family Onychorhynchidae			
Myiobius barbatus (J.F. Gmelin, 1789)	Whiskered Flycatcher	-	V
Family Tityridae			
Tityra inquisitor (M.H.C. Lichtenstein, 1823)	Black-crowned Tityra	-	V
Tityra cayana (Linnaeus, 1766)	Black-tailed Tityra	UFMT 0901	H,V
Tityra semifasciata (von Spix, 1825)	Masked Tityra	-	V
Xenopsaris albinucha (Burmeister, 1869)	White-naped Xenopsaris	UFMT 0217, 0227	H,P,V
Pachyramphus viridis (Vieillot, 1816)	Green-backed Becard	UFMT 0383, 0752	H,V
Pachyramphus validus (M.H.C. Lichtenstein, 1823)	Crested Becard	UFMT 0269	H,V

Taxon	English name	Specimens	Evidentiary information
Pachyramphus marginatus (M.H.C. Lichtenstein, 1823)	Black-capped Becard	-	H,V
Pachyramphus polychopterus (Vieillot, 1818)	White-winged Becard	UFMT 0464, 0886	H,V
Family Platyrinchidae			
Platyrinchus mystaceus Vieillot, 1818	White-throated Spadebill	-	H,V
Family Pipromorphidae			
Leptopogon amaurocephalus von Tschudi, 1846	Sepia-capped Flycatcher	-	H,P,V
Tolmomyias sulphurescens (von Spix, 1825)	Yellow-olive Flycatcher	UFMT 0206, 0638	H,V
Myiornis ecaudatus (d'Orbigny & Lafresnaye, 1837)	Short-tailed Pygmy-tyrant	-	V
Hemitriccus striaticollis (Lafresnaye, 1853)	Stripe-necked Tody-tyrant	UFMT 0475	H,V
Hemitriccus margaritaceiventer (d'Orbigny &Lafresnaye, 1837)	Pearly-vented Tody-tyrant	UFMT 0474, *0585*, 3371, 3374	H,V
Poecilotriccus latirostris (von Pelzeln, 1868)	Rusty-fronted Tody-flycatcher	DZUFMG 5147; UFMT 0472, *0487, 0490, 0832,* 3311	H,P,V
Todirostrum cinereum (Linnaeus, 1766)	Common Tody-flycatcher	UFMT *0480*	H,P,V
Family Tyrannidae			
Inezia inornata (Salvadori, 1897)	Plain Tyrannulet	DZUFMG 5088; UFMT 0470, 3312	P,V
Euscarthmus meloryphus zu Wied, 1831	Tawny-crowned Pygmy-tyrant	-	H,V
Camptostoma obsoletum (Temminck, 1824)	Southern Beardless-tyrannulet	UFMT 0187	H,V
Elaenia flavogaster (Thunberg, 1822)	Yellow-bellied Elaenia	-	H,V
Elaenia parvirostris von Pelzeln, 1868	Small-billed Elaenia	-	V
Elaenia spectabilis von Pelzeln, 1868	Large Elaenia	UFMT 0264, 0365, 0647	H,V
Elaenia chiriquensis Lawrence, 1865	Lesser Elaenia	UFMT 0205	V
Elaenia albiceps chilensis Hellmayr, 1927	Chilean Elaenia	UFMT 0342, 0494, 0495, 0636	V
Myiopagis gaimardii (d'Orbigny, 1840)	Forest Elaenia	DZUFMG 5095; UFMT 0645	H,V
Myiopagis viridicata (Vieillot, 1817)	Greenish Elaenia	DZUFMG 5096; UFMT 0646	H,V
Suiriri suiriri affinis (Burmeister, 1856)	Suiriri Flycatcher	DZUFMG 5126; UFMT *0498*	H,V
Capsiempis flaveola (M.H.C. Lichtenstein, 1823)	Yellow Tyrannulet	-	H,P,V
Phaeomyias murina (von Spix, 1825)	Mouse-colored Tyrannulet	-	H,V
Attila phoenicurus von Pelzeln, 1868	Rufous-tailed Attila	-	V
Attila bolivianus Lafresnaye, 1848	Dull-capped Attila	DZUFMG 5023, 5024	H,P,V
Legatus leucophaius (Vieillot, 1818)	Piratic Flycatcher	DZUFMG 5090	H,V
Pitangus sulphuratus (Linnaeus, 1766)	Great Kiskadee	UFMT 0199, 0208, 0209, 3353, 3365, 3411, 3417, 3435, 3468	H,V
Pitangus lictor (M.H.C. Lichtenstein, 1823)	Lesser Kiskadee	DZUFMG 5104, 5105	H,V
Machetornis rixosa (Vieillot, 1819)	Cattle Tyrant	UFMT *0773*, 3426, 3431	H,P,V
Megarynchus pitangua (Linnaeus, 1766)	Boat-billed Flycatcher	-	H,V
Myiodynastes maculatus (Statius Muller, 1776)	Streaked Flycatcher	-	H,V
Myiozetetes cayanensis (Linnaeus, 1766)	Rusty-margined Flycatcher	UFMT 0754, 3395	H,V
Tyrannus albogularis Burmeister, 1856	White-throated Kingbird	-	H,P,V
Tyrannus melancholicus Vieillot, 1819	Tropical Kingbird	DZUFMG 5148	H,V
Tyrannus savana Daudin, 1802	Fork-tailed Flycatcher	-	H,P,V
Casiornis rufus (Vieillot, 1816)	Rufous Casiornis	DZUFMG 5047, 5048; UFMT 0774	H,P,V
Myiarchus swainsoni Cabanis & Heine, 1859	Swainson's Flycatcher	UFMT 0240, 3400	H,V

Taxon	**English name**	**Specimens**	**Evidentiary information**
Myiarchus ferox (J.F. Gmelin, 1789)	Short-crested Flycatcher	DZUFMG 5094; UFMT 0237, 0479, 0499, 3398	H,V
Myiarchus tyrannulus (Statius Muller, 1776)	Brown-crested Flycatcher	UFMT 0272	H,V
Sublegatus modestus (zu Wied, 1831)	Southern Scrub-flycatcher	DZUFMG 5125; UFMT 0463	H,V
Pyrocephalus rubinus (Boddaert, 1783)	Vermilion Flycatcher	UFMT 2582, 2585, 3320	P,V
Fluvicola albiventer (von Spix, 1825)	Black-backed Water-tyrant	DZUFMG 5070; UFMT 0188	H,V
Arundinicola leucocephala (Linnaeus, 1764)	White-headed Marsh-tyrant	UFMT 3351	H,V
Xolmis cinereus (Vieillot, 1816)	Gray Monjita	-	H,P,V
Xolmis velatus (M.H.C. Lichtenstein, 1823)	White-rumped Monjita	UFMT *0577*, 0578, 0579, 0658	H,P,V
Xolmis irupero (Vieillot, 1823)	White Monjita	-	P,V
Cnemotriccus fuscatus (zu Wied, 1831)	Fuscous Flycatcher	UFMT 0178, 0270, 0637	H,P,V
Lathrotriccus euleri (Cabani, 1868)	Euler's Flycatcher	UFMT 3343	H,V
Empidonax alnorum Brewster, 1856	Alder Flycatcher	UFMT 0644	V
Contopus cinereus (von Spix, 1825)	Tropical Peewee	-	V
Family Thamnophilidae			
Formicivora grisea (Boddaert, 1783)	White-fringed Antwren	-	P,V
Formicivora melanogaster von Pelzeln, 1868	Black-bellied Antwren	UFMT 0195, 0652	V
Formicivora rufa (zu Wied, 1831)	Rusty-backed Antwren	DZUFMG 5071	H,V
Dysithamnus mentalis (Temminck, 1823)	Plain Antvireo	UFMT 0305, 0306	H,V
Herpsilochmus longirostris von Pelzeln, 1868	Large-billed Antwren	DZUFMG 5032, 5033, 5075, 5076; UFMT 0484, 0485, 0492	H,V
Taraba major (Vieillot, 1816)	Great Antshrike	DZUFMG 5128, 5129; UFMT 0276, 0301, 0771, 3427	H,P,V
Thamnophilus doliatus (Linnaeus, 1764)	Barred Antshrike	DZUFMG 5130-5143; UFMT 0467, 0751	H,P,V
Thamnophilus pelzelni Hellmayr, 1924	Planalto Slaty-antshrike	UFMT *0204*, 0230, 0366, *0657*, 3356, 3806	H,P,V
Cercomacra melanaria (Ménétries, 1835)	Mato Grosso Antbird	CAF 0184; DZUFMG 5026-5029, 5051, 5052; UFMT 0226, 0641	H,P,V
Hypocnemoides maculicauda (von Pelzeln, 1868)	Band-tailed Antbird	DZUFMG 5078; UFMT 0194, 0303, 0304	H,P,V
Pyriglena leuconota maura (Ménétries, 1835)	White-backed Fire-eye	-	H,P,V
Family Dendrocolaptidae			
Sittasomus griseicapillus (Vieillot, 1818)	Olivaceous Woodcreeper	DZUFMG 5123	H,P,V
Xiphocolaptes major (Vieillot, 1818)	Great Rufous Woodcreeper	DZUFMG 5154, 5155; UFMT 0185	H,P,V
Xiphorhynchus guttatus (M.H.C. Lichtenstein, 1820)	Buff-throated Woodcreeper	-	H,P,V
Dendroplex picus (J.F. Gmelin, 1788)	Straight-billed Woodcreeper	DZUFMG 5156; UFMT 0253, 3188	H,P,V
Campylorhamphus trochilirostris (M.H.C. Lichtenstein,1820)	Red-billed Scythebill	UFMT 0274	H,V
Lepidocolaptes angustirostris (Vieillot, 1818)	Narrow-billed Woodcreeper	DZUFMG 5091	H,P,V
Family Furnariidae			
Xenops rutilus Temminck, 1821	Streaked Xenops	-	H,V
Furnarius leucopus Swainson, 1838	Pale-legged Hornero	DZUFMG 5072; UFMT 0219, 0256, 0284, 0302	H,P,V
Furnarius rufus (J.F. Gmelin, 1788)	Rufous Hornero	DZUFMG 5073; UFMT 0186, 0200	H,P,V

Taxon	**English name**	**Specimens**	**Evidentiary information**
Phacellodomus rufifrons (zu Wied, 1821)	Rufous-fronted Thornbird	-	H,V
Phacellodomus ruber (Vieillot, 1817)	Greater Thornbird	UFMT 0476, 3218	H,V
Cranioleuca vulpina (von Pelzeln, 1856)	Rusty-backed Spinetail	DZUFMG 5055; UFMT 0285, 0374, 3222	H,V
Pseudoseisura unirufa (d'Orbigny & Lafresnaye,1838)	Grey-crested Cacholote	CAF 0223; DZUFMG 5118	H,P,V
Schoeniophylax phryganophilus (Vieillot, 1817)	Chotoy Spinetail	-	H,V
Certhiaxis cinnamomeus (J.F. Gmelin, 1788)	Yellow-chinned Spinetail	UFMT 0373	H,P,V
Synallaxis scutata P.L. Sclater, 1859	Ochre-cheeked Spinetail	-	H,V
Synallaxis albilora von Pelzeln, 1856	White-lored Spinetail	DZUFMG 5037, 5127	H,P,V
Synallaxis hypospodia P.L. Sclater, 1874	Cinereous-breasted Spinetail	-	H,V
Synallaxis frontalis von Pelzeln, 1859	Sooty-fronted Spinetail	UFMT 0203	H,V
Family Vireonidae			
Cyclarhis gujanensis (J.F. Gmelin, 1789)	Rufous-browed Peppershrike	UFMT 0830	H,V
Vireo olivaceus (Linnaeus, 1766)	Red-eyed Vireo	UMT 0233, 0483	H,P,V
Hylophilus pectoralis P.L. Sclater, 1866	Ashy-headed Greenlet	DZUFMG 5077; UFMT 3224	H,P,V
Family Corvidae			
Cyanocorax cyanomelas (Vieillot, 1818)	Purplish Jay	DZUFMG 5066; UFMT 0489, 0502, 0775, 3340, 3396, 3407, 3424	H,P,V
Family Motacillidae			
Anthus lutescens Pucheran, 1855	Yellowish Pipit	UFMT 0197	H,V
Family Fringillidae			
Euphonia chlorotica (Linnaeus, 1766)	Purple-throated Euphonia	-	H,P,V
Family Passerelidae			
Arremon flavirostris Swainson, 1838	Saffron-billed Sparrow	-	H,V
Zonotrichia capensis (Statius Muller, 1776)	Rufous-collared Sparrow	-	H,V
Ammodramus humeralis (Bosc, 1792)	Grassland Sparrow	-	H,V
Family Parulidae			
Setophaga pitiayumi (Vieillot, 1817)	Tropical Parula	UFMT 0471	H,V
Basileuterus culicivorus hypoleucus Bonaparte, 1850	White-bellied Warbler	UFMT 0478	H,V
Myiothlypis leucophrys (von Pelzeln, 1868)	White-striped Warbler	UFMT 0236	V
Myiothlypis flaveola S.F. Baird, 1865	Flavescent Warbler	-	H,P,V
Family Icteridae			
Dolichonyx oryzivorus (Linnaeus, 1758)	Bobolink	-	P,V
Leistes superciliaris (Bonaparte, 1850)	White-browed Blackbird	-	V
Psarocolius decumanus (Pallas, 1769)	Crested Oropendola	UFMT 0843, 3360, 3367	H,P,V
Procacicus solitarius (Vieillot, 1816)	Solitary Cacique	DZUFMG 5043	H,P,V
Cacicus cela (Linnaeus, 1758)	Yellow-rumped Cacique	DZUFMG 5025; UFMT 3361, 3362	H,P,V
Icterus croconotus (Wagler, 1829)	Orange-backed Troupial	DZUFMG 5086; UFMT 0504, 3215, 3449	H,P,V
Icterus pyrrhopterus (Vieillot, 1819)	Epaulet Oriole	DZUFMG 5034, 5079-5085	H,V
Agelaioides badius (Vieillot, 1819)	Bay-winged Cowbird	CAF 0180; DZUFMG 5092	H,P,V
Molothrus oryzivorus (J.F. Gmelin, 1788)	Giant Cowbird	CAF 0204	H,P,V
Molothrus bonariensis (J.F. Gmelin, 1789)	Shiny Cowbird	-	H,P,V
Gnorimopsar chopi (Vieillot, 1819)	Chopi Blackbird	-	H,P,V

Taxon	**English name**	**Specimens**	**Evidentiary information**
Agelasticus cyanopus (Vieillot, 1819)	Unicolored Blackbird	UFMT 0283, 0286, 0294, 0295, 0496, 3211	H,V
Chrysomus ruficapillus (Vieillot, 1819)	Chestnut-capped Blackbird	-	H,V
Family Thraupidae			
Nemosia pileata (Boddaert, 1783)	Hooded Tanager	-	H,V
Conirostrum speciosum (Temminck, 1824)	Chestnut-vented Conebill	-	H,V
Sicalis flaveola (Linnaeus, 1766)	Saffron Finch	DZUFMG 5122; UFMT 0300, 3377, 3378, 3380, 3481	H,P,V
Volatinia jacarina (Linnaeus, 1766)	Blue-black Grassquit	UFMT 0225, 0231, 0656	H,P,V
Tachyphonus rufus (Boddaert, 1783)	White-lined Tanager	DZUFMG 5038	H,P,V
Eucometis penicillata (von Spix, 1825)	Gray-headed Tanager	-	H,P,V
Coryphospingus cucullatus (Statius Muller, 1776)	Red-crested Finch	-	H,P,V
Ramphocelus carbo (Pallas, 1764)	Silver-beaked Tanager	DZUFMG 5036; UFMT 0223, 0368, 0369, 0469, 0500, 3408	H,P,V
Sporophila lineola (Linnaeus, 1758)	Lined Seedeater	-	H,V
Sporophila leucoptera (Vieillot, 1817)	White-bellied Seedeater	-	H,V
Sporophila bouvreuil (Statius Muller, 1776)	Capped Seedeater	-	H,V
Sporophila angolensis (Linnaeus, 1766)	Chestnut-bellied Seed-finch	DZUFMG 5124	H,P,V
Sporophila caerulescens (Vieillot, 1823)	Double-collared Seedeater	-	H,V
Sporophila plumbea (zu Wied, 1830)	Plumbeous Seedeater	-	H,V
Sporophila collaris (Boddaert, 1783)	Rusty-collared Seedeater	CAF 0229; UFMT 0218, 0222, 0232, 0235, 0275, 0937, 3214	H,V
Saltatricula atricollis (Vieillot, 1817)	Black-throated Saltator	DZUFMG 5120	H,P,V
Saltator coerulescens Vieillot, 1817	Grayish Saltator	DZUFMG 5121; UMT 0228, 0262, 2144	H,P,V
Saltator similis d'Orbigny & Lafresnaye, 1837	Green-winged Saltator	UFMT *0766*	H,P,V
Emberizoides herbicola (Vieillot, 1817)	Wedge-tailed Grass-finch	-	H,V
Thlypopsis sordida (d'Orbigny & Lafresnaye, 1837)	Orange-headed Tanager	UFMT 0493	H,V
Cypsnagra hirundinacea (Lesson, 1831)	White-rumped Tanager	DZUFMG 5067; UFMT 0477	H,V
Coereba flaveola (Linnaeus, 1758)	Bananaquit	UFMT *0807*	H,P,V
Paroaria coronata (J.F. Miller, 1776)	Red-crested Cardinal	CAF 0213; UFMT 3198	H,V
Paroaria capitata (d'Orbigny & Lafresnaye, 1837)	Yellow-billed Cardinal	CAF 0212; DZUFMG 5100, 5101; UFMT 0254, 0260, 0297, 0482	H,P,V
Pipraeidea melanonota (Vieillot, 1819)	Fawn-breasted Tanager	-	H,V
Tangara sayaca (Linnaeus, 1766)	Sayaca Tanager	UFMT 0221, 0234, 3420, 3430	H,P,V
Tangara palmarum (zu Wied, 1823)	Palm Tanager	DZUFMG 5145; UFMT 0257, 0772	H,P,V
Family Donacobiidae			
Donacobius atricapilla (Linnaeus, 1766)	Black-capped Donacobius	UFMT 0244, 0291	H,P,V
Family Hirundinidae			
Petrochelidon pyrrhonota (Vieillot, 1817)	Cliff Swallow	DZUFMG 5102	V
Hirundo rustica Linnaeus, 1758	Barn Swallow	UFMT 0473	V
Tachycineta albiventer (Boddaert, 1783)	White-winged Swallow	-	V
Tachycineta leucorrhoa (Vieillot, 1817)	White-rumped Swallow	-	P,V
Riparia riparia (Linnaeus, 1758)	Bank Swallow	-	P,V
Progne tapera (Vieillot, 1817)	Brown-chested Martin	UFMT 0328	H,P,V
Progne subis (Linnaeus, 1758)	Purple Martin	-	V

Taxon	**English name**	**Specimens**	**Evidentiary information**
Progne chalybea (J.F. Gmelin, 1789)	Grey-breasted Martin	-	H,V
Stelgidopteryx ruficollis (Vieillot, 1817)	Southern Rough-winged Swallow	-	H,P,V
Family Troglodytidae			
Troglodytes aedon Vieillot, 1809	Southern House-wren	-	H,V
Campylorhynchus turdinus (zu Wied, 1831)	Thrush-like Wren	CAF 0183; DZUFMG 5044-5046; UFMT 3220, 3409, 3410	H,P,V
Pheugopedius genibarbis (Swainson, 1838)	Moustached Wren	DZUFMG 5039; UFMT 0654	H,P,V
Cantorchilus leucotis (Lafresnaye, 1845)	Buff-breasted Wren	UFMT 0175, 0268, 0292, 0632, 0650	H,P,V
Family Polioptilidae			
Polioptila dumicola (Vieillot, 1817)	Masked Gnatcatcher	DZUFMG 5112-5117; UFMT 3321	H,P,V
Family Mimidae			
Mimus saturninus (M.H.C. Lichtenstein, 1823)	Chalk-browed Mockingbird	UFMT 2159, 3332	H,P,V
Family Turdidae			
Catharus fuscescens (Stephens, 1817)	Veery	UFMT 0201	V
Turdus leucomelas Vieillot, 1818	Pale-breasted Thrush	UFMT 3246	H,P,V
Turdus fumigatus M.H.C. Lichtenstein, 1823	Cocoa Thrush	UFMT 3475	V
Turdus albicollis Vieillot, 1818	White-necked Trush	UFMT 3334	V
Turdus rufiventris Vieillot, 1818	Rufous-bellied Thrush	UFMT 3484	H,V
Turdus amaurochalinus Cabanis, 1851	Creamy-bellied Thrush	UFMT 3223	H,V

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SHORT-COMMUNICATION

The first confirmed record of the White-capped Albatross *Thalassarche steadi* in Brazil

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ABSTRACT: On 13 November 2011, an immature female White-capped Albatross *Thalassarche steadi* (identified using discriminant functions and molecular techniques) was found alive on a beach in the state of Rio Grande do Sul, southern Brazil. Its complete skeleton was prepared and deposited at *Museu de Ciências Naturais da Universidade Federal do Rio Grande do Sul*. Although there are previous records of "Shy-type Albatrosses" – which collectively includes both Shy Albatross *T. cauta* and *T. steadi* – in Brazil, this is the first record of a "Shy-type Albatross" identified to the species-level in the country.

KEY-WORDS: Diomedeidae, Shy Albatross, southwestern Atlantic Ocean, taxonomy, *Thalassarche cauta.*

The so-called "Shy Albatross complex" includes four taxa, all breeding on islands off Australia and New Zealand (Marchant & Higgins 1990). Historically, these taxa have generally been placed under a single polytypic species: the Shy Albatross *Diomedea cauta* (Marchant & Higgins 1990, Carboneras 1992). However, they are nowadays considered as either three or four species in the genus *Thalassarche*, based on phenotypic, molecular, and behavioral (differences in breeding times) characters (Robertson & Nunn 1998, Taxonomy Working Group 2006, Sangster *et al.* 2015). Robertson & Nunn (1998), adopting the Phylogenetic Species Concept as defined by Cracraft (1983), proposed the recognition of three species in addition to *T. cauta* (*stricto sensu*): White-capped *T. steadi*, Salvin's *T. salvini*, and Chatham *T. eremita* Albatrosses. This four-way split has been adopted by the Agreement on the Conservation of Albatrosses and Petrels – ACAP (Taxonomy Working Group 2006, ACAP 2011) and BirdLife International (2016), but rejected by some authors. The point of disagreement is whether or not a species status should be given to the White-capped Albatross. For example, to Sangster *et al.* (2015), the available evidence justifies its assignment to the subspecific rank under *T. cauta*. Here, we follow ACAP (2011) and BirdLife International (2016) in considering the White-capped Albatross as a distinct species.

The Shy Albatross (*stricto sensu*) breeds from April to September on three islands off Tasmania, whereas the White-capped Albatross breeds from November to July on islands off New Zealand (Marchant & Higgins 1990, Checklist Committee of the Ornithological Society of New Zealand 2010). Their pelagic distribution extends to continental shelf waters off both coasts of southern South America and South Africa (Marchant & Higgins 1990, Carboneras 1992, Phalan *et al.* 2004, Baker *et al.* 2007, Marin 2011, Jiménez *et al.* 2009, 2015, Gianuca *et al.* 2011, Seco-Pon & Tamini 2013, Savigny & Carbajal 2015). These species are phenotypically similar, and hence are collectively termed "Shy-type albatrosses". Non-breeding adults and immature of either species are indistinguishable on external appearance. Breeding adult Shy Albatrosses often (but not always) have darker face and some yellow coloration on the culminicorn upper end (Marchant & Higgins 1990, Onley & Scofield 2007, Carlos 2008, Savigny & Carbajal 2015). The Shy Albatross is on average smaller than the White-capped Albatross, but overlap is large and identification is possible only with discriminant functions that involve measurements of bill, head, and wing (Double *et al.* 2003). Furthermore, the White-capped Albatrosses can be identified by a fixed substitution in Domain I of the mitochondrial DNA control region (Abbott & Double

2003). In this paper, we report the first confirmed record of a White-capped Albatross in Brazil.

On 13 November 2011, the Wildlife and Marine Animal Rehabilitation Center of Ceclimar (*Centro de Estudos Costeiros, Limnológicos e Marinhos, Instituto de Biociências, Universidade Federal do Rio Grande do Sul*), received a *Thalassarche* albatross found alive on the beach at Nova Tramandaí (30°02'54.32''S; 50°09'03.54''W), state of Rio Grande do Sul in southern Brazil. The bird eventually died and its skeleton was deposited at the bird collection of the *Museu de Ciências Naturais da Universidade Federal do Rio Grande do Sul*, under the registration number MUCIN 769. Muscle tissue samples were preserved in absolute ethanol.

The specimen was sexed by dissection and direct examination of gonads as a female. It has a grey head and neck, the color not extending to forehead and throat; grayish back; mostly white underwings with narrow black margins and pale primary bases; and pale grey bill with blackish tip (Figure 1). No moult was noted and feathers did not seem worn. Its plumage resembles that of immature Shy and White-capped Albatrosses. Immature Salvin's Albatrosses are similar to immature "shy-types", but have more extensively black underwing margins and dusky undersides to primaries (Marchant & Higgins 1990, Onley & Scofield 2007, Carlos 2008). Note that the Salvin's Albatross has been recently recorded in Uruguay (Jiménez 2013).

FIGURE 1. A White-capped Albatross *Thalassarche steadi* (MUCIN 769) from Nova Tramandaí, Rio Grande do Sul, southern Brazil. Photos: Nicholas W. Daudt.

The measurements of the specimen (after Double *et al.* 2003) in millimeters are as follows: head length, 82.1; maximum head width, 69.3; culmen length, 128.15; basal bill width, 34.4; basal bill depth, 51.44; minimum bill depth, 28.15; upper bill depth, 30.4; tarsus, 95.45; middletoe, 120.6; and wing chord, 554.0. The application of the discriminant function to identify species and sex (Double *et al.* 2003) resulted in the highest classification score to female White-capped Albatross. According to Double *et al.* (2003), this function correctly identified both the sex and species of 84% of specimens from a sample of 70 previously identified using molecular data.

Molecular species identification was carried out by PCR essay and partial sequencing (289 base pairs) of the Domain I of the mitochondrial control region (Abbott & Double 2003). Total genomic DNA was extracted using the PureLink Genomic DNA Mini Kit (Invitrogen, Carlsbad, CA) according to the manufacturer's instructions. PCR products were assessed on 1% agarose gel, enzymatically purified with shrimp alkaline phosphatase and exonuclease I (GE Healthcare), and sequenced at Macrogen Inc. (Seoul). The sequence was aligned by eye in the program BioEdit v. 7.1.11 (Hall 1999) together with other 15 sequences of Shy and 22 of White-capped Albatrosses available from GenBank (Abbot & Double 2003). We detected the adenine to guanine substitution at the 121 nucleotide position, which is diagnostic to the White-capped Albatross (Abbot & Double 2003). The sequence is deposited in GenBank under accession number KX810168.

The earliest Brazilian records of "shy-type albatrosses" were two beached specimens, one from São Simão in the state of Rio Grande do Sul (Petry *et al.* 1991) and the other from Mangue Seco in the state of Bahia, on the country's northeastern coast (Lima *et al.* 2004). The former was attributed to "*Diomedea cauta*", whereas the latter to "*Diomedea cauta cauta*". Note, however, that these names, as applied at that time, included Shy and White-capped Albatrosses (Marchant & Higgins 1990, Carboneras 1992). Carlos (2006) examined both these specimens and concluded they are immature "shy-type albatrosses". Dénes *et al.* (2007) mentioned a skull of a "shy-type albatross" in the *Museu Oceanográfico Univali* (Balneário Piçarras, Brazil), which was caught on a longline off southern Brazil. However, according to Gianuca *et al.* (2011), this bird was actually captured in international waters beyond the limit of the 200 nautical miles of Brazilian Exclusive Economic Zone. Gianuca *et al.* (2011) also reported sights of "shy-type albatrosses", most documented by photographs, over the continental slope of southern Brazil. All these records involved immature birds except for a single adult, which however could not be identified to species with certainty.

In the most recent checklist of birds of Brazil (Piacentini *et al.* 2015), "*T. cauta cauta*" was listed for the country, whereas "*T. cauta steadi*" was considered as of probable occurrence (footnote 44 on page 104). Molecular identification of birds caught on longlines in neighboring Uruguayan waters revealed that the White-capped Albatross is the most frequent "shy-type albatross" in the region. Out of 34 specimens tested only one was Shy Albatross (Jiménez *et al.* 2009, 2015). White-capped Albatrosses are thus probably the more common "shy-type albatross" in Brazilian waters.

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SHORT-COMMUNICATION

First records of Todd's Nightjar (*Setopagis heterura*) for Brazil

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ABSTRACT: *Setopagis heterura* is a poorly known nightjar that occurs in grasslands and forest edges in central-north Venezuela, northern Colombia and western Guyana. We report here a remarkable southward range extension for the species based on fieldwork and skin specimens, representing the first documented records for Brazil, from the state of Roraima, and for southern Colombia. We encourage new searches and studies of this species to determine its status of occurrence in Brazil.

KEY-WORDS: Caprimulgidae, Roraima, savanna.

Setopagis heterura was originally described as a full species based on a specimen collected in Santa Marta region, Colombia (Todd 1915), but has been long considered a subspecies of the widespread *S. parvula* due to their morphological similarity and clear close relationship (Peters 1940, Schwartz 1968). Only recently the species had its specific status reinstated based mostly on its highly distinct voice, as shown by Davis (1978), and subtle plumage characters, especially the greater extent of white on the tips of the rectrices (Schwartz 1968, Cleere 1998, Holyoak 2001, Remsen-Jr. *et al.* 2015).

Until recently, the species was known to occur exclusively in grasslands and forest edges in central-north Venezuela and northern Colombia (Cleere 1999). This distribution is distant from that of its sister species *S. parvula*, which has a large range in the central-south part of the continent and is not known to occur regularly north of the Amazon River (Cleere 1999, Holyoak 2001). Thus, a considerable gap exists between the ranges of the two species, as already pointed out by Schwartz (1968).

On 17 March 1992, DFS tape-recorded an individual *S. heterura*, then considered a subspecies of *S. parvula*, in central Roraima, northern Brazil, representing a considerable southern range extension and the first record for Brazil. The bird was recorded close to the Quitauau River, a left bank tributary of the Branco River, *c.* 10 km south of the town of Serra Grande and roughly 35 km southeast from Boa Vista (Figure 1). He also heard at least two additional birds at the same site. At the time, the site was in the ecotone between the Roraiman savanna and Amazonian Forest. The original tape recording has been deposited at the Arquivo Sonoro Neotropical of UNICAMP. Almost 15 years later, on 11 February 2007, LFS collected an adult male *S. heterura* (MZUSP 77954, Figure 2) at Serra da Lua (02°13'N; 60°19'W), 70 km southeast from Boa Vista and *c.* 50 km in straight line from the site where DFS tape-recorded the species in 1992 and in a similar habitat (Figure 1), representing the second record for Brazil and the first specimen for the country. The confirmation of the occurrence of *S. heterura* for Brazil brings the total number of Caprimulgidae species for the country to 25, making Roraima among the richest Brazilian states for that avian family with 15 species (see Naka *et al.* 2006).

The southern range limits of the species in Colombia are also very poorly known. To date, the species is only known to occur in the northern region in the Departments of Magdalena, Norte de Santander, Santander and Cundinamarca (Cleere 1998). However, two overlooked skin specimens expand the species' known range further south in the central-south part of that country. One adult male (No. 1621) deposited at the Instituto Alexander von Humboldt, Bogotá, Colombia, was collected on 21 November 1977 at the Rio Guaviare, Bocas del Ariari, Meta Department. That new locality represents a major range extension from the closest localities in that country (in Cundinamarca Department), and the first record for Meta, being roughly at the same latitude as the Brazilian records. Another specimen, an adult female, deposited at the Los Angeles County Museum of Natural

History (No.73170) was collected on 7 August 1967 at Mitu, Vaupés Department. That specimen represents the first report of *S. heterura* for Vaupés and the world's southernmost locality (Figure 1). This record is also *c.* 35 km from the border with the extreme northwestern portion of the Brazilian state of Amazonas.

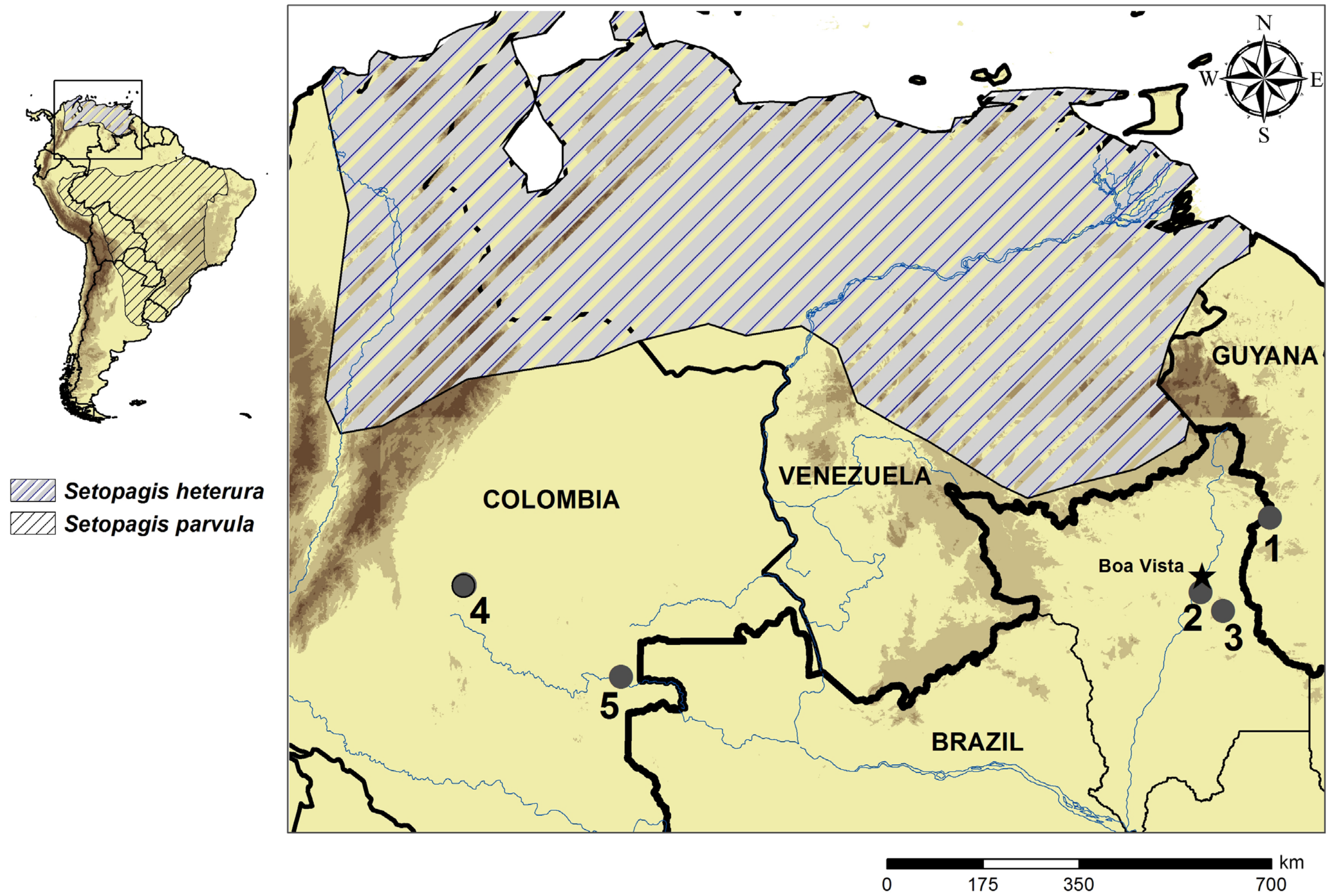

FIGURE 1. Map of northern South America, depicting the current known range of *Setopagis heterura* (hatched, on the right) and *S. parvula* (hatched in the small map on the left) according to Cleere (1998, 2010). Star represents the Brazilian city of Boa Vista, Roraima, and gray dots represent the following localities: 1 – Rupununi savanna, Guyana (Milensky *et al.* 2009); 2 – Serra Grande, Roraima, Brazil; 3 – Serra da Lua, Roraima, Brazil; 4 – Rio Guaviare, Meta, Colombia; and 5 – Mitu, Vaupés, Colombia.

FIGURE 2. Ventral views of the holotype of *Setopagis heterura* (CMNH 41904, above) and the first Brazilian specimen (MZUSP 77954, below) collected at Serra da Lua, Roraima. The former presents extensive white in the wings and tail compared to the latter, which seems to be related to intraspecific variation.

Morphologically, the extension of the white in the tail seems to be the only reliable character that separates *S. heterura* from *S. parvula* (Schwartz 1968). However, this character seems to vary among individuals within both species. According to Schwartz, *S. heterura* presents the outermost rectrices completely (or almost completely) white-tipped, the second and third outermost tail feathers with at least some white on the outer web, and the fourth outermost pairs with white restricted to the inner web. According to the same author, in *S. parvula* the white is usually restricted to the inner web in all rectrices, even though some individuals may present some white on the outer web of the outermost feathers. On the specimen collected at Serra da Lua, both the first and second outermost pair of rectrices have white on both webs, albeit reduced in the outer web, and the third and fourth pairs have the white confined to the inner web only. In a few *S. parvula* specimens (*e.g.* MZUSP 97046, from southern Pará State, Brazil), the outermost rectrices are completely white-tipped, the second and third outermost feathers present some white on the outer web, and the fourth outermost pair has white also restricted to the inner web. Differences in the wing between the two species have already been suggested, especially in the width of the white band in the primaries (Cleere 1999). Schwartz (1968) mentions that some individuals of *S. heterura* do have larger wing bands compared to *S. parvula*, and that there is a tendency in the former to have the band extending to outer web of the outer primary, but the differences between the species are masked by overlapping variation and seem to have limited usefulness for identification. The specimen collected at Serra da Lua presents an apparently narrower white band across the primaries compared to the holotype, and the white on the outermost primary is restricted to the inner web. Hence, further studies are still needed to verify the extent of variation of the white markings in the remiges and rectrices in these species and whether they represent taxonomically useful characters.

Differences in wing and tail length between the two species are not significant, even though *S. heterura* seems to show slightly longer wings and shorter tail, what results in a larger wing/tail ratio in that species (Schwartz 1968). The wing (chord) length of our Brazilian specimen is 144 mm, within the range of the measurements of this species presented by Schwartz, 135–146 mm versus 134–143 mm in *S. parvula* (only males); on the other hand, tail length (99 mm) falls within the range of variation of the two species, 89–98 mm in *S. heterura* and 94–105 mm in *S. parvula*.

As with many other nightjars and nocturnal birds, the actual range limits of *S. heterura* have not been well known. Before the early 90', the southernmost known records of the species were from northeastern Bolívar, Venezuela, roughly 600 km north of the localities in central Roraima reported here. About six months earlier than our record in Serra da Lua, the species was also recorded at the Rupununi savanna in western Guyana (Milensky *et al.* 2009), *c.* 35 km from the border with Roraima and almost 200 km northeastern of Serra da Lua. The fact that the species has not been regularly recorded in that region may indicate that the individuals represented vagrant or migrant birds. On the other hand, and like many species of Neotropical nightjars with poorly known distribution, it is not surprising that *S. heterura* has proven to be more widespread than previously known, albeit uncommon. Regarding the Colombian localities, even though situated in a largely forested area, Meta includes large areas of *llanos* and Vaupés is also well-known for having extensive areas of white-sand forests, which might be suitable habitats for the species.

However, more studies are needed to determine whether *S. heterura* is a resident species in Roraima and in southern Colombia, or represents a migratory or vagrant species in those localities. Searches for the species should focus mainly on forest edges and open areas in hilly terrain, but also in savannas and white-sand forests.

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