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Capa: Espécies de aves que respondem ao "efeito barreira" de rios da bacia do Madeira, na Amazônia brasileira, como documentado por Fernandes *et al.,* neste volume. Alto à esquerda: macho imaturo de rendadinho *Willisornis poecilinotus* (foto de Anselmo d'Affonseca); alto ao centro: flautin marrom *Schiffornis turdina* (foto de Alexander C. Lees); alto à direita: arapaçu-bico-de-cunha *Glyphorynchus spirurus* (foto de Anselmo d'Affonseca). Embaixo: Vista do rio Aripuanã durante o pôr do sol (foto de Alexandre Fernandes).

Cover: Species of birds responding to the "barrier effect" of rivers in the Madeira drainage, Amazonian Brazil, as documented by Fernandes *et al.,* in this volume. Top left: Immature male Common Scale-backed Antbird *Willisornis poecilinotus* (photo by Anselmo d'Affonseca); top center: Thrush-like Mourner *Schiffornis turdina* (photo by Alexander C. Lees); top right: Wedge-billed Woodcreeper *Glyphorynchus spirurus* (photo by Anselmo d'Affonseca). Below: View of the Aripuanã River by sunset (photo by Alexandre Fernandes).

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COMMENTARY

Experimental translocations: pitfalls and alternatives for quantifying animal movement in fragmented landscapes

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ABSTRACT: As anthropogenic change continues to fragment terrestrial habitats, conservation biologists are increasingly concerned with how wild animals move through fragmented landscapes. Experimental translocations have recently gained popularity as a technique to determine landscape permeability by wild animals in fragmented landscapes. In experimental translocations, researchers capture individuals — usually adults — and release them elsewhere in order to determine whether they are able to cross the landscape and return to their original location. We argue that most experimental translocations have two inherent confounding factors — age of the individual and homing ability — and that the narrow spatiotemporal scale of the technique may give it limited ability to address the most important conservation and management questions in fragmented landscapes. We discuss three alternative techniques (telemetry, capture-mark-recapture, and landscape genetics), and recommend that experimental translocations only be undertaken if: 1) they avoid confounding factors; 2) they are validated by other techniques; and 3) no other options are available for obtaining the data. We stress that researchers that do proceed with experimental translocations must acknowledge that they are using an indirect proxy to quantify natural animal movement.

KEY-WORDS: Capture-Mark-Recapture, connectivity, dispersal, landscape genetics, telemetry, translocation experiment.

INTRODUCTION

As anthropogenic change continues to fragment terrestrial habitats, conservation biologists are increasingly concerned with understanding the dynamics of movement (and dispersal) from one habitat patch to another, as these processes are fundamental to source-sink and metapopulation dynamics (Brawn & Robinson 1996), gene flow, genetic structure (Bates *et al.* 2004), and species' persistence in isolated patches (Ferraz *et al.* 2007). Recently, experimental translocations have gained popularity as a means to develop indices of habitat permeability (Boscolo *et al.* 2008; Huste *et al.* 2006; Ibarra-Macias *et al.* 2011; Knowlton & Graham 2010; Villard & Haché 2012). In experimental translocations (also referred to as translocation experiments), researchers capture individuals — usually adults — and release them elsewhere in order to determine whether they are able to cross the landscape and return to their original location. Results are then interpreted as a measure of the likelihood that natural population processes would include the reverse movement (i.e. dispersal), based on the rationale that dispersal events are rare and difficult to detect directly. Manipulative field experiments can provide powerful contexts for controlling environmental variation, but in the case of experimental translocations, researchers can introduce confounding factors (e.g., age effects, homing ability) that may bias results or make them difficult to interpret. Here we argue that to provide a meaningful index of animal movement, particularly dispersal, in fragmented systems, researchers undertaking experimental translocations must take great care to reduce confounding factors and to validate results with other techniques. We suggest three alternatives to experimental translocations, and discuss how these alternatives can be useful to validate or replace experimental translocations.

CONFOUNDING FACTORS

Age of translocated individuals

Experimental translocations frequently use territorial animals because those individuals are invested in a particular area, and are thus motivated to return to the area after translocation; thus "successful" returns are relatively

easy for technicians to detect (e.g., Wilson *et al.* 2007, Hadley and Betts 2009). Most experimental translocations of this type mimic patterns of adult dispersal (dispersal: directed movement from one territory in search of another; Greenwood and Harvey 1982), as they attempt to quantify an animal's ability to move from one territory to another. The overwhelming majority of dispersal events, however, are undertaken by juveniles (Greenwood & Harvey 1982), so although dispersing adults certainly can contribute to gene flow, their contribution is likely small relative to that of dispersing juveniles. Understanding juvenile dispersal is particularly important in fragmented landscapes where habitat quality is variable, as they may represent pioneers who cross non-habitat matrix and occupy marginal habitats (Johnson 2011; Rohwer 2004) thus contributing disproportionately to metapopulation dynamics compared to adults. Dispersing juveniles generally venture out from their natal home ranges in search of other areas with suitable resources but without intraspecific competitors; unlike translocated adult territory holders, they have no motivation to return to a specific location. Juvenile animals are fundamentally different from adults in their physiological state and level of experience on the landscape (Yoder *et al.* 2004), so attempting to mimic dispersal using territorial adults may produce an inaccurate picture of dispersal patterns (Knowlton & Graham 2010). The inexperience of juveniles makes them vulnerable to predators (Yoder *et al.* 2004), which again suggests that their decisions on how to move about the landscape will be fundamentally different from those of older conspecifics. We know of no experimental translocation that validates the assumption that territorial adults and dispersing juveniles move similarly across fragmented landscapes — a step that we believe is critical if data are to be meaningfully applied to conservation or management.

Homing ability

Experimentally translocated animals are generally tested on their ability to return to or toward their territories, which introduces the confounding factor of homing. When animals are captured for translocation, they are generally placed in an opaque receptacle and blindly transported to a new location for release. An animal attempting to return to its territory should take one of three approaches: (1) prior knowledge of the landscape; (2) internal homing capacity; or (3) undirected movement. Thus, experimental translocations do not control for homing ability of individuals or species — individuals could easily fail to return because they lost their way, died, or simply settled elsewhere, rather than because they encountered barriers to movement. For example, Kennedy and Marra (2010) acknowledge that the faster return times of translocated wintering migrant American Redstarts (*Setophaga ruticilla*) relative to resident Jamaican Todies (*Todus todus*) could have been because of the redstarts' ability to traverse the matrix, or because their previous experience or homing ability allowed them to better navigate the landscape.

ALTERNATIVE TECHNIQUES

While acknowledging that no technique for studying animal movement is without considerable assumptions, biases, and costs, we present three alternatives that can provide useful data to supplement or replace data provided by translocation experiments.

Telemetry on dispersing individuals

Telemetry is the most direct way to study how individuals move about the landscape. Based on home range size, frequency of movement, or compositional analyses of habitat use (Aebischer *et al.* 1993), researchers can draw conclusions about the suitability of certain landscape types, the permeability of barriers, and the porosity of the matrix. For an assessment of dispersal across variable landscape features, researchers can track juveniles during dispersal. The obvious advantage here is that naturally dispersing animals will reveal their own habitat choices, compared to translocated animals that are instead revealing their response to translocation to a location chosen by the investigator. Indeed, telemetry studies of dispersal can be insightful with a reasonable sample size, but this may be challenging if the focal species is rare, suffers high juvenile mortality, or is too small to support a tracking device. To limit the effects of transmitters on juvenile mortality, tracking devices should generally be <5%, or ideally <3% of body weight for small birds (pers. obs.). Real-world constraints may make it difficult to use telemetry on naturally moving animals to address questions regarding movement decisions, but under the right conditions, it can provide powerful insights (e.g., Riecken and Raths 1996; Yoder *et al.* 2004; Tarwater and Brawn 2010). Transmitters (e.g., radio, global positioning system [GPS], global system for mobile communications [GSM]) can be costly, but technology is evolving rapidly such that smaller, longer-lasting, precise and powerful transmitters are ever more affordable. The benefits of telemetry on juvenile animals must be carefully weighed against the disadvantages, which include the cost of transmitters and the challenge in matching the spatiotemporal scale of data collection to the scale of the research question.

Capture-mark-recapture (CMR) studies

CMR studies have been used for decades to determine how animals move about in fragmented landscapes. For example, researchers have applied state-space CMR models to dozens of different systems (Spendelow *et al.* 1995; Skvarla *et al.* 2004; Royle *et al.* 2013). CMR studies assume that individuals are identifiable, either by marking (e.g., band), or by some distinctive feature (e.g., DNA, unique spot pattern). Other spatially-explicit models consider the locations of "traps" (including nets and camera traps), and are flexible with regards to survey design (Royle *et al.* 2010). These models can be extended to determine how the distribution of habitat on the landscape affects movement among capture locations (Wang *et al.* 2011). With CMR models, biologists can gain a real understanding of both individual movements and population distribution across fragmented landscapes (frequently with the bonus estimation of survival and density) — often with no more effort than experimental translocations. Granted, many long-distance dispersers are never recaptured, but established statistical techniques can account detectability (e.g., Royle *et al.* 2011). Disadvantages to CMR include the lack of spatial resolution on movement paths, the potential computational complexity of statistical models (but see White and Burnham 1999), and the considerable number of recaptures required for models to run. Further, recapture rates may be quite low and vary enormously by organism. To plan for sample size issues, researchers can run simulations to determine the number of recaptures necessary for the desired level of statistical power.

Landscape genetics

Landscape genetics is an essential component of fragmentation research because it can estimate the consequences of dispersal (or the lack thereof) within fragmented landscapes as expressed in the form of gene flow (Manel *et al.* 2003; Storfer et al 2007; Holderegger and Wagner 2008). Once time-consuming and costly, landscape genetics techniques are increasingly inexpensive and straightforward. Primers and reagents are becoming less expensive, genetics labs are more common, and DNA is easier to collect and preserve. Further, the time-consuming task of developing a genetic library (e.g., microsatellites, single nucleotide polymorphisms [SNPs]) has become easier with next-generation sequencing, which can identify hundreds of potentially polymorphic loci that can then be used in analyses of genetic structure (Lerner & Fleischer 2010). In fragmented landscapes, genetic drift, mutation, selection, and dispersal can lead to measurable genetic structure among populations. Researchers can then use measures of genetic differentiation (e.g., F_{st}, R_{st}) to estimate gene flow (e.g., Woltmann *et al.* 2012) and migration rate among habitat patches (Beerli & Felsenstein 2001). As in CMR studies, researchers can overlay landscape variables to determine how the landscape affects gene flow in fragmented systems (e.g., Pavlacky *et al.* 2009). Using landscape genetics, researchers can track movement of genetic information among populations on the timescale of generations, which reflects dynamic landscape patterns over time.

We believe the important research question is whether fragmented landscapes have sufficient gene flow among populations, thus although translocation experiments may provide interesting insights on individual movement across the matrix (Moore *et al.* 2008), they represent only a small part of the spatiotemporal dynamics of animal movement. Granted, landscapes appropriate for genetics studies can be challenging to locate on the ground, and the technique has its limitations (Storfer *et al.* 2010); however, if researchers take care to find landscape replicates appropriate to address their questions (Beier & Gregory 2012), a well-designed landscape genetics study can address many of the important questions sought by translocation studies (e.g., can species X cross barrier Y?), yet with populations rather than individuals, and without the confounding factors of animal age and homing ability. Species with small, isolated populations and fast generation times are most likely to show genetic structure (Allendorf & Luikart 2007), with minimum divergence times of about 10–20 generations — depending on the effective population size (Slatkin 1993; Waples 2007; Wright 1943). Again, before investing in field work, researchers can run simulations to calculate the number of individuals necessary for the desired level of power (Ryman & Palm 2006). Although the advantages to landscape genetics are many, disadvantages include the cost of lab work, the effort required for capture, and the relatively poor resolution of genetic techniques on small spatiotemporal scales.

EXAMPLES OF MEANINGFUL TRANSLOCATION EXPERIMENTS

When carefully validated with other techniques, translocation experiments may provide useful information for managers — particularly when alternative techniques cannot provide answers at the scale appropriate of the research question. Moore *et al.* (2008) performed an experiment in which they captured birds at Barro Colorado Island in Panama, rowed them out into Lake Gatun, and released them at different distances from

the shore to determine how far they could fly in a single flight. Moore *et al.*'s (2008) study cleverly demonstrated how far birds can fly across water — a critical issue in their island system. Importantly, the fundamental test they performed had nothing to do with interpreting movements back to a territory; rather, the birds were simply trying to return to any dry land. Although Moore *et al.*'s (2008) study addressed an important issue, it remains unclear whether the results provide "evidence for extreme dispersal limitation" in landscapes fragmented by matrices other than water.

In the face of rapid habitat fragmentation, conservation biologists have recently employed large-scale models of how populations move and disperse through variable landscapes to inform conservation planning (Knowlton & Graham 2010; Castellon and Sieving 2007). Those models can be informed (parameterized) using small-scale studies of individuals, including those using occupancy and experimental translocations. In one such example, Castellon and Sieving (2007) elegantly combined data from several of their previous small-scale studies (Castellón & Sieving 2006a 2006b) to parameterize a population viability analysis and landscape movement model designed to evaluate how increases in connectivity among isolated habitat patches would support increases in number of breeding birds called Chucao Tapaculos (*Scelorchilus rubecula*). Here the authors were appropriately cautious when applying the data from a translocation experiment (Castellón & Sieving 2006a), using them only in the absence of other data to confirm that: 1) tapaculos used wooded corridors; and 2) inter-patch distance was on the scale of typical tapaculo movement. They did not use their data on boundary permeability or return times through different matrix types by translocated adults, which would been a riskier assumption; rather, data on patch size and matrix composition were applied to the model via studies of patch occupancy — a measure of animal presence (MacKenzie *et al.* 2006). In this case, experimental translocations certainly provided an improvement over an uninformed model. On the other hand, the assumption remains that territorial adults returning towards their territories used corridors similarly to dispersing juveniles. To validate this tapaculo population viability analysis and landscape movement model, researchers could employ a well-designed, replicated natural experiment of tapaculo genetic structure across different matrices.

In another well designed example of a translocation experiment, Stevens *et al.* (2006a) captured Natterjack toadlets (*Epidalea* [formerly *Bufo*] *calamita*) and transferred them to a Y-shaped device in which the toadlets could select from two different habitats, i.e. the two branches of the Y. The authors avoided confounding factors of age and homing because: 1) toadlets are the dispersing stage of the species; and, 2) toadlets were not trying to return to territories. Further, the researchers carefully designed this translocation experiment to assess boundary permeability. Ultimately, Stevens *et al.*(2006b) used the translocation data along with data on dispersal rates obtained from a microsatellite landscape genetics study to test the hypothesis that differences in boundary permeability among habitat types affected dispersal of the species — it did. Here researchers had a specific piece of data in mind that would be difficult to obtain without experimental translocations, performed the experiment with little cost, and integrated results with those obtained from genetics and lab experiments — a combined approach considered advantageous when studying dispersal (Nathan *et al.* 2003; Nathan 2001)

CONCLUSIONS

Given the potential for confounding factors (e.g., individual age, homing ability) in experimental translocations, they should be used with great caution, especially in the absence of results from telemetry, CMR, or landscape genetics (e.g., Lowe *et al.* 2008). Ecosystems are being fragmented at a frightening rate (e.g., Numata, *et al.* 2011) and climate change will force distribution shifts across these altered landscapes (Wright *et al.* 2009). Conservation planning efforts designed to increase connectivity will maximize biodiversity conservation if the studies that inform them are as close to real conditions as possible and at the appropriate spatiotemporal scale for the question. We believe that the critical question in fragmented landscapes is not: "could this translocated adult potentially cross barrier X?"; rather, it is: "does barrier X significantly reduce population processes or gene flow?" Therefore, we caution that translocation experiments may not be applicable to the appropriate conservation questions unless they are part of research aimed at a larger spatiotemporal scale. When the information gained from experimental translocations cannot be obtained elsewhere, researchers must control for confounding effects and use experimental translocations in conjunction with other techniques, such as validating findings from experimental translocations with species-specific studies of naturally moving individuals (Volpe *et al.* 2014). Finally, researchers that do proceed with experimental translocations must acknowledge that they are using an indirect proxy to quantify natural animal movement. Given the great need for us to understand how animals move and disperse through heterogeneous landscapes in this critical period for biodiversity conservation (Barnosky *et al.* 2012; Lawrence & Wright 2009; Van Dyck & Baguette 2005; Wright *et al.* 2009) researchers should apply resources to contemporary techniques that most directly and realistically quantify animal movement

at the appropriate spatiotemporal scale, undertaking experimental translocations cautiously, and only in the absence of other solutions.

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ARTICLE

An avifaunal inventory and conservation prospects for the Gurupi Biological Reserve, Maranhão, Brazil

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ABSTRACT: We carried out an avifaunal inventory of the Gurupi Biological Reserve, Maranhão, municipalities of Bom Jardim and Centro Novo do Maranhão, between December 2009 and December 2013. The main objective was to estimate species richness and identify endemic species. A further objective was to identify vulnerable and endangered species to provide information for the development of conservation strategies. Data were collected using mist-netting and MacKinnon lists, as well as nonsystematic observations. A total of 424 species were recorded from 64 families; 18 of which considered endemic taxa. Seven are threatened nationally: *Psophia obscura, Guaruba guarouba, Pyrrhura lepida lepida, Pteroglossus bitorquatus bitorquatus, Phlegopsis nigromaculata paraensis, Dendrocincla merula badia,* and *Dendrocolaptes medius.* In addition to these, another eight are threatened internationally (IUCN 2014): *Tinamus tao*, *Penelope pileata, Lophornis gouldii*, *Pyrrhura amazonum*, *Touit huetii, Pionites leucogaster, Pyrilia vulturina* and *Lepidothrix iris.* Survey results underscore the extreme importance of the Gurupi Biological Reserve as a strategic site for the conservation and maintenance of endemic and endangered species of the Belém Center of Endemism in Brazilian Amazonia.

KEY-WORDS: Amazon, birds, Belém Center of Endemism, endangered species, inventory.

INTRODUCTION

During the 1980s, a number of scientific expeditions were conducted in the remaining tracts of Amazonian forest in the Brazilian state of Maranhão, many of which involved the ornithological division of the Goeldi Museum, in Belém (IBAMA 1999).

These studies resulted in the production of a number of reports, which were presented in 1984 by the Brazilian Institute for Forestry Development (*Instituto Brasileiro de Desenvolvimeno Florestal* - IBDF), as the federal forestry institute was then known, concerning the Golden Parakeet, *Guaruba guarouba* (IBAMA 1999). These documents recommended the creation of a national park or biological reserve in western Maranhão. This proposal was based on biogeographical analyses of endemism and total species richness (Oren 1988), which focused primarily on the threatened species that occur in the region.

These initiatives led to the creation of the Gurupi Biological Reserve (REBIO Gurupi), through the Federal Decree N° 95614 of January 12, 1988, which had the primary objective of ensuring the conservation of the fauna and flora of one of the last significant remnants of the typical dense alluvial and plateau rainforests of the state of Maranhão (IBAMA 1999).

The REBIO Gurupi is an extremely important area for bird conservation in the Amazon, since it is located in the most threatened endemism center in Brazil, the Belém Center of Endemism (hereafter Belém CE) (Silva *et al.* 2005, De Luca *et al.* 2009). The greatest threats to this center are disorderly occupation, illegal logging and deforestation due to the expansion of agricultural activities (Skole & Tucker 1993, Gascon *et al.* 2001, Valois 2003). The expansion of agriculture and deforestation in the Brazilian Amazon has reached its highest rates in 1970s, with western and southern Maranhão ranking among the most heavily deforested areas. Only a few scattered forest fragments, located primarily within reserves, remained (Aleixo 2009).

These areas are important for studies on historical biogeography, as well as providing data for the testing of hypotheses on the processes that resulted in the formation of the region's biota (Cracraft 1985, 1994, Morrone 1994, Morrone & Crisci 1995). They also contain a number of unique and irreplaceable species (Silva *et al.* 2005).

There have been no comprehensive surveys of the avifauna of the interior of the REBIO Gurupi. The few available studies have been conducted in the areas surrounding the reserve, such as Oren & Roma (2011) and Oren (1992), who described a new subspecies, *Celeus torquatus pieteroyensi* (Pieter Oyen's Ringed Woodpecker), from the region of the Gurupi River in Maranhão, and also the forested districts of Marajo Island. To further illustrate the lack of primary data on the bird fauna of REBIO Gurupi, the appendix VII of the reserve's management plan provides a list of species actually found in a nearby forest reserve belonging to the Vale do Rio Doce mining company, in the municipality of Buriticupu (IBAMA 1999).

Here, we compile a list of bird species for the REBIO of Gurupi, identifying endemic, endangered and vulnerable species to support conservation and protection strategies in the area.

MATERIAL AND METHODS

Study area

The REBIO Gurupi is an integral protection conservation unit, created by decree number 95,614 of January 12th, 1988, which delimits a total area of 341,650 hectares. Subsequently, however, measurements of the area using a Global Positioning System corrected the area to 271,000 ha, partially located within the municipalities of Bom Jardim, Centro Novo do Maranhão, and São João do Carú, all in the state of Maranhão. The reserve is bordered by three indigenous reservations, Alto Turiaçu to the north, and Carú and Awa to the west, and is located within the Belém CE.

The reserve's management plan establishes three zones, that is, areas that present specific characteristics, which require distinct strategies of intervention and protection. During the present study, data were collected at 12 points within two of these zones - the undisturbed zone and the recovery zone (Figure 1). The points were located to best sample the different successional stages and aquatic environments found within each zone (Figure 2). All sampling points were georeferenced using a Garmin Etrex Vista, Datum SAD 69 handheld GPS (Table 1).

Undisturbed zone

The REBIO Gurupi management plan defines this area as the central and best preserved portion of the reserve (IBAMA 1999). The vegetation is dense rainforest with a continuous canopy of approximately 35 m in height, with emergent trees reaching 50 m. The most frequent canopy tree species include *Manilkara huberi* (Ducke) Standl, *Shefflera morototoni* (Aubl.) March., *Hymenaea courbaril* Linnaeus, Cenostigma tocantinum Ducke, and Goupia glabra Aubl., in addition to genera such as Hymenolobium Benth., Eschweilera Mart. ex DC., *Cordia* L., *Inga* Mill., *Jacaranda* Juss., *Simarouba* Aubl., *Spondias* L., and *Vismia* Vand. Below the canopy, the lower strata are formed by a diversity of trees, shrubs, lianas, and herbaceous plants, which formed a well stratified, shady and humid understory, with a thick layer of leaf litter. This zone is dominated by plant species of the families Rubiaceae, Maranthaceae, and Arecaceae. The structure and composition of this forest are characteristic of an advanced stage of maturity (Freitas *et al.* 2005, Prata 2007, Guariguata & Ostertag 2001). However, some areas have suffered the effects of illegal logging, which has resulted in clearings produced by the felling and dragging of trees.

Recovery zone

The REBIO Gurupi management plan defines this area as the portion of the reserve affected by anthropogenic impacts, which will be reclassified as and when it will be completely restored. This zone is characterized by the presence of a number of tracts of degraded primary forest as well as many areas previously deforested for the establishment of pastures and "slash and burn" agriculture, presenting different successional stages. Some of the sampling points were located in areas characterized by widely-spaced emergents of the genera Eschweilera Mart. Ex DC., *Byrsonima* H.B.K., *Ocotea* Aubl., and *Inga* Mill., with an understory dominated by shrubs of the family Piperaceae which are typical of an advanced stage of regeneration (Prata 2007). Other areas of this zone are characterized by the presence of the Jamaican nettletree (*Trema micrantha* (L.) Blume.), a number of different *Cecropia* species, as well as *Tapirira guianensis* Aubl., which are considered to be indicators of early-growth forests (Guariguata & Ostertag 2001). Other records were collected at distinct features of the landscape in the study areas, such as pastures, and small marshes and permanent lakes.

Systematic field work was conducted by D. M. L. and D. S. L. R., beginning in August, 2010, and ending in December, 2012. Nonsystematic observations were carried out by C. M. between December, 2009, and December, 2013. Surveys of the reserve's avifauna also involved the use of complementary qualitative and quantitative methods for the collection of data in the different habitats sampled. Survey data were collected using mist-nets and MacKinnon lists (Anjos *et al.* 2010, Ribon 2010).

The MacKinnon lists method employed (MacKinnon 1991) consisted of the identification of 10 species, which represent a sampling unit, based on the modifications suggested by Herzog *et al.* (2002). This

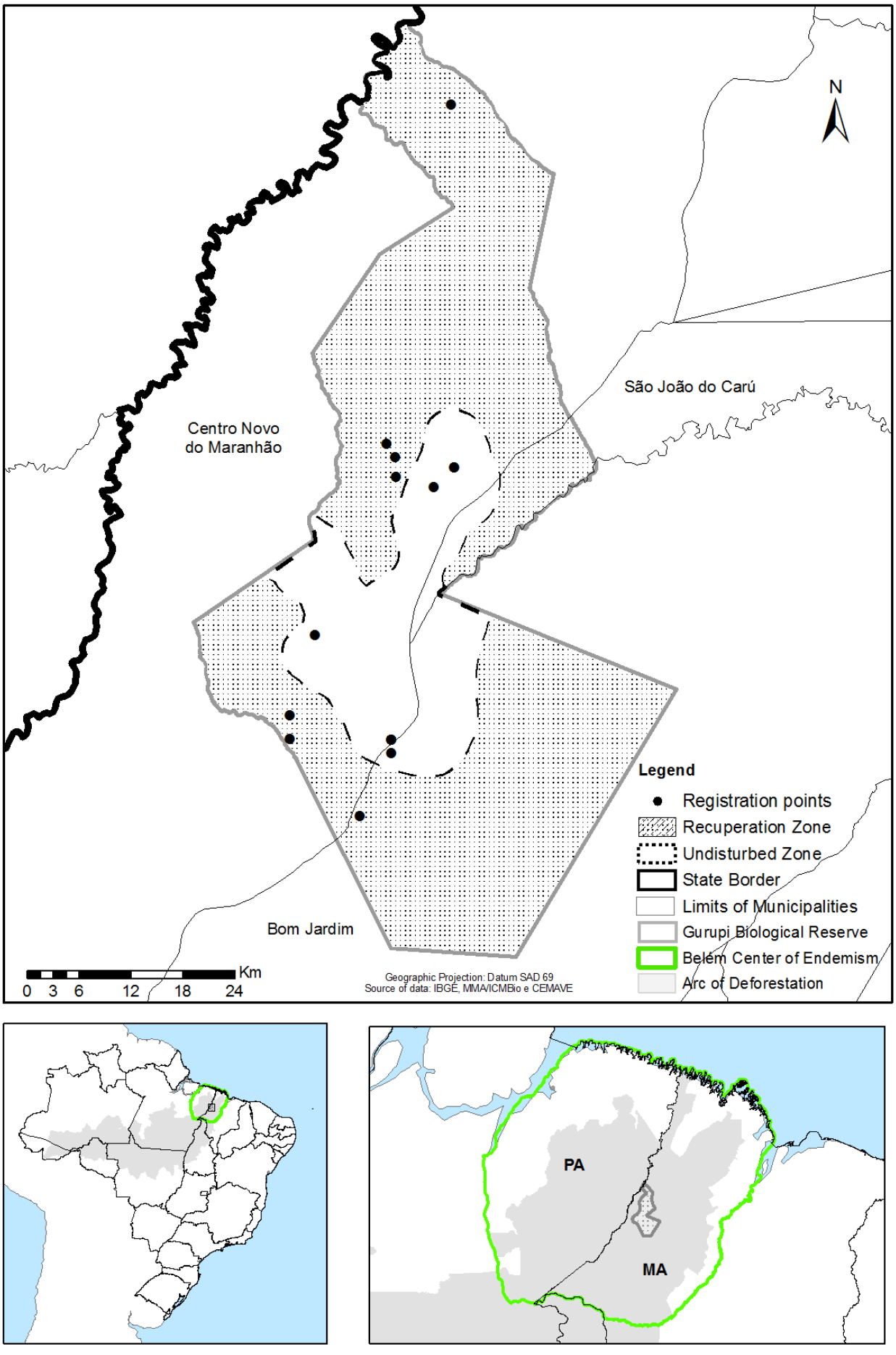

FIGURE 1. Localities surveyed during this study at REBIO Gurupi between December 2009 and December 2012. The figure also shows the location of the reservation with respect to the state of Maranhão, adjacent municipalities, the Belém Center of Endemism, and the arc of deforestation in Brazil.

FIGURE 2. Habitats surveyed in both undisturbed and recovery areas at REBIO Gurupi: (a) primary forest; (b) forest regeneration in advanced stage; (c) small marshes; (d) forest regeneration in early stage; (e) disturbed areas / pastures; (f) temporary lake. Photographs were taken by D. M. L.

procedure was used to survey all different habitat types found within the reserve, and resulted in the collection of a total of 199 lists, in order to obtain a rarefaction curve and quantify the number of species. These records were collected during 30 nonconsecutive days, generally between 06:00 h and 10:00 h in the morning, and 15:00-18:30 h in the afternoon, with a total of 225 hours of sampling time. Complementary data were collected in a nonsystematic manner by C. M. between December, 2009, and December, 2013, during periodic visits to the reserve as part of the eastern Amazonian division of the national Program for Biodiversity Research (PPBio). However, nonsystematic data obtained by C. M. were not used to estimate a rarefaction curve.

Estimates of species richness obtained with the Mackinnon lists were carried out with Bootstrap Mean estimators and CHAO 2 using the statistical program EstimateSWin 8.2 (Colwell 2006).

Additional data were collected using mist nets, with 10 nets (9 m x 2.5 m, with a 25 mm mesh) set up on nonconsecutive days in each sampling area, with five days spent in the recovery Zone, and four days in the undisturbed zone. The nets were open between 05:30 h and 18:00 h, with a total sampling effort of 625 net-hours in the recovery Zone, and 500 net-hours in the undisturbed zone. Following identification and processing, the birds captured were marked with standard CEMAVE/ICMBio metallic bands before released back into the wild.

Species were identified based on the specialized literature (Erize *et al.* 2006, Ridgely & Tudor 1989, 1994, 2009, Sick 1997, Sigrist 2009, van Perlo 2009). Photographic records obtained in the field of considerable biogeographic importance were compared with material available online (www.wikiaves.com.br), and later archived this same database. In the case of threatened species for which no documentation was available, a detailed description was recorded, based on field observations. Species of relevant biogeographical interest, for which we obtained only isolated observations, were listed separately (Appendix 1), following the recommendations in Lees *et al.* (2014).

RESULTS

Altogether 424 species were recorded at the REBIO Gurupi (Table 2). Among the species and subspecies recorded, seven were considered endangered according to the National List of Brazilian Fauna Threatened with Extinction (MMA 2003), as follows: *Psophia obscura* (Endangered - EN; also regarded as threatened globaly, see IUCN 2014), *Guaruba guarouba* (Vulnerable - VU; also threatened globaly according to the IUCN 2014), *Pyrrhura lepida lepida* (Endangered - EN, also threatened globaly according to the IUCN 2014), *Pteroglossus bitorquatus bitorquatus* (Vulnerable - VU), *Phlegopsis nigromaculata paraensis* (Endangered - EN), *Dendrocincla merula badia* (Endangered - EN), and *Dendrocolaptes medius* (Endangered - EN). In addition to these, eight species are threatened globally (IUCN 2014): *Tinamus tao* (Vulnerable - VU), *Penelope pileata* (Vulnerable - VU), *Lophornis gouldii* (Vulnerable - VU), *Pyrrhura amazonum* (Endangered - EN), *Touit huetii* (Vulnerable - VU), *Pionites leucogaster* (Vulnerable - VU), *Pyrilia vulturina* (Vulnerable - VU), and *Lepidothrix iris* (Vulnerable - VU).

We recorded 18 taxa endemic to the Belém CE: *Ortalis superciliaris*, *P. obscura*, *P. lepida lepida*, *P. bitorquatus bitorquatus*, *Celeus torquatus pieteroyensi*, *Thamnophilus aethiops incertus*, *Pyriglena leuconota leuconota*, *Phlegopsis nigromaculata paraensis*, *Dendrocincla merula badia*, *Synallaxis rutilans omissa*, *Todirostrum chrysocrotaphum illigeri*, *Piprites chloris grisescens*, *Manacus manacus purissimus*, *Terenotriccus erythrurus hellmayri*, *Ramphocaenus melanurus austerus*, *Lanio cristatus pallidigula*, *Tangara velia signata* and *Granatellus pelzelni paraensis*.

The data from mist-net captures are included here only for the calculation of species richness. The cumulative species curve based on the 10 species MacKinnon lists accumulated throughout REBIO Gurupi (n = 199) reached a total of 320 species. The CHAO 2 and Boostrap estimators calculated a total species richness of 380 and 364, respectively. Therefore, the estimated values are higher than the species richness recorded empirically (Figure 3).

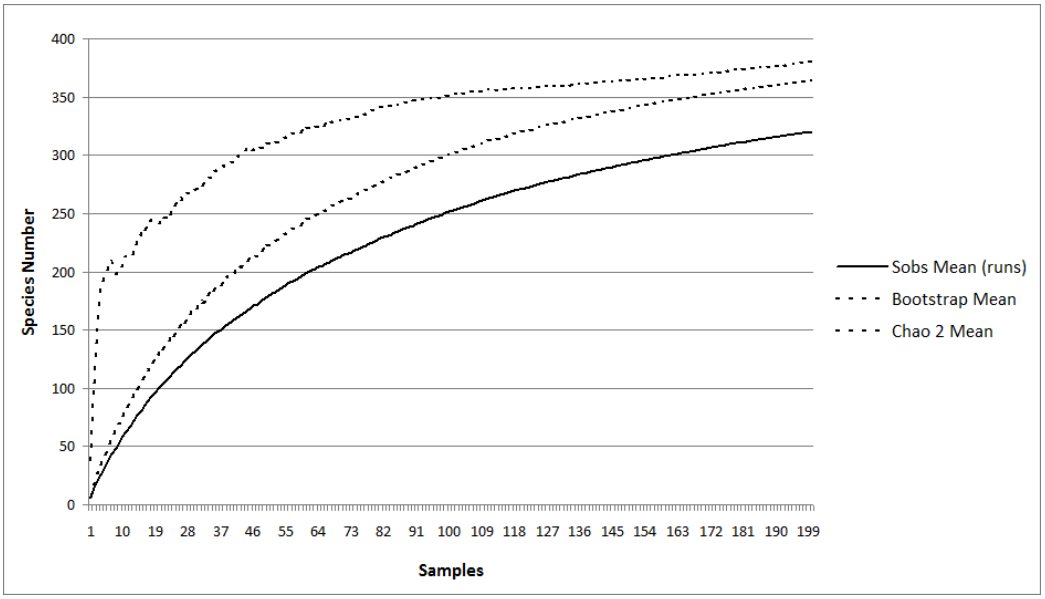

FIGURE 3. Species accumulation curve based on 199 Mackinnon lists obtained between August 2010 and December 2012 at REBIO Gurupi. Values of observed species richness (Sobs) along with those estimated by Bootstrap and CHAO 2 are shown.

TABLE 1. Coordinates (SAD 69 Lat/Lon hddd°mm'ss.s") of sampling points in undisturbed (Zd) and recovery zones (Zr) of REBIO Gurupi.

Points	Lat	Long	Area
1	W 46 42 38.0	S 03 38 33.7	Zd
2	W 46 41 21.5	S 03 37 21.2	Zd
3	W 46 50 03.1	S 03 47 50.0	Zd
4	W 46 45 16.7	S 03 54 21.2	Zd
5	W 46 45 18.0	S 03 55 10.0	Zd
6	W 46 47 15.5	S 03 59 07.4	Zr
7	W 46 51 38.1	S 03 52 48.7	Zr
8	W 46 51 36.3	S 03 54 17.3	Zr
9	W 46 44 57.9	S 03 37 57.1	Zr
10	W 46 45 02.5	S 03 36 41.2	Zr
11	W 46 45 35.2	S 03 35 52.2	Zr
12	W 46 41 34.2	S 03 14 42.5	Zr

DISCUSSION

According to Oren & Roma (2011) 503 species of birds were recorded in the Amazonian sector of Maranhão State. According to our data, REBIO Gurupi holds at least 84% of these species. Compared with the total number of species recorded for the state of Maranhão (640 spp., Oren 1991), REBIO Gurupi harbors about 66% of the bird species recorded in the state. The number of species inventoried by us in the reserve, taking into account the proportions of the sampled area, habitat heterogeneity, and sampling effort, is also significant in comparison to the total number of species recorded for the Belém CE. Roma (1996) lists 529 species for the Belém CE in the eastern part of the state of Pará, while Novaes & Lima (2009) recorded 490 species for the Belém metropolitan area, and Lees *et al*. (2012) listed 440 species for several sites at Paragominas. Only Portes *et al*. (2011) recorded a slightly greater number of species (441 species) than us at nine forest fragments of the Belém CE in the state of Pará, covering the municipalities of Paragominas, Tailândia and Tomé-Açu.

In our study, the cumulative species curve did not stabilize by the end of the sampling (Figure 3), indicating that additional species would probably have been recorded if more MacKinnon lists had been collected. The asymptote may rarely be reached in areas of high diversity (Ribon 2010), and it seems likely that further surveys at REBIO Gurupi will render a more complete picture of the diversity of the reserve's avifauna.

In the present study, the most diverse bird family was Tyrannidae, which is the third richest avian taxon in Brazil (CBRO 2014). Tyrannids are highly versatile ecologically, and are able to live in a wide range of habitats, including primary and secondary forests, as well as more open spaces (Sick 1997, Sigrist 2009). In the present study, species typical of open areas, such as *Pitangus sulphuratus, Tyrannus melancholicus, Machetornis rixosa*, and *Fluvicola nengeta*, were common in the recovery Zone. Early and mid-growth secondary forests also favor the occurrence of more generalist species, tolerant of habitat disturbance, such as *Forpus xanthopterygius, Thamnophilus doliatus, Thamnophilus palliatus, Taraba major, Legatus leucophaius, Cyanocorax cyanopogon, Pheugopedius genibarbis*, and *Ramphocelus carbo*.

The geographical proximity to other, more open biomes, such as the cerrado and dry forests, may account for species from other biomes occurring into the study area following the new open areas created by deforestation (Develey 2009, Sick 1997). Species in this category are, for example, *Bubo virginianus*, *Ara severus*, *Brotogeris chiriri*, *Columbina minuta* and *Polioptila plumbea*.

Army ant swarms, which displace insects such as crickets and cockroaches during their forays, are common in the Amazon basin (Sick 1997). These columns attract birds that habitually exploit the insect prey disturbed by the ants' foraging behavior, including species of the families Thamnophilidae, Dendrocolaptidae, and Furnaridae. This phenomenon was observed frequently during the period of the present study, with the following species commonly attending the army ant swarms: *Pyriglena leuconota, Willisornis vidua, Phlegopsis nigromaculata paraensis*, *Dendrocincla merula badia, Deconychura longicauda* and *Dendrocincla fuliginosa*. The largest numbers of thamnophilid, dendrocolaptid and furnarid species were observed in mixed species flocks in the undergrowth, which normally included *Thamnomanes caesius*, *Xenops minutus, Glyphorynchus spirurus, Deconychura longicauda, Dendrocincla fuliginosa, Dendroplex picus, Xiphorhynchus guttatus, Myrmotherula axillaris, Isleria hauxwelli, Myrmotherula menetriesii, Dysithamnus mentalis*, *Automolus rufipileatus* and *Herpsilochmus rufimarginatus.*

The relatively large number of accipitrid species recorded during the present study, in addition to a number of frugivores that are sensitive to habitat fragmentation, such as *Selenidera gouldii*, *Cotinga cotinga, Cotinga cayana, Xipholena lamellipennis, Iodopleura isabellae, Haematoderus militaris*, and *Aburria cujubi* indicate the presence of good quality habitat, and suggest a relatively well-balanced food web at REBIO Gurupi (Willis 1979, Ricklefs 2001, Noss & Csuti 1997, Lees & Peres 2006). In particular, records of *Harpia harpyja*, *Spizaetus tyrannus*, and *Leucopternis albicollis* indicate good primary forest cover, given that the presence of these raptor species may be dependent on large areas of pristine habitat (Oren & Roma 2011).

The family Psittacidae was one of the five most diverse recorded in the present study, as might be expected, considering that the Amazon region has the highest diversity of parrots (Sick 1997). Two of the taxa recorded - *Guaruba guarouba* and *Pyrrhura lepida lepida* - are listed in Brazil (MMA 2003) as threatened with extinction.

Noteworthy conservation and biogeographic records

Harpy Eagle (*Harpia harpyja*). An individual was observed perched on a maçaranduba tree (*Manilkara huberi*) in the recovery Zone in September, 2011, at around 08:00 h. This relatively robust specimen was presumed to be a female. In the same area in March, 2012, a second individual was sighted flying over an area of late-growth secondary forest. A third photographic record was obtained from a local resident of the sustainable forest management project adjacent to the biological reserve. Prior to the present study, in January, 2000, C. M. observed the species in a peripheral area of the reserve, which has now been deforested. There is evidence of genetic structuring of the *Harpia* populations in the Amazon biome, which are still relatively large, although there is lower variability in the Arc of Deforestation (ICMBio 2008). Given this, the populations located in highly impacted areas may be at increased risk of local extinction, given that this species is sensitive to anthropogenic disturbance, and is among the first to disappear when deforestation accelerates (Trinca *et al*. 2008, ICMBio 2008). The species is included in Appendix I of CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) and is also listed as near-threatened by the IUCN (2014).

Black-and-white Hawk-Eagle (*Spizaetus melanoleucus*). D. M. L. recorded an individual flying over the margin of the primary forest in the northern extreme of the reserve, at 03°14'42.56"S, 46°41'34.22"W (Lima 2010). In December, 2013, C. M. recorded another individual in the south of the reserve. These appear to be the first published records of the species in the Amazon sector of Maranhão, given that it is not cited in Oren & Roma (2011), although C. M. observed the species previously at a different locality (unpublished data). According to Sick (1997) the species occurs from Mexico to Argentina, and in Brazil its presence is characterized by scattered occurrences.

Orange-breasted Falcon (*Falco deiroleucus*). C. M. observed one individual on 4th March 2010 a few km south of the ICMBio station, not strictly inside the Reserve, but in the buffer zone. As far as we know, this is the first report for this species in Maranhão. The observation took place at around 07:00 hs, during a walk in the area, and the bird was perched, eating an individual of *Eupsittula aurea* (Psittacidae). The falcon showed a less compact appearence than the similar and far more common *Falco rufigularis*. It seemed to be longer-tailed than the latter species, and showed a rufous color in the upper breast. Further and most importantly, the falcon was around twice the size of the parakeet it had captured, eliminating any possible misidentification.

Dark-winged Trumpeter (*Psophia obscura*). This species was recorded on 20 occasions during the present study. Two records were obtained in December, 2009, three in June, 2010, three in August, 2010 (Lima & Raíces 2012), two in December, 2010, two in September, 2011, and six in December, 2013, all in the recovery Zone (Figure 4, C. M. photographed), with a further two records obtained in the undisturbed zone in November, 2011 (D.M. L. and D. S. L. R.). The species was observed at several locations in primary forest, but sometimes also in disturbed areas affected by illegal deforestation. While most of the sightings were recorded in the recovery zone, the vast majority of these observations coincided with the areas of pristine forest within this zone. While the species may occur throughout the Belém CE (Oren & Roma 2011), it is dependent on well-preserved habitats, and may thus be vulnerable to disturbance, which may often lead to local extinction. The species is considered to be endangered, both in Brazil (MMA 2003) and within its geographic range in general (IUCN 2014), as well as in the state of Pará (COEMA 2007). The species is rare and difficult to observe in most other forest remnants located within the Belém CE (A. Aleixo *pers. comm*.).

Golden Parakeet (*Guaruba guarouba*). This species was recorded in both recovery and undisturbed zones. On October, 2010, D. M. L. and D. S. L. R observed an active *G. guarouba* nest containing two nestlings in an angelim tree (*Hymenolobium* sp.) of approximately 40 m in height in an area of secondary forest at the edge of an access road close to the sustainable forest management project (Lima 2012a). Laranjeiras (2011) also observed Golden Parakeet nests in open areas adjacent to the continuous forest, which were exposed to potential disturbance such as nest robbery for the illegal wild bird trade. During observations of this nest, a group of three individuals were observed feeding the nestlings. Similar cooperative infant care involving family members has been observed in this species by Silveira & Belmonte (2005). During the present study, a total of approximately 145 individuals were observed during 19 encounters with the species, although it seems likely that many of these parakeets were recorded more than once, given that it was not possible to identify the animals individually. The maximum number of individuals observed during a single encounter was 34.

Pearly Parakeet (*Pyrrhura lepida lepida*) – C. M. observed four individuals flying over an area of the recovery zone in December 2009 and two other individuals were seen, also in flight, on September, 2011. Four individuals were sighted resting in the subdossel of a forest in an

advanced state of regeneration, connected by continuous primary forest in December 2011 (registration by D. M. L). In December 2012 a flock of about 8-10 individuals was sighted consuming the inflorescence of *Parkia decussata* Ducke (Fabaceae) (Lima 2012b). This species was sighted at least four times in December, 2013, in flocks of up to six individuals (registration by C. M.). Once again, it is not possible to confirm whether these encounters involved the same or different groups. Silveira (2008a) indicated that recent records of the subspecies are scarce and poorly documented, but that it probably occurred in the REBIO Gurupi. Thus, this is the first documented record of this species for the REBIO Gurupi (Table 2). The nominate subspecies distribution is in upland forest of northern and eastern Pará, between the Tocantins and Gurupi Rivers and western Maranhão, being endemic to the Belém CE (Oren & Roma 2011, Silveira 2008a). It is categorized as endangered (MMA 2003). The main threats are habitat loss and, in recent years, capture to the illegal trade of wild birds (Silveira 2008b).

FIGURE 4. Flock of Dark-winged trumpeters (*Psophia obscura*). Photograph taken on December, 2013 by C. M.

TABLE 2. List of the 424 bird species recorded in the Gurupi Biological Reserve (MA, Brazil), from December 2010 to December 2012 and (*) complementary data collected in a nonsystematic manner by C. M. between December, 2009, and December, 2013. Zoning: Zd = undisturbed zone; Zr = recovery zone. Habitat: P = primary forest; S = forest regeneration in advanced stage; Cp = forest regeneration in early stage; B = small marshes; L = lakes; aa = disturbed areas / pasture. Type of record: A = Auditory, V = Visual, Ca = capture in mist nets; F = Photographed. Photo reference numbers are searchable in the online databases of www.wikiaves.com.br (WA). Taxon/species names followed by the acronym (Tn) indicate those regarded as threatened according to the National List of Brazilian Fauna Species Threatened with Extinction (MMA 2003). Taxon/species names followed by the acronym (Ti) indicate those regarded as threatened globally according to IUCN (2014). EN = Endemic species / subspecies to the Belém Center of Endemism according to Oren & Roma (2011). Taxonomy and nomenclature follows CBRO (2014).

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Tinamidae Gray, 1840					
Tinamus major (Gmelin, 1789)*		x	P	A	
Tinamus tao Temminck, 1815 [Ti]	x	x	P, S	A	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Crypturellus cinereus (Gmelin, 1789)		x	Cp	A	
Crypturellus soui (Hermann, 1783)	x		S	A	
Crypturellus strigulosus (Temminck, 1815)		x	Cp	A	
Crypturellus variegatus (Gmelin, 1789)	x	x	P, Cp	A	
Crypturellus parvirostris (Wagler, 1827)	x	x	P, S	V, A	
Anhimidae Stejneger, 1885					
Anhima cornuta (Linnaeus, 1766)	x	x	Cp, B	F,V	1037719
Anatidae Leach, 1820					
Dendrocygna viduata (Linnaeus, 1766)	x		B, L	F	
Dendrocygna autumnalis (Linnaeus, 1758)	x		B, L	V	
Cairina moschata (Linnaeus, 1758)	x		B, L	F	
Amazonetta brasiliensis (Gmelin, 1789)	x		B, L	F	1064152
Cracidae Rafinesque, 1815					
Ortalis superciliaris (Gray, 1867) [EN]	x	x	P, Cp, S, B	V	
Penelope superciliaris Temminck, 1815	x	x	Cp, S	V	
Penelope pileata Wagler, 1830 [Ti]	x		P, S	F,V	1036681
Aburria cujubi (Pelzeln, 1858)	x	x	P, Cp	V	
Pauxi tuberosa (Spix, 1825)		x	P, Cp	F	1029277
Odontophoridae Gould, 1844					
Odontophorus gujanensis (Gmelin, 1789)*		x	P	A	
Podicipedidae Bonaparte, 1831					
Tachybaptus dominicus (Linnaeus, 1766)*		x	B	V	
Podilymbus podiceps (Linnaeus, 1758)	x		B, L	V	
Ciconiidae Sundevall, 1836					
Mycteria americana Linnaeus, 1758	x		B	F	1065020
Anhingidae Reichenbach, 1849					
Anhinga anhinga (Linnaeus, 1766)	x		B, L	F	1041429
Ardeidae Leach, 1820					
Tigrisoma lineatum (Boddaert, 1783)	x		B, L	V	
Cochlearius cochlearius (Linnaeus, 1766)	x		B	V	
Nycticorax nycticorax (Linnaeus, 1758)	x		B	V	
Butorides striata (Linnaeus, 1758)	x		B, L	V	
Bubulcus ibis (Linnaeus, 1758)	x	x	B	V	
Ardea cocoi Linnaeus, 1766	x		L	V	
Ardea alba Linnaeus, 1758	x		B, L	V	
Pilherodius pileatus (Boddaert, 1783)	x		B	V	
Egretta thula (Molina, 1782)	x		B, L	V	
Threskiornithidae Poche, 1904					
Mesembrinibis cayennensis (Gmelin, 1789)*	x		B	V	
Theristicus caudatus (Boddaert, 1783)	x		B	V	
Cathartidae Lafresnaye, 1839					
Cathartes aura (Linnaeus, 1758)	x	x	P, S, Cp, B, C	V	
Cathartes burrovianus Cassin, 1845	x	x	P, Cp, B, C	V	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Cathartes melambrotus Wetmore, 1964		x	Cp	F	1064209
Coragyps atratus (Bechstein, 1793)	x	x	P, Cp, aa	V	
Sarcoramphus papa (Linnaeus, 1758)	x	x	P, Cp	V	
Accipitridae Vigors, 1824					
Leptodon cayanensis (Latham, 1790)	x	x	P, S	F	1065446
Chondrohierax uncinatus (Temminck, 1822)		x	S	V	
Elanoides forficatus (Linnaeus, 1758)	x	x	P, Cp, B	F	1036637
Gampsonyx swainsonii Vigors, 1825		x	Cp	V	
Elanus leucurus (Vieillot, 1818)	x	x	aa	V	
Harpagus bidentatus (Latham, 1790)		x	Cp	V, F	1180188
Harpagus diodon (Temminck, 1823)	x		S	V	
Ictinia plumbea (Gmelin, 1788)		x	Cp	V	
Accipiter superciliosus (Linnaeus, 1766)*		x	P	V	
Accipiter bicolor (Vieillot, 1817)*		x	P	V	
Busarellus nigricollis (Latham, 1790)	x	x	P, Cp	V	
Rostrhamus sociabilis (Vieillot, 1817)*		x	B	V	
Geranospiza caerulescens (Vieillot, 1817)		x	S	V	
Heterospizias meridionalis (Latham, 1790)	x	x	P	V	
Urubitinga urubitinga (Gmelin, 1788)	x		B	F	1180181
Rupornis magnirostris (Gmelin, 1788)	x	x	Cp, S	V	
Geranoaetus albicaudatus (Vieillot, 1816)	x	x	aa	V	
Pseudastur albicollis (Latham, 1790)	x	x	P, S	F	1030148
Leucopternis kuhli Bonaparte, 1850*		x	P	V	
Buteo nitidus (Latham, 1790)		x	Cp	V, F	1238809
Buteo brachyurus Vieillot, 1816	x		Cp, S	V, F	1194316
Buteo albonotatus Kaup, 1847	x		P	V, F	1238793
Harpia harpyja (Linnaeus, 1758)		x	P	V	
Spizaetus tyrannus (Wied, 1820)	x	x	P	V	
Spizaetus melanoleucus (Vieillot, 1816)	x	x	P	F	1065501
Aramidae Bonaparte, 1852					
Aramus guarauna (Linnaeus, 1766)		x	B	V	
Psophiidae Bonaparte, 1831					
Psophia obscura Pelzeln [Tn; Ti; EN]	x	x	P, Cp	V, A, F	C. M. R.
Rallidae Rafinesque, 1815					
Aramides cajaneus (Statius Muller, 1776)	x		B	A	
Laterallus viridis (Statius Muller, 1776)	x		B	A	
Laterallus melanophaius (Vieillot, 1819)	x		B, L	V	
Porzana flaviventer (Boddaert, 1783)	x		B	V	
Gallinula galeata (Lichtenstein,1818)	x		B, L	V	
Porphyrio martinicus (Linnaeus, 1766)	x		B, L	V	
Charadriidae Leach, 1820					
Vanellus chilensis (Molina, 1782)	x	x	B, aa	V	
Scolopacidae Rafinesque, 1815					

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Actitis macularius (Linnaeus, 1766)	x	x	B, L	V	
Tringa solitaria Wilson, 1813		x	B, L	F	1038987
Jacanidae Chenu & Des Murs, 1854					
Jacana jacana (Linnaeus, 1766)	x	x	B, L	V	
Columbidae Leach, 1820					
Columbina passerina (Linnaeus, 1758)	x		Cp, aa, S	V	
Columbina minuta (Linnaeus, 1766)*		x	Cp	V	
Columbina talpacoti (Temminck, 1811)	x	x	Cp, aa, B	V	
Columbina squammata (Lesson, 1831)	x		Cp, aa	V,A	
Columbina picui (Temminck, 1813)*		x	Cp	V	
Claravis pretiosa (Ferrari-Perez, 1886)	x	x	Cp, S	V, A, Ca	
Patagioenas speciosa (Gmelin, 1789)		x	P, Cp	V	
Patagioenas cayennensis (Bonnaterre, 1792)*		x	P, S, Cp	V	
Patagioenas plumbea (Vieillot, 1818)		x	P, Cp	V	
Patagioenas subvinacea (Lawrence, 1868)*		x	P	V	
Zenaida auriculata (Des Murs, 1847)		x	Cp	V	
Leptotila verreauxi Bonaparte, 1855	x	x	Cp	A	
Leptotila rufaxilla (Richard & Bernard, 1792)	x	x	Cp	V, A, Ca	
Geotrygon montana (Linnaeus, 1758)	x	x	Cp, S	A, Ca	
Cuculidae Leach, 1820					
Coccycua minuta (Vieillot, 1817)	x	x	P	V,F	
Piaya cayana (Linnaeus, 1766)	x	x	P, Cp	V	
Coccyzus melacoryphus Vieillot, 1817	x		S	V	
Coccyzus americanus (Linnaeus, 1758)*		x	S	V	
Coccyzus euleri Cabanis, 1873	x		P, S	A	
Crotophaga major Gmelin, 1788	x	x	Cp, B, aa	V	
Crotophaga ani Gmelin, 1788		x	B, aa	V	
Guira guira (Gmelin, 1788)	x	x	Cp, B, aa	V	
Tapera naevia (Linnaeus, 1766)	x		aa	V	
Dromococcyx phasianellus (Spix, 1824)*		x	Cp	V	
Tytonidae Mathews, 1912					
Tyto furcata (Temminck, 1827)*		x	Cp, aa	V	
Strigidae Leach, 1820					
Megascops choliba (Vieillot, 1817)		x	Cp	A	
Megascops usta (Sclater, 1858)		x	Cp	Ca	
Lophostrix cristata (Daudin, 1800)	x		P	A	
Pulsatrix perspicillata (Latham, 1790)		x	P, Cp	A	
Bubo virginianus (Gmelin, 1788)*		x	S	V, A	
Strix virgata (Cassin, 1849)*		x	P, S	V, A	
Strix huhula Daudin, 1800	x	x	P, Cp	A	
Glaucidium hardyi Vielliard, 1990*		x	P	A	
Glaucidium brasilianum (Gmelin, 1788)		x	Cp	A, Ca	
Athene cunicularia (Molina, 1782)	x		aa	V	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Nyctibiidae Chenu & Des Murs, 1851					
Nyctibius grandis (Gmelin, 1789)		x	P, Cp	A	
Nyctibius griseus (Gmelin, 1789)	x	x	Cp	V, A	
Nyctibius leucopterus (Wied, 1821)*		x	P	V	
Caprimulgidae Vigors, 1825					
Nyctiphrynus ocellatus (Tschudi, 1844)*		x	P, S	V	
Antrostomus rufus (Boddaert, 1783)*		x	P, S	V, A	
Antrostomus sericocaudatus Cassin, 1849*		x	P	V	
Hydropsalis leucopyga (Spix, 1825)*		x	P, S	V	
Hydropsalis nigrescens (Cabanis, 1848)	x	x	P, Cp	V	
Hydropsalis albicollis (Gmelin, 1789)	x	x	P, Cp	V, A, Ca	
Hydropsalis parvula (Gould, 1837)*		x	P, S	V, A	
Chordeiles acutipennis (Hermann, 1783)	x		Cp	V	
Apodidae Olphe-Galliard, 1887					
Chaetura spinicaudus (Temminck, 1839)	x	x	Cp, aa	V	
Chaetura chapmani Hellmayr, 1907*		x	S	V	
Chaetura brachyura (Jardine, 1846)	x	x	Cp, aa, S	V	
Tachornis squamata (Cassin, 1853)	x	x	Cp	V	
Panyptila cayennensis (Gmelin, 1789)	x	x	Cp	V	
Trochilidae Vigors, 1825					
Glaucis hirsutus (Gmelin, 1788)		x	Cp	V, Ca	
Phaethornis ruber (Linnaeus, 1758)	x	x	P, Cp, S	V, Ca	
Phaethornis superciliosus (Linnaeus, 1766)	x	x	P, Cp, S	V, Ca	
Campylopterus largipennis obscurus Gould, 1848[EN]*		x	P, S	V, Ca	
Eupetomena macroura (Gmelin, 1788)		x	Cp	V	
Florisuga mellivora (Linnaeus, 1758)*		x	P	V	
Anthracothorax nigricollis (Vieillot, 1817)		x	Cp	V	
Topaza pella (Linnaeus, 1758)	x	x	P, Cp, S	V	
Chrysolampis mosquitus (Linnaeus, 1758)	x	x	P, Cp, S	V, Ca	
Lophornis gouldii (Lesson, 1832)[Ti]*	x	x	S	V	
Chlorostilbon notatus (Reich, 1793)*		x	P,S	V, Ca	
Thalurania furcata (Gmelin, 1788)	x	x	P, Cp	V, Ca	
Amazilia versicolor (Vieillot, 1818)*		x	S	V	
Amazilia fimbriata (Gmelin, 1788)	x	x	Cp, S	V	
Heliothryx auritus (Gmelin, 1788)	x	x	P, Cp	V	
Heliomaster longirostris (Audebert & Vieillot, 1801)*		x	S	V	
Calliphlox amethystina (Boddaert, 1783)*		x	S	V	
Trogonidae Lesson, 1828					
Trogon melanurus Swainson, 1838	x	x	P	V	
Trogon viridis Linnaeus, 1766		x	Cp	V, A	
Trogon ramonianus Deville & DesMurs, 1849	x	x	P, S	V, A	
Trogon curucui Linnaeus, 1766	x		P	V, A	
Trogon rufus Gmelin, 1788	x		P	Ca	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Alcedinidae Rafinesque, 1815					
Megaceryle torquata (Linnaeus, 1766)	x	x	B	V	
Chloroceryle amazona (Latham, 1790)	x	x	B	V	
Chloroceryle americana (Gmelin, 1788)	x		L	V	
Chloroceryle inda (Linnaeus, 1766)	x		L	V	
Momotidae Gray, 1840					
Momotus momota (Linnaeus, 1766)		x	P, S	V, A	
Galbulidae Vigors, 1825					
Brachygalba lugubris (Swainson, 1838)	x		B	F	1041472
Galbula cyanicollis Cassin, 1851	x	x	P, Cp	V, Ca	
Galbula ruficauda Cuvier, 1816	x	x	P, Cp, S	V, F	
Galbula dea (Linnaeus, 1758)	x		B	V	
Jacamerops aureus (Statius Muller, 1776)*		x	P	V	
Bucconidae Horsfield, 1821					
Notharchus hyperrhynchus (Sclater, 1856)	x	x	P	F	1073816
Notharchus tectus (Boddaert, 1783)	x	x	P, Cp, S	V, F	1081976
Bucco tamatia Gmelin, 1788	x		S	V	
Bucco capensis Linnaeus, 1766	x	x	P, Cp	A	
Nystalus torridus Bond & Meyer de Schauensee, 1940	x	x	P, Cp, S	A, F	1073824
Nystalus maculatus (Gmelin, 1788)	x	x	Cp	A	
Monasa nigrifrons (Spix, 1824)	x	x	P, Cp	V, A	
Monasa morphoeus (Hahn & Küster, 1823)	x	x	P, Cp, S	V, F,A	1030081
Chelidoptera tenebrosa (Pallas, 1782)	x	x	Aa	F	1029232
Ramphastidae Vigors, 1825					
Ramphastos tucanus Linnaeus, 1758	x	x	P, Cp, S	V, A, F	1180193
Ramphastos vitellinus Lichtenstein, 1823	x	x	P, Cp, S	V, A, F	1036649
Selenidera gouldii (Natterer, 1837)	x		P	A,F	1238732
Pteroglossus inscriptus Swainson, 1822	x	x	P, Cp	V, A, F	1031536
Pteroglossus bitorquatus bitorquatus Vigors, 1826 Tn; Ti; EN	x	x	P, Cp, S	V, F	1029361
Pteroglossus aracari (Linnaeus, 1758)	x	x	S, Cp	V	
Picidae Leach, 1820					
Picumnus exilis (Lichtenstein, 1823)*	z		P, Cp	V	
Melanerpes candidus (Otto, 1796)		x	Cp	V	
Melanerpes cruentatus (Boddaert, 1783)		x	Cp	V, F	1032436
Veniliornis affinis (Swainson, 1821)*		x	P, S	V	
Piculus flavigula (Boddaert, 1783)*		x	P, S	V	
Piculus paraensis (Snethlage, 1907) EN*		x	P	V	
Colaptes melanochloros (Gmelin, 1788)		x	Cp	V	
Celeus elegans (Statius Muller, 1776)	x	x	S	V, A	
Celeus ochraceus (Spix, 1824)*		x	P	V	
Celeus flavus (Statius Muller, 1776)*		x	P	V	
Celeus torquatus pieteroyensi Oren, 1992 EN	x	x	P	V, A	
Dryocopus lineatus (Linnaeus, 1766)	x	x	P, Cp, S	V, F	1041940

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Campephilus rubricollis (Boddaert, 1783)	x	x	P, Cp, S	V, F	1083897
Campephilus melanoleucos (Gmelin, 1788)	x	x	P	V	
Falconidae Leach, 1820					
Ibycter americanus (Boddaert, 1783)	x	x	P, Cp, S	F	1180215
Caracara plancus (Miller, 1777)	x	x	B, aa	F	
Milvago chimachima (Vieillot, 1816)		x	aa	V	
Herpetotheres cachinnans (Linnaeus, 1758)	x	x	Cp	F	1031555
Micrastur ruficollis (Vieillot, 1817)*		x	P	V	
Micrastur mintoni Whittaker, 2002	x	x	P	V	
Micrastur semitorquatus (Vieillot, 1817)	x		P	V	
Falco sparverius Linnaeus, 1758		x	Cp, aa	V	
Falco rufigularis Daudin, 1800	x	x	Cp	F	1083881
Falco deiroleucus Temminck, 1825*	x		Cp	V	
Psittacidae Rafinesque, 1815					
Ara macao (Linnaeus, 1758)	x	x	P, Cp, S	F	1036661
Ara chloropterus Gray, 1859	x		P, S	F	1030079
Ara severus (Linnaeus, 1758)*		x	P, S, Cp	V	
Orthopsittaca manilatus (Boddaert, 1783)		x	P, Cp	V	
Diopsittaca nobilis (Linnaeus, 1758)		x	S, Cp	V	
Guaruba guarouba (Gmelin, 1788) Tn; Ti	x	x	P, Cp, S	F	1029265
Psittacara leucophthalmus (Statius Muller, 1776)	x	x	Cp, S	F	1185791
Aratinga jandaya (Gmelin, 1788)	x	x	P, Cp, S	V,F	
Eupsittula aurea (Gmelin, 1788)*		x	S, Cp	V	
Pyrrhura lepida lepida (Wagler, 1832) Tn; Ti; EN	x	x	P, S	F	1027814
Pyrrhura amazonum Hellmayr, 1906 Ti *		x	P, S	V	
Forpus xanthopterygius (Spix, 1824)	x	x	Cp	V	
Brotogeris chiriri (Vieillot, 1818)*	x	x	Cp, S	V	
Brotogeris chrysoptera (Linnaeus, 1766)	x	x	P	V	
Touit huetii (Temminck, 1830) Ti *		x	P	V	
Pionites leucogaster (Kuhl, 1820) Ti	x	x	P, Cp, S	V	
Pyrilia vulturina (Kuhl, 1820) Ti	x		P	F	1238382
Pionus menstruus (Linnaeus, 1766)	x	x	P, Cp, S	F	1038941
Pionus fuscus (Statius Muller, 1776)	x	x	P, Cp	F	1029310
Amazona farinosa (Boddaert, 1783)	x	x	Cp, S	V	
Amazona amazonica (Linnaeus, 1766)	x	x	P	V	
Amazona ochrocephala (Gmelin, 1788)*		x	P	V,F	1083958
Deroptyus accipitrinus (Linnaeus, 1758)	x	x	P, S	F	1180250
Thamnophilidae Swainson, 1824					
Pygiptila stellaris (Spix, 1825)	x	x	P, Cp	A	
Myrmotherula multostriata Sclater, 1858	x	x	P	V, A	
Myrmotherula longipennis Pelzeln, 1868*		x	P	V	
Myrmotherula axillaris (Vieillot, 1817)	x	x	P, Cp	A, Ca	
Myrmotherula menetriesii (d'Orbigny, 1837)	x	x	P, Cp	V, Ca	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Formicivora grisea (Boddaert, 1783)	x	x	P, Cp	A, Ca	
Isleria hauxwelli (Sclater, 1857)	x		P, S	A, Ca	
Thamnomanes caesius (Temminck, 1820)	x	x	P, Cp	A, Ca	
Dysithamnus mentalis (Temminck, 1823)	x	x	P, Cp	A, P, Ca	
Herpsilochmus rufimarginatus (Temminck, 1822)	x	x	P, Cp, S	A	
Sakesphorus luctuosus (Lichtenstein, 1823)	x		P	A	
Thamnophilus doliatus (Linnaeus, 1764)*		x	Cp	V	
Thamnophilus palliatus (Lichtenstein, 1823)	x		Cp, S, B	F	1041503
Thamnophilus pelzelni Hellmayr, 1924	x		P	A	
Thamnophilus aethiops incertus Pelzeln, 1869 EN	x	x	P, Cp	A, Ca	
Thamnophilus amazonicus Sclater, 1858	x	x	P, Cp, S	A, Ca	
Taraba major (Vieillot, 1816)	x		Cp, S	V, A, F	1036704
Hypocnemoides maculicauda (Pelzeln, 1868)	x		S	A	
Pyriglena leuconota leuconota (Spix, 1824) EN	x	x	P, Cp	V, A, Ca	
Cercomacra cinerascens (Sclater, 1857)*	x	x	P, Cp	A	
Cercomacra laeta Todd, 1920*		x	P, S, Cp	V, A, Ca	
Willisornis vidua (Hellmayr, 1905)	x	x	P, Cp	A, Ca	
Phlegopsis nigromaculata paraensis Hellmayr, 1904 Tn; EN	x	x	P, Cp	V	
Conopophagidae Sclater & Salvin, 1873					
Conopophaga roberti Hellmayr, 1905EN		x	Cp	V, A, Ca	
Grallariidae Sclater & Salvin, 1873					
Hylopezus paraensis Snethlage, 1910	x	x	P, Cp	A	
Formicariidae Gray, 1840					
Formicarius colma Boddaert, 1783		x	Cp	A, Ca	
Formicarius analis (d'Orbigny & Lafresnaye, 1837)*		x	P, S	V, A	
Scleruridae Swainson, 1827					
Sclerurus macconnelli Chubb, 1919	x		P	A	
Sclerurus rufigularis Pelzeln, 1868		x	P	V, A	
Sclerurus caudacutus (Vieillot, 1816)	x	x	P, Cp, S	V, A	
Dendrocolaptidae Gray, 1840					
Dendrocincla fuliginosa (Vieillot, 1818)	x	x	P, Cp	A,Ca	
Dendrocincla merula badia (Zimmer, 1934) Tn; EN	x		P	A, Ca	
Deconychura longicauda (Pelzeln, 1868) *		x	P	Ca	
Certhiasomus stictolaemus (Pelzeln, 1868)		x	Cp	A	
Glyphorynchus spirurus (Vieillot, 1819)	x	x	P, Cp	V,Ca	
Xiphorhynchus spixii (Lesson, 1830)	x	x	S	A	
Xiphorhynchus obsoletus (Lichtenstein, 1820)		x	S	A, Ca	
Xiphorhynchus guttatus (Lichtenstein, 1820)	x	x	P, S	A, F	1038873
Dendroplex picus (Gmelin, 1788)	x	x	P, Cp, S	A, Ca	
Lepidocolaptes layardi (Sclater, 1873)*		x	P, S	V, A	
Dendrocolaptes medius Todd, 1920 Tn; EN	x	x	P, Cp, S	V, A	
Xenopidae Bonaparte, 1854					
Xenops minutus (Sparrman, 1788)	x	x	P, Cp	Ca	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Furnariidae Gray, 1840					
Berlepschia rikeri (Ridgway, 1886)	x	x	P, Cp	A	
Automolus paraensis Hartert, 1902*		x	P	V, A	
Automolus rufipileatus (Pelzeln, 1859)*	x		P, S	V, A, Ca	
Anabacerthia ruficaudata (d'Orbigny & Lafresnaye, 1838) *		x	P	V	
Philydor erythrocercum (Pelzeln, 1859)*		x	P	V, Ca	
Philydor pyrrhodes (Cabanis, 1848)	x		P	A	
Certhiaxis cinnamomeus (Gmelin, 1788)	x		B	A	
Synallaxis albescens Temminck, 1823	x		Cp, B	A	
Synallaxis rutilans omissa (Hartert, 1901) [EN]	x	x	P, Cp	A	
Synallaxis gujanensis (Gmelin, 1789)*		x	S	V	
Pipridae Rafinesque, 1815					
Tyranneutes stolzmanni (Hellmayr, 1906)*		x	P	V, A	
Ceratopipra rubrocapilla Temminck, 1821*		x	P	V, A	
Lepidothrix iris (Schinz, 1851) [Ti]		x	P	A	
Manacus manacus purissimus Todd, 1928 [EN]	x	x	Cp	V, Ca	
Chiroxiphia pareola (Linnaeus, 1766)	x	x	Cp, S	V, Ca	
Dixiphia pipra (Linnaeus, 1758)		x	P	V, A	
Onychorhynchidae Tello, Moyle, Marchese & Cracraft, 2009					
Onychorhynchus coronatus (Statius Muller, 1776)	x	x	P, Cp	V, Ca	
Terenotriccus erythrurus hellmayri (E. Snethlage, 1907) [EN]	x	x	P, Cp, S	V, Ca	
Myiobius atricaudus Lawrence, 1863	x	x	Cp, S	V, Ca	
Tityridae Gray, 1840					
Schiffornis turdina (Wied, 1831)*		x	P	A, Ca	
Iodopleura isabellae Parzudaki, 1847*		x	P	V	
Tityra inquisitor (Lichtenstein, 1823)	x	x	P, S	V	
Tityra cayana (Linnaeus, 1766)	x	x	P, S	F	1194380
Tityra semifasciata (Spix, 1825)	x	x	P, Cp	V	
Pachyramphus castaneus (Jardine & Selby, 1827)*		x	S	V	
Pachyramphus polychopterus (Vieillot, 1818)	x	x	P, Cp	A	
Pachyramphus marginatus (Lichtenstein, 1823)	x		P, S	V	
Pachyramphus minor (Lesson, 1830)		x	S	V, A	
Pachyramphus validus (Lichtenstein, 1823)	x	x	P	V, A	
Cotingidae Bonaparte, 1849					
Lipaugus vociferans (Wied, 1820)	x	x	P, Cp, S	A	
Gymnoderus foetidus (Linnaeus, 1758)*		x	P	V	
Xipholena lamellipennis (Lafresnaye, 1839)	x	x	P	F	1180204
Cotinga cotinga (Linnaeus, 1766)	x	x	P, S	F	1422358
Cotinga cayana (Linnaeus, 1766)*		x	P	V	
Haematoderus militaris (Shaw, 1792)	x		P	F	1080430
Querula purpurata (Statius Muller, 1776)		x	Cp	F	1081252
Pipritidae Ohlson, Irestedt, Ericson & Fjeldså, 2013					
Piprites chloris grisescens (Novaes, 1964) [EN]	x	x	P, Cp, S	V, A	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Platyrinchidae Bonaparte, 1854					
Platyrinchus saturatus Salvin & Godman, 1882*		x	P	V	
Platyrinchus platyrhynchos (Gmelin, 1788)*		x	P	V	
Rhynchocyclidae Berlepsch, 1907					
Taeniotriccus andrei (Berlepsch & Hartert, 1902)*		x	P	A	
Mionectes oleagineus (Lichtenstein, 1823)	x	x	P, Cp	A, Ca	
Mionectes macconnelli (Chubb, 1919)	x	x	P	Ca	
Tolmomyias sulphurescens Zimmer, 1939	x	x	P	V	
Tolmomyias flaviventris (Wied, 1831)	x	x	P, S	V	
Todirostrum maculatum (Desmarest, 1806)		x	P	V	
Todirostrum cinereum (Linnaeus, 1766)	x	x	P, Cp	V	
Todirostrum chrysocrotaphum illigeri (Cabanis & Heine, 1859) EN *	x	x	P, Cp	V, A	
Poecilotriccus fumifrons (Hartlaub, 1853)*		x	P	V	
Poecilotriccus sylvia (Desmarest, 1806)*		x	P	V	
Myiornis ecaudatus (d'Orbigny & Lafresnaye, 1837)*		x	P	V	
Hemitriccus striaticollis (Lafresnaye, 1853)	x		S	V	
Lophotriccus galeatus (Boddaert, 1783)	x	x	P, Cp	V, Ca	
Tyrannidae Vigors, 1825					
Zimmerius acer (Salvin & Godman, 1883)*		x	P, S, Cp	V, A,	
Ornithion inerme Hartlaub, 1853*		x	P	V	
Camptostoma obsoletum (Temminck, 1824)	x	x	Cp, S, B	A	
Elaenia flavogaster (Thunberg, 1822)		x	Cp	A	
Elaenia cristata Pelzeln, 1868*		x	Cp	A	
Myiopagis gaimardii (d'Orbigny, 1839)*		x	P, S	V,A	
Myiopagis viridicata (Vieillot, 1817)		x	Cp	A	
Tyrannulus elatus (Latham, 1790)*		x	S	V, A	
Phaeomyias murina (Spix, 1825)	x	x	P, S	A	
Attila spadiceus (Gmelin, 1789)	x	x	P	V, A	
Legatus leucophaius (Vieillot, 1818)	x	x	P, Cp, aa, B, S	A, F, V	1038926
Ramphotrigon ruficauda (Spix, 1825)*		x	P	V	
Myiarchus tuberculifer (d'Orbigny & Lafresnaye, 1837)*		x	P, S, Cp	V	
Myiarchus swainsoni Cabanis & Heine, 1859	x		S	A	
Myiarchus ferox (Gmelin, 1789)	x	x	P, Cp, S	A	
Myiarchus tyrannulus (Statius Muller, 1776)*		x	S	V, A	
Casiornis fuscus Sclater & Salvin, 1873	x		P	V	
Pitangus sulphuratus (Linnaeus, 1766)	x	x	Cp, aa, S	V, A	
Machetornis rixosa (Vieillot, 1819)*		x	aa	V	
Myiodynastes maculatus (Statius Muller, 1776)	x	x	Cp, aa	F	1030139
Tyrannopsis sulphurea (Spix, 1825)*		x	S,B	V, A	
Megarynchus pitangua (Linnaeus, 1766)	x	x	Cp, aa	A	
Myiozetetes cayanensis (Linnaeus, 1766)	x	x	Cp, B, aa	V, A	
Myiozetetes similis (Spix, 1825)	x	x	Cp	V, A	
Tyrannus melancholicus Vieillot, 1819	x	x	Cp, aa, B,S	V, A	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Tyrannus savana Vieillot, 1808*		x	S, Cp	V	
Empidonomus varius (Vieillot, 1818)		x	Cp	V	
Colonia colonus (Vieillot, 1818)*		x	P	V	
Myiophobus fasciatus (Statius Muller, 1776)*		x	S	V	
Fluvicola nengeta (Linnaeus, 1766)	x	x	Cp, B, aa	V	
Arundinicola leucocephala (Linnaeus, 1764)	x		B	V	
Lathrotriccus euleri (Cabanis, 1868)*		x	P, S	V	
Cnemotriccus fuscatus (Wied, 1831)*		x	S	V	
Contopus nigrescens (Sclater & Salvin, 1880)	x	x	P, S	F	1151531
Vireonidae Swainson, 1837					
Cyclarhis gujanensis (Gmelin, 1789)	x	x	Cp, aa, S	V, A	
Vireo chivi (Vieillot, 1817)	x	x	P, S	A	
Hylophilus semicinereus Sclater & Salvin, 1867	x	x	P, Cp, S	V, A	
Hylophilus pectoralis Sclater, 1866		x	Cp	A	
Corvidae Leach, 1820					
Cyanocorax cyanopogon (Wied, 1821)*		x	S, Cp	V	
Hirundinidae Rafinesque, 1815					
Stelgidopteryx ruficollis (Vieillot, 1817)	x	x	B, aa	V	
Progne tapera (Vieillot, 1817)	x	x	Cp, aa, B	V	
Progne chalybea (Gmelin, 1789)	x	x	aa	V	
Tachycineta albiventer (Boddaert, 1783)	x	x	B	V	
Troglodytidae Swainson, 1831					
Microcerculus marginatus (Sclater, 1855)*		x	S	Ca	
Troglodytes musculus Naumann, 1823	x		aa	V	
Campylorhynchus turdinus (Wied, 1831)		x	Cp	V	
Pheugopedius genibarbis (Swainson, 1838)	x	x	P, Cp, S	A, Ca	
Cantorchilus leucotis (Lafresnaye, 1845)		x	P	A	
Donacobiidae Aleixo & Pacheco, 2006					
Donacobius atricapilla (Linnaeus, 1766)	x		B	V	
Polioptilidae Baird, 1858					
Ramphocaenus melanurus austerus Zimmer, 1937 [EN]*		x	P, S, Cp	V	
Polioptila plumbea (Gmelin, 1788)	x	x	Cp	V	
Polioptila paraensis Todd, 1937*		x	S	V	
Turdidae Rafinesque, 1815					
Turdus nudigenis Lafresnaye, 1848*		x	P, S	V	
Turdus fumigatus Lichtenstein, 1823*		x	P, S	V	
Turdus leucomelas Vieillot, 1818		x	S	V, A	
Turdus amaurochalinus Cabanis, 1850	x	x	P, Cp	A	
Turdus albicollis Vieillot, 1818	x	x	P	A	
Passerellidae Cabanis & Heine, 1850					
Ammodramus humeralis (Bosc, 1792)	x	x	aa	V	
Arremon taciturnus (Hermann, 1783)	x	x	Cp, S	A, Ca	
Parulidae Wetmore & Zimmer 1947					

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Myiothlypis mesoleuca (Sclater, 1866)	x	x	P, Cp	A	
Icteridae Vigors, 1825					
Psarocolius viridis (Statius Muller, 1776)		x	S	V, F	1031543
Psarocolius decumanus (Pallas, 1769)		x	S, Cp	V	
Psarocolius bifasciatus (Spix, 1824)	x	x	P, S	V, A	
Procacicus solitarius (Vieillot, 1816)*		x	P, S	V	
Cacicus haemorrhous (Linnaeus, 1766)	x	x	P, Cp, S	V	
Cacicus cela (Linnaeus, 1758)	x	x	P, Cp	V, F	1037714
Icterus cayanensis (Linnaeus, 1766)	x	x	P, Cp	V	
Icterus jamacaii (Gmelin, 1788)		x	Cp	V	
Molothrus oryzivorus (Gmelin, 1788)		x	Cp, S	V	
Molothrus bonariensis (Gmelin, 1789)		x	B,aa	V	
Sturnella militaris (Linnaeus, 1758)	x	x	Cp, aa	V,F	1030127
Mitrospingidae Barker, Burns, Klicka, Lanyon & Lovette, 2013					
Lamprospiza melanoleuca (Vieillot, 1817)	x	x	P, S	F	1081284
Thraupidae Cabanis, 1847					
Coereba flaveola (Linnaeus, 1758)	x	x	Cp, S	V	
Saltator grossus (Linnaeus, 1766)*		x	P, S	V, A	
Saltator coerulescens Vieillot, 1817*		x	S, Cp	V	
Saltator maximus (Statius Muller, 1776)	x	x	Cp, S	V,A	
Parkerthraustes humeralis (Lawrence, 1867)*		x	P	V	
Nemosia pileata (Boddaert, 1783)	x		S	V	
Tachyphonus rufus (Boddaert, 1783)	x	x	P, Cp, S, B	V	
Ramphocelus carbo (Pallas, 1764)	x	x	P, Cp, S	V	
Lanio luctuosus (d'Orbigny & Lafresnaye, 1837)		x	Cp	V	
Lanio cristatus pallidigula Zimmer, 1945 EN		x	Ca	V	
Tangara mexicana (Linnaeus, 1766)	x		P	V	
Tangara velia signata (Hellmayr, 1905)* EN		x	P	V	
Tangara punctata (Linnaeus, 1766)	x		S	V	
Tangara episcopus (Linnaeus, 1766)	x	x	P, Cp, B, S	V	
Tangara palmarum (Wied, 1823)	x	x	P, Cp, S	V,F	1041465
Tangara cayana (Linnaeus, 1766)	x		Cp	V	
Cissopis leverianus (Gmelin, 1788)		x	Cp	V	
Dacnis lineata (Gmelin, 1789)*		x	P	V	
Dacnis cayana (Linnaeus, 1766)	x	x	P, Cp, S	V	
Cyanerpes caeruleus (Linnaeus, 1758)*		x	P, S		
Cyanerpes cyaneus (Linnaeus, 1766)	x	x	P, Cp,S	V	
Chlorophanes spiza (Linnaeus, 1758)		x	P, S, Cp	V	
Hemithraupis guira (Linnaeus, 1766)	x	x	P, Cp, S	V	
Conirostrum speciosum (Temminck, 1824)		x	P, S	V	
Emberizoides herbicola (Vieillot, 1817)	x	x	aa	V	
Volatinia jacarina (Linnaeus, 1766)	x	x	aa, B, Cp	V	
Sicalis columbiana Cabanis, 1851*		x	Cp, aa	V	

Taxon	Zoning		Habitats	Type of record	Photo Ref. WA:
	Zd	Zr			
Sporophila lineola (Linnaeus, 1758)	x	x	aa	V	
Sporophila nigricollis (Vieillot, 1823)	x	x	aa, B	V	
Sporophila bouvreuil (Statius Muller, 1776)	x		aa	V	
Sporophila minuta (Linnaeus, 1758)	x		B	F	1027698
Sporophila angolensis (Linnaeus, 1766)	x	x	Cp, aa, B	V	
Cardinalidae Ridgway, 1901					
Granatellus pelzelni paraensis Rothschild, 1906 EN	x	x	P, Cp, S	A, Ca	
Caryothraustes canadensis (Linnaeus, 1766)	x	x	P, Cp, S	F	1043126
Cyanoloxia rothschildii (Lafresnaye, 1847)*		x	S, Cp	V	
Fringillidae Leach, 1820				V	
Euphonia chlorotica (Linnaeus, 1766)	x	x	P, Cp, S	V	
Euphonia violacea (Linnaeus, 1758)	x	x	P, Cp	A	
Euphonia cayennensis (Gmelin, 1789)*		x	P	V	

Vulturine Parrot (*Pyrilia vulturina*). An individual was photographed in November 2011 by D. M. L. (Lima 2011a). The species was recorded in an area of continuous primary forest. *Pyrilia vulturina* is endemic to eastern Amazon (lower Amazon), with other recent records in the Belém CE by Portes *et al.* (2011) and Oren & Roma (2011). Due to habitat loss the species was assessed globally by the IUCN (2014) as vulnerable of extinction.

White-winged Potoo (*Nyctibius leucopterus*). C.M. held a single sighting, from December 10th, 2010. The bird was found around 1 km NW from the ICMBio station, in the southern border of the Reserve. As far as we know, this is the first report for this species in Maranhão. The observation took place at around 20:00 hs, during a nocturnal spot lighting, and the bird was perched in the usual attitude for the species of *Nyctibius*, in a primary *terra firme* forest. The bird remained perched, and could be observed for several minutes, under the spot-light, and using binoculars. The diagnostic large white patch on wing coverts could be observed under optimal conditions.

Red-necked Aracari (*Pteroglossus bitorquatus bitorquatus*). The species was recorded at base camp of the Gurupi REBIO consuming papaya (registration by D. M. L). This is a disturbed area with forest regeneration in advanced stage. It was also recorded in the recovery zone with predominant secondary vegetation and plenty of *Cecropia* spp. (Lima 2012c), as well as in the undisturbed zone where it was sighted consuming the fruits of a Sapotaceae of the genus *Pouteria* sp. The species is common in the reserve area and its surroundings. The species is distributed in lowland forests from the right bank of the Tocantins River through northern Maranhão, and according to Silveira (2008b) it would likely occur in the Gurupi REBIO. This is the first documented record of the species inside the reserve. However, it is relatively common in the whole area and in preserved forest remnants in neighboring localities.

White-chinned Woodcreeper (*Dendrocincla merula badia*). The first record of this species at REBIO Gurupi was documented by Lima & Raíces (2012). During the survey the species was recorded only in the undisturbed zone of the protected area, where the vegetation is characterized as dense rainforest, with a continuous canopy (D. M. L). The species was sighted foraging alongside army ants in the undersrtorey. This subspecies is endemic to the Belém CE, occurring east of the Tocantins river into Amazonian Maranhão (Aleixo 2008a). The species is considered endangered at both national (MMA 2003) and state (Pará) levels (COEMA 2007).

Todd's Woodcreeper (*Dendrocolaptes medius*). This species was recorded both in primary forest and *capoeira* (secondary forest) inside the reserve (registration by D. M. L). According to Aleixo (2008b) the species can often be found in upland forests, floodplains and forest in an advanced stage of succession. According to the list of species of Brazilian fauna threatened with extinction (MMA 2003), the species is endangered under the same category of threat as in the state of Pará (COEMA 2007).

Black-spotted Bare-eye (*Phlegopsis nigromaculata paraensis*). The species was recorded foraging solitarily in primary forest and forest in advanced stage of succession inside the reserve (D. M. L). Aleixo (2008c) reports that this species may forage alone, in pairs, or family groups. Apparently, the species is more tolerant to fragmentation and degradation of forest structure than other species associated with army ants (Aleixo 2008c). This explains the presence of the species in forest at advanced stages of regeneration, which suffered from selective logging.

Blackish Pewee (*Contopus nigrescens*). D.M.L. and C. M. observed this species on five occasions during the present study in an area of primary forest in the recovery zone, and in the undisturbed zone. On all occasions, a solitary individual was observed perched in the middle stratum of the forest, engaging in flying forays during which it captured insects on the wing, a typical behavior of this genus. D. M. L. photographed the species in December 2011 (Lima 2011b) where the diagnostic overall uniform dark sooty-gray plumage, dark head, neck and upper parts, blackish-brown wings, blackish tail (sooty gray below) and slightly paler throat could be easily noticed. Sick (1997) reports that the species is rare, with a patchy distribution in the eastern Andes, and in the Acary Mountains of Guyana, for example. In Brazil, the species is known from specimens collected at Itupiranga, Pará (specimens housed at *Museu de Zoologia da Universidade de São Paulo* – MZUSP number 64232), and from observations in the Serra dos Carajás, and one sighting in the area of the Pindaré River, Maranhão, in November, 1977 (Ridgely & Tudor 1994). The species was recently recorded in the Carajás National Forest by Aleixo *et al.* (2012), but was not registered by Oren & Roma (2011), Portes *et al.* (2011) or Lees *et al.* (2012) for the Belém CE. C. M. has also recorded the species several times from a site near Açailândia.

Crimson Fruitcrow (*Haematoderus militaris*). D.M.L. recorded this species on August, 2012. A male perched on a tree was photographed from a distance (Lima 2012d) in an area of primary forest surrounded by secondary growth. This species is considered to be rare, and is probably sensitive to habitat fragmentation and disturbance (Lees *et al.* 2012).

Actions for conservation

The REBIO Gurupi is the only integral protection conservation unit located within the Belém CE, which encompasses the most impacted region of the Brazilian Amazon basin, located between eastern Pará and western Maranhão. This reserve is even more significant in the local context of the Amazon sector of Maranhão, where forest cover has been reduced to less than 25% of the original area (Martins 2011). This whole region, including the REBIO Gurupi, is suffering from the ongoing expansion of the Arc of Deforestation, which is converting forest into pasture at an alarming rate, reducing the once continuous forest to a series of fragments.

One of the major bottlenecks hindering the conservation unit from fully realizing its goal of preserving the flora and fauna within its limits is non-sustainable illegal occupation. For decades REBIO Gurupi has been occupied by irregular settlements approved by government agencies and by squatters (Lima & Raíces 2012); this occupation has resulted in the raising of livestock and has stimulated illegal logging. According to the latest land survey of the reserve, there are roughly 6,306 people living within REBIO Gurupi (ESTRUTURAL 2007).

Actions that can minimize the loss of habitat and hunting of the local avifauna have been performed, for example: demarcation of the unit, judicial direction to begin proceedings for land compensation, creation of an advisory board, and drafting terms of commitment for settlers. Furthermore, an institutional presence has been established in the form of two operational field bases with full-time policing, as well as instruction in administrative processes for the removal of cattle from inside the reserve. At the time of the study, approximately 3,500 heads of cattle were removed from inside the reserve (E.A. Lisboa *pers. comm.*).

Given that much of the Gurupi reserve has been impacted by illegal logging, in addition to the areas cleared for pastures and other land use, there is an urgent need for the development of a reforestation project, which will guarantee the connectivity of habitats, especially for those species that require large tracts of continuous forest for their survival. These species include the members of the Cracidae, in particular *Crax fasciolata pinima*, which was reported by local residents to still occur in the region, and may in fact be held in captivity in some households.

The presence in the reserve of seven endangered species, and two others (*Harpia harpyja* and *Pyrilia vulturina*) that are likely to be included in the Brazilian list of threatened species in the near future, reinforce the need for the establishment of a continuous research program for the REBIO Gurupi, with the aim of providing effective conservation measures that can be implemented by the unit's administrators and partner institutions. In particular, the confirmation of the occurrence of *Crax fasciolata pinima* in the reserve and adjoining indigenous reservations, is a major research priority.

Surrounding the unit grows the demand for permits to implement plans for selective logging and vegetation removal. Therefore, it is important that the National Action Plan for the Conservation of Endangered Species of the Amazon is enforced since it contains the regulatory instructions and resolutions governing the environmental licensing procedures. As such, environmental agencies are legally required to heed protocols that establish conditions and procedures for protection, for example, of trees that present nests of *Harpya harpyja* and *Guaruba guarouba*; as well as to promote the recovery of degraded areas.

New formats for the planning and execution of inspection activities have been carried out, providing an intelligence service aimed at disrupting illegal logging. Another aspect strengthening enforcement actions is the publication of the term of reciprocity between the

Public Security Bureau of Maranhão and the Chico Mendes Institute for Biodiversity Conservation, since the agreement fosters the training of law enforcement agents and police support staff in the field to identify any species that are targeted for trafficking or hunting, as well as the development of allocation protocols for *Crax fasciolata pinima*, *Pteroglossus bitorquatus bitorquatus*, *Psophia obscura*, *Guaruba guarouba*, *Pyrrhura lepida lepida* and *Harpya harpyja*.

Public policy actions, along with the participation of civil entities, in the commitment to protect and conserve the Amazonian forest fragments existing in the REBIO Gurupi and indigenous lands with their surrounding areas have strengthened the implementation and consolidation of the conservation unit. The high number of endemic and endangered species identified in the reserve reinforces its importance for conservation. It is essential to continue all efforts by the federal government to implement these actions specific to the unit, established as effective and efficient tools for the full compliance of the conservation unit's original mission.

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APPENDIX

Species of relevant biogeographical interest, for which we obtained only isolated and undocumented records. We recommend that they are added to the REBIO Gurupi checklist whenever material evidence such as digital or specimen vouchers are obtained.

Species
Tinamus guttatus
Porzana flaviventer
Phaethornis maranhaoensis
Chlorostilbon mellisugus
Myrmornis torquata
Synallaxis frontalis
Myiobius barbatus
Elaenia chiriquensis

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ARTICLE

Breeding biology of the White-collared Swift *Streptoprocne zonaris* in southeastern Brazil

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ABSTRACT: White-collared Swifts *Streptoprocne zonaris* are common throughout the tropical Americas. They usually breed in colonies in wet caves and next to waterfalls. Despite their widespread range, little is known about their breeding biology. Here I present data gathered from 2012 to 2014 at two breeding sites, Luminosa Cave and Água Comprida waterfall, located within Intervales State Park, in the state of São Paulo, Brazil. More than 30 nests were found in the cave and one behind a waterfall. The egg-laying period began in late October and lasted until the first week of November. Nests were made mostly of bryophytes, with some fresh and dry leaves and sand. Eggs were dull white, and had an oval shape. Nestlings per nest varied from 1 to 3. The fledging period was between 41-51 days. This is the first record for this species of a successful nest with 3 nestlings. The species showed high nest site fidelity. Plumage development was similar to other species in the genus.

KEY-WORDS: Apodidae, caves, nest, nestlings, *Streptoprocne*.

INTRODUCTION

The White-collared Swift *Streptoprocne zonaris* is a common species with a wide range throughout the Americas, occurring from South Mexico to the southern Andean highlands (Chantler 1999). In Brazil, it has been recorded from Amazonas to Rio Grande do Sul. One of the largest known concentrations of the species is in Aripuanã, Mato Grosso, where, together with Great Dusky Swifts, *Cypseloides senex*, they form a colony of more than one million individuals (Sick 2001, De Luca *et al*. 2009).

Adult White-collared Swifts have a distinctive black and brown plumage with a clear white collar circling the entire neck (Sick 2001). Like other swifts of the Cypseloidinae subfamily, White-collared Swifts breed near waterfalls, in canyons and wet caves in large colonies and show high nest site fidelity (Lack 1956, Rowley & Orr 1965, Whitacre 1989, Marín & Stiles 1992). They forage in large flocks, and it is common to see mixed groups with Biscutate Swifts, *Streptoprocne biscutata*, other *Cypseloides* and *Chaetura* spp., and Neotropical Palm Swifts, *Tachornis squamata* (Pichorim 2002, Chávez-Portilla *et al*. 2007, Pearman *et al*. 2010). Although its range is well documented and the species is relatively common in this country, there is a lack of information on its breeding biology in Brazil and in South America, with few reliable records (Marín & Carrión 1994, De Luca *et al*. 2009, Passeggi 2011).

The objective of this work is to describe the nests, eggs and nestlings of White-collared Swifts based on observations conducted between December 2012 and February 2014 at two breeding sites in a fragment of Atlantic rainforest in southeastern Brazil.

METHODS

The study was conducted between March 2012 and February 2014 at two sites, Luminosa Cave and Água Comprida waterfall, both located in Intervales State Park (ISP), municipality of Ribeirão Grande, São Paulo, Brazil (24º12' / 24º25'S and 48º03' / 48º30'W). The climate is classified as Cfb in Koppen's International System and the rainy season lasts from late October to March (Koppen 1948, Furlan & Leite 2009).

Luminosa Cave is a limestone cave located within the buffer zone of ISP. It has three entrances: one is a large opening at the top, resembling a skylight, from where water drips down, and two others at the entrance and the exit of Lajeado River that cascades over an approximately 7 m high vertical cliff and flows into the cave. It has variable luminosity conditions throughout the day, but the innermost area remains dark. The floor is composed of piled rocky blocks and boulders, sand, leaves and guano. Just next to the cave's riverside entrance, on the left side, a high rock wall is used by the swifts to roost.

Água Comprida waterfall is a small waterfall, approximately 4 meters high, formed by the Água Comprida River. On the left side of the falls there is a rock wall covered with moss where both White-collared Swifts and Sooty Swifts, *Cypseloides fumigatus* are known to breed and roost.

Active nest searching and monitoring was conducted in March and December 2012 (10 h of observation), from January to March 2013 (16 h) and from October 2013 to February 2014 (51 h). Visits both to the cave and the falls were made throughout the day (7 – 10 h; 14 – 17 h) and at three occasions at night (20 – 23 h). Direct observations of adults and chicks were made with Nikon Monarch 8 x 42 binoculars. A ladder and flashlights were used to access the nests. Measurements were taken with digital calipers, measuring tapes and 100g (+- 1 g) Pesola spring scales. Photographs were taken with Canon Rebel XSi, T3i and PowerShot SX50 cameras, Sigma 150-500 lens and with an IPhone 4S mobile phone.

RESULTS

The breeding season of the White-collared Swift lasted from mid-October to early January. Luminosa cave nests were concentrated in four distinct areas, many of which did not receive any direct sunlight. Most nests were isolated from each other by natural barriers such as openings, stalactites or vertical walls that barred any possible movement of offspring from one nest to another. More than 30 nests were found in Luminosa Cave between the 2012 and 2013 breeding seasons, but most were inaccessible. Only 25 nests were monitored (Table 1). The most accessible nest measured: inside diameter 12 cm, outside height 7 cm, internal depth 1.4 cm and height above ground 1.7 m.

In Água Comprida waterfall, I found a single White-collared Swift nest. Nest measurements taken in 2013 were: external diameter 17.5 cm, inside diameter 14 cm, outside height 13.5 cm, internal depth 1.8 cm and height above ground 2.7 m. It was built on a rock wall that had no protection from direct sunlight. It was directly exposed to spray from the waterfall and was located above a Sooty Swift nest. During nocturnal visits, two adult White-collared Swifts were observed roosting next to their nest.

These observations revealed variations in the shape of White-collared Swift nests. While Luminosa Cave nests were disk-shaped and positioned on horizontal rock shelfs and ledges, with a much shorter mud base, the Água Comprida waterfall nest was truncated and cone-shaped and built on a vertical rock wall, with a solid mud base. Nests were made of bryophytes, along with some roots, fresh and dry leaves of angiosperms, ferns, sand, and mud. Fresh material was continuously added to the nests during the incubation period. Although some nests looked ready to use, they remained empty, with no signs of incubating adults or eggs. At the end of the season, when most nestlings had fledged, nests in Luminosa looked completely different from their original shape, and many were reduced to just a thin layer of sand. The opposite was observed in the Água Comprida nest, which was almost intact and the moss that covered the exterior part was fresh and green, both in the 2012/2013 and 2013/2014 breeding seasons.

Two oval shaped eggs were found and measured (egg 1: 13g, 37 x 25 mm; egg 2: 12 g, 35 x 26 mm). One was larger than the other, and also exhibited a mud-stained coloration while the other was dull white.

Adults were observed in their nests incubating at the beginning of the egg laying period in mid October and would remain in the same position for long periods. Many broken egg-shells were found on the ground near the nesting walls during the egg laying period. No attempts were made to replace lost eggs or nestlings. One clutch was laid per nest per reproductive season.

Nestlings per nest varied between 1 (n = 9), 2 (n = 16) and 3 (n =1). I did not observe any newly hatched chicks. Nestlings were active and many were clinging to the rock wall, seemingly curious with the flashlights. On the same day I found a single nest in Água Comprida waterfall with two chicks. Their bodies were covered with semiplumes and they left their nest within the difference of a day, between January 5th and 6th 2013, and were observed roosting on the rock wall below their nest two weeks later, during an afternoon visit. On November 25th 2013, a chick was observed together with an adult in Água Comprida waterfall. It had its body covered with a thin layer of gray semiplumes. On December 18th the nest was empty.

I was able to follow the development of six nestlings during the 2013/2014 breeding season. On November 25th 2013 two nestlings were observed (Figure 1). Determining the age of nestlings was based on our previous observations of the nest with two eggs on November 15th 2013 and by comparisons with more detailed data for the species. Nestlings were assumed to be between 6-10 days old. Both had pink skin with short light gray semiplumes on the mantle and on the rump. On the crown and on the coverts the semiplumes were just emerging from the skin. Feet were large and pinkish with dark gray nails. An egg tooth was visible on the point of the beak with a pinkish commissure. Only one of the nestlings had its eyes open. Both were lethargic, simply resting their heads on the nest's rim. Two broken eggs shells were found on a rock 1 m below it. The nest was covered with fresh green moss and mud and two fecal sacs were observed in the back. When 11-15 days old, the nestlings were more active.

FIGURE 1. Chronology of White-collared Swift nestlings: A: with 6-10 days; B: with 11-15 days; C: with 19-23 days; D: with 22-26 days; E: with 23-27 days; F: with 26-30 days; G: with 29-33 days; H: with 34-38 days. Photos: A, B, D, G, H: Renato Paiva; C, E, F: Renata Biancalana.

TABLE 1. Fates of eggs and nestlings of the White-collared Swift found at Intervales State Park in 2012 and 2013. Whenever information on eggs is lacking for active nests during a given year, their content at the time could not be visually inspected.

Nest Number	Usage		Eggs		Fledglings	Event
	2012	2013	Laid	Hatched		
Água Comprida waterfall						
N1	+				2	
		+	2	1		Disappeared
Luminosa Cave						
N1	+				2	
		+		2	2	
N2	+				1	
		+			2	
N3	+				1	
		+	1	0		Disappeared
N4	+				1	
N5	+				2	
N6	+				1	
		+			2	
N7	+				1	
		+	2	2	2	
N8	+				2	
		+	2	2	2	
N9	+				2	
		+	2	2	2	
N10	+				2	
		+			2	
N11	+				2	
		+			3	
N12	+				1	
		+	2	2	2	
N13	+				1	
		+	2	2	2	
N14		+			1	

Their bodies were covered with a thicker layer of light gray semiplumes, with a bare strip near the abdomen. The feet were darker, with a grayish coloration. In the loral area and around the beak many tiny spots of feathers in pin could be seen. The beak was dark gray. The eyes were black and opaque blue. From this day onwards, the nest became increasingly dry and exhibited a less muddy aspect. When 19-24 days old their bodies and heads were covered with semiplumes, with the coverts covering part of the wings and primaries and secondaries breaking the sheaths. Tail feathers were growing and exhibited pointy shafts. Chicks used to be very vocal when approached and handled, emitting a sequence of high-pitched "pee-pee-pee" squeals. Nestlings would occasionally peck each other on the head and on the back. When they were 22-27 days old, the primaries were growing and the all-surrounding white collar was not yet completely formed. Semiplumes were visible on the neck, mantle, nape and flanks. The head was covered with feathers. There was a bare area on the eye patch with tiny feathers in pins coming out. When 26-31 days old, the head and body were covered with contour feathers with semiplumes still visible on the flanks, mantle and axillaries. With 29-34 days, the nape and mantle were covered with semiplumes, with a few feathers emerging from the sheaths. Semiplumes were visible on the flanks. Lesser coverts and the alula had feathers with thin whitish tips. Primaries and upper tail coverts also had pale border markings. When 32-37 days old, the body was largely covered with contour feathers and semiplumes were only visible on the flanks. When the nestlings were 37-42 days old, their body was fully covered with contour feathers and it was possible to observe the completed white neck collar and a light white patch on the chest. Semiplumes were still visible only on the thighs and on the flanks. One of the nestlings was out of its nest, resting on a rock 1 m below it. On December 30th, the nest with two nestlings was empty, with no signs of the fledgings. Insect fragments were found next to all nests; it was not possible to determine if they had been present in excrement or had been dropped during chick provisioning.

An unusual nest with 3 chicks was discovered on December 8th 2013. The three chicks were covered with a thick layer of semiplumes. They were very active and exhibited a wing raising display when approached. On

December 11th, the chicks already exhibited white feathers on the nape, but they were different with regard to their body size and feather development. Two of them had their heads covered with contour feathers, whereas the third still had semiplumes showing on its crown. Nestlings left the nest within a space of 5 days. The first left between January 3rd and 6th 2014, and the second and the third between January 6th and 8th (Figure 2). The nest was monitored until all three nestlings fledged.

On February 13th 2014 we observed a large amount of feathers and droppings, mostly a combination of insect fragments and guano, on the cave floor.

Adults were observed flying in and out of Luminosa Cave all day long, and could be seen at night on the roost wall, next to the cave's entrance. When clinging on the wall, they would occupy themselves with preening activities, raising their wings and turning their heads towards each other. They were very active and vocal.

Large flocks of White-collared Swifts, sometimes with more than 100 individuals, were observed foraging mostly during cloudy and stormy afternoons. When leaving or entering the cave or flying over a gorge they would begin voicing loud harsh calls. They were also observed foraging with Sooty Swifts but in smaller groups.

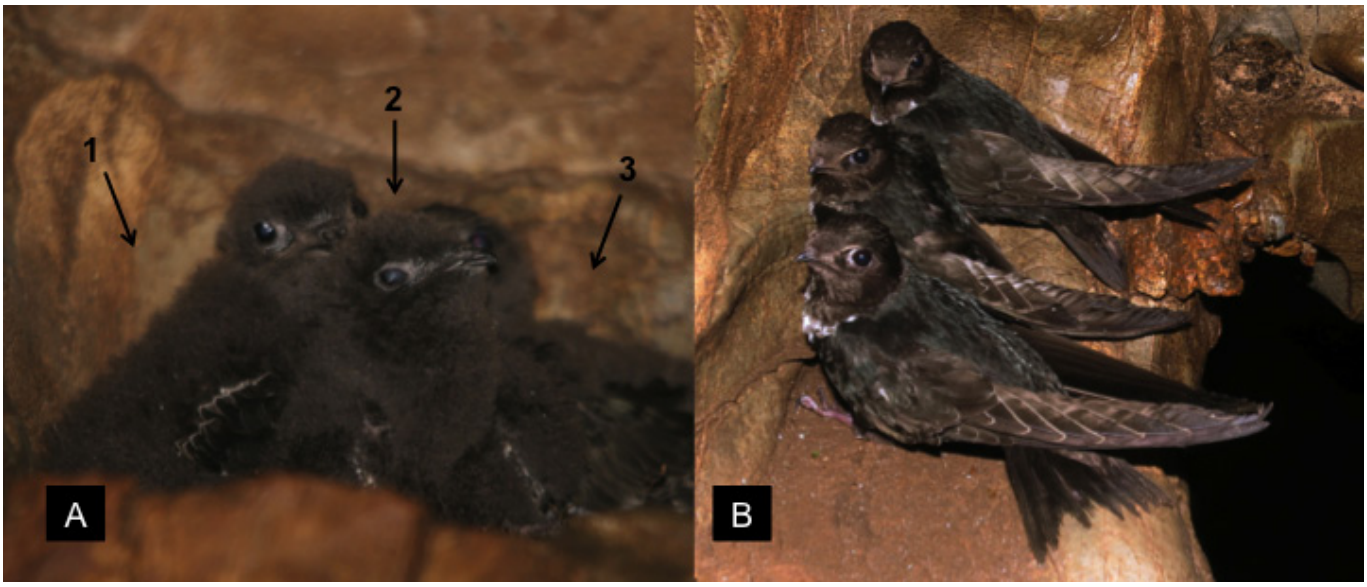

FIGURE 2. Nest with three nestlings: A. On December 8th 2013, when I discovered the nest; B. On January 3rd 2014, the last time they were seen together. Photos: A. Renata Biancalana; B: Renato Paiva.

DISCUSSION

Breeding activity started in mid-October. Egg-laying occurred at the beginning of the rainy season, the same period described for the species in Argentina (Passeggi 2011). The presence of broken eggs on the cave floor was noted by other authors for White-naped, *S. semicollaris*, Biscutate and White-collared Swifts and was analyzed in different ways. Some thought it was the result of accidental ejections, while others attributed these findings to nest disputes, brood parasitism or even from the intentional riddance of infertile eggs (Lack & Lack 1951, Rowley & Orr 1965, Pichorim 2002). Whitacre (1989) states that egg rolling would also be a main cause of reproductive failure of White-naped Swifts in Mexico. Pichorim & Monteiro-Filho (2008) even considered egg ejection as a means of possible brood population control by adults, depending on the foraging conditions they might face. Hotta (1994) suggests that egg ejection occurs as a consequence of severe competition for nests, which are a valuable asset since they last for many years and are costly in time and energy to construct.

Nests were similar in shape and the materials used to those described in previous studies (Rowley & Orr 1965, Whitacre 1989, Marín & Stiles 1992, Marín & Carrión 1994). Many Luminosa nests were far from waterfall spray and were located in drier areas of the cave, which is different from what is described by some authors as the typical position for the nests of this species (Chantler 1999).

Like other species of the Cypseloidinae subfamily, White-collared Swifts showed high nest site fidelity, reusing the same niches and crevices in the cave and even the same structure of previous nests, in the falls. This agrees with previous observations (Marín & Stiles 1992). After carefully looking at and comparing the pictures of nests both at the beginning and at the end of the breeding season, it was possible to observe that all nests at Luminosa Cave collapsed and were transformed into a thin layer of sand, probably due to the movements of nestlings and the decomposition of plant material in a dark environment. This suggests that Luminosa Cave nests are rebuilt at the beginning of the rainy season each year. On the other hand, the nest in Água Comprida contained live moss

and was left almost intact during the whole year. The large structure of some nests is probably due to material accumulation during several years of use. The proximity of White-collared Swift nests to other Cypseloidinae species breeding at the same site was also observed in Argentina by Pearman *et al*. (2010), with the difference that in Água Comprida waterfall two more nests of Sooty Swifts were located higher than that of White-collared Swifts.

Eggs were similar to those detailed in other studies, regarding coloration and measurements, although the eggs found were more oval-shaped than the sub-eliptical form described in previous papers (Passeggi 2011, Dabbene 1918, Marín & Carrión 1994). Clutch size was similar to that observed in Mexico, Costa Rica and Argentina, except for the single nest with three chicks (Whitacre 1989, Marín & Stiles 1992, Passeggi 2011). Plumage development chronology resembled that described by Pergolani (1944) in Argentina, by Marín & Stiles (1992) for White-collared Swifts in Costa Rica. Nestlings were accompanied by an adult until they were covered with a thick layer of semiplumes, usually during the three first weeks. Similarly to what was discussed for *Cypseloides* spp., the presence of an adult can be analyzed as a way of providing smaller nestlings with thermal protection from the cold environment in which the nest is located, either a cave or next to a waterfall (Marín & Stiles 1992). During the weeks that followed older chicks would remain alone for several hours and probably were fed at night as observed for other Cypseloidinae species (RNB *pers. obs*.; Collins 1998, Collins & Peterson 1998). Fledgings left the nest between 41-51 days, similar to what was observed in Costa Rica and Argentina (Marín & Stiles 1992, Passeggi 2011). The wing raising display is an agonistic behavior commonly observed in species of the Cypseloidinae and was noted right from the tender age of nestlings (Marín & Stiles 1992, Marín 1997, Chantler 1999).

The large amount of feathers found on the cave floor a few weeks after the last fledgings left their nests suggests that adults might begin molt immediately after the breeding period. After that, the number of swifts that use the cave diminishes, as they probably migrate to unknown sites assumingly with better foraging conditions.

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ARTICLE

A *Cerrado* bird community in the northernmost portion of northeastern Brazil - recommendations for conservation

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ABSTRACT: The *Cerrado* is the largest savanna in South America and it is rich in fauna and flora and considered a biodiversity hotspot. Its contact with the surrounding Amazon, Atlantic Forest and *Caatinga* is irregular, forming large diffuse ecotones in some regions and disjointed patches in others. The *Cerrado* patches located in the Amazon are relatively studied, but little is known about those in the Atlantic Forest and *Caatinga*. This article presents information on the composition of a bird community in a savanna formation on the coast of the northernmost portion of northeast Brazil (5°23'25"S / 35°30'25"W). This site was visited 17 times between October 2006 and August 2013. The total richness was 87 species distributed into 32 families. The following *Cerrado* endemics were recorded: *Charitospiza eucosma* and *Porphyrospiza caerulescens*. Other species recorded associated mainly with the *Cerrado* biome were *Heliactin bilophus*, *Cypsnagra hirundinacea* and *Coryphaspiza melanotis*. Some vulnerable and near threatened species were also recorded for the first time in the northernmost portion of northeastern Brazil, with some of these more than 1,000 km from their previously known localities. The results broaden the knowledge on the distribution of various species, in addition to providing information on seasonality and reproduction of others and revealing an overall lack of information on the composition of avian communities in little studied areas of Brazil.

KEY-WORDS: *Charitospiza eucosma*, *Coryphaspiza melanotis*, *Cypsnagra hirundinacea*, *Porphyrospiza caerulescens*, Rio Grande do Norte, threatened species.

INTRODUCTION

The *Cerrado* is the largest savanna in South America, encompassing approximately 1.8 million km² of its central part (Oliveira-Filho & Ratter 2002, Silva & Santos 2005). It is rich in fauna and flora and considered a biodiversity hotspot (Mittermeier *et al.* 1999, Silva & Bates 2002, Klink & Machado 2005, Proença *et al.* 2010). It has undergone rapid transformations primarily due to increased agriculture, with only 20% of the original area still intact (Myers *et al.* 2000, Ritter *et al.* 2010). The evolution of its biota was influenced by the expansion and retraction of forest caused by past climatic changes (Prado & Gibbs 1993, Pennington *et al.* 2000, Prado 2000, Fernandes 2003), where gallery forests played a key role in dispersing and altering biodiversity (Rodrigues 2005, Silva & Santos 2005). The current result is a complex region of dry and humid forests, arboreal savannas, bushy areas and fields (Eiten 1993, Ratter *et al.* 2003). Its contact with the surrounding Amazon, Atlantic Forest and *Caatinga* is irregular, forming large diffuse ecotones in some regions and disjointed patches in others (Eiten 1972, Capobianco *et al.* 2001). Islands of *Cerrado* in the Amazon contain relatively well studied avifauna (*e.g.,* Silva *et al.* 1997, Brace *et al.* 1997, Henriques & Oren 1997, Sanaiotti & Cintra 2001, Aleixo & Poletto 2007, Mittermeier *et al.* 2010), but little is known about isolated *Cerrado* areas in the Atlantic Forest and *Caatinga*. In northeastern Brazil savanna formations occur at low altitudes near the coast (Castro 1999, Sarmento & Soares 1971, Tavares 1988, Oliveira-Filho & Carvalho 1993, Figueiredo 1989, Costa *et al.* 2004, Oliveira *et al.* 2012). These areas have received scant attention in terms of conservation and biogeographic investigation, and are currently significantly impacted. This article presents information on the composition of bird communities in a savanna formation on the coast of

the northernmost portion of northeast Brazil and discusses the need for conservation. In the area that we studied we confirmed the presence of birds endemic to the *Cerrado* and threatened with extinction, broadened the knowledge on the distribution of other taxa and suggested biogeographic studies to better understand the current distribution of *Cerrado* forest patches on the northeast coast of Brazil.

METHODS

The main sampling site (5º 23' 25" S and 35º 30' 25" W) is located near Punaú in the township of Rio do Fogo. We investigated an area within a 10 km radius, encompassing the cities of Pureza and Touros in Rio Grande do Norte state, northeastern Brazil (Figure 1). This consists of a flat area (~30,000 ha) near the coast at an altitude ranging between ~30 and 100 m in the east-west direction. The soil is sandy and derived from the *Barreiras* Group formation (IDEMA 2002). The vegetation is primarily herbaceous/sub-bushy, harboring species of the families Poaceae, Fabaceae, Cyperaceae, Rubiaceae and Convolvulaceae, with sparse bushy-arboreal components composed of Fabaceae, Myrtaceae, Chrysobalanaceae and Rubiaceae, where genera often associated with *Cerrado* vegetation are found (*e.g.*, *Byrsonima*, *Eugenia*, *Anacardium*, *Erythroxylum* and *Tocoyena*) (Oliveira *et al.* 2012).

Between October 2006 and August 2013 we visited the area 17 times (2006 - 9, 20-21, 28-29 Oct, 11-12 Nov, 21 Dec; 2007 - 17 Jan, 1 May, 10-11 Aug, 10-11 Nov; 2008 - 1-2 Mar, 16 Aug; 2009 - 1-2 May, 15-16 Aug; 2012 - 10 Jun; 2013 - 21 Apr, 9-11 Aug, 16 Nov). We used conventional bird survey methods (active search, playback, listening points and occasional mist nets). The observations were made through binoculars (10 x 42), scope (60 x), and a camera fitted with a 500 mm lens. We also recorded a number of songs and calls with a Marantz PMD-661. The number of individuals sighted, type of recording (audio or visual) and signs of reproduction such as nests and/or immature birds being fed by their parents were also registered. We concentrated the surveys in the *Cerrado*, with marginal investigations in the lagoons and gallery forest. The taxonomy and nomenclature of the species follow *Comitê Brasileiro de Registros Ornitológicos* (CBRO 2014).

RESULTS

We recorded 87 bird species distributed into 32 families, Tyrannidae being the most represented (15 species) followed by Thraupidae (11 species) (Appendix). As endemic *Cerrado* species we recorded *Porphyrospiza caerulescens* and *Charitospiza eucosma* (following Silva 1997, Silva & Santos 2005). Other species distributed mainly in the *Cerrado* region were *Heliactin bilophus*, *Cypsnagra hirundinacea* and *Coryphaspiza melanotis*. These records are the first in the northernmost portion of northeastern Brazil. Some of these are distributed more than 1,000 km from their previously known localities. Among the species recorded, *Coryphaspiza melanotis* is considered vulnerable and *Charitospiza eucosma* as near threatened (BirdLife International 2014). All these species were recorded in an open physiognomy *Cerrado* with herbaceous or sub-bushy vegetation characterized mainly as Poaceae, Fabaceae, Cyperaceae (Figure 2, see Oliveira *et al.* 2012). The details of the most important records are described below.

Peach-fronted Parakeet - *Eupsittula aurea*. Recorded on 29 October and 21 December 2006, and 11 November 2007. On all occasions we saw two specimens in flight and vocalizing. This species is mainly recorded in southeastern and central Brazil, Paraguay and Bolivia (Stotz *et al.* 1996). In the *Caatinga* it occurs marginally, mainly in transition areas with the *Cerrado* (Pacheco 2004, Santos 2004, Vasconcelos *et al.* 2012, Schunck *et al.* 2012). It has recently been recorded along a thin strip of the northeast coast from Bahia to Pernambuco (WikiAves 2014), and there are two records on the south coast of Rio Grande do Norte (Duarte 2013, Silva 2011). Our records extend the distribution of the species ~150 km northwards. We did not observe any sign of reproduction in the area, but on 16 May 2009 we witnessed a young specimen being sold at a street fair in the city of Macaíba, near Natal, Rio Grande do Norte. The species is listed under CITES Appendix II and has been heavily traded (BirdLife International 2014).

Horned Sungem - *Heliactin bilophus*. Recorded on 21 October and 12 November 2006 and 17 January 2007. Only one male was sighted on each occasion. This species is common in central Brazil, extending to Bolivia in the west (BirdLife International 2014), but there have been recent records on the coast of Bahia, Sergipe and Paraíba (Lima & Buzzetti 2006, Sonntag 2011, Mendonça 2013, Silva 2013). Our records extend the distribution of the species ~200 km northwards.

Rusty-backed Antwren - *Formicivora rufa*. Recorded on 13 occasions between 2006 and 2013 in January, March, May, August, October and November, where at least one couple was observed (Appendix). On 5 May 2009 we observed a couple followed by a possible fledgling, indicating the breeding period in the region. This species occurs mainly in central and southeast Brazil, Bolivia, Paraguay and some disjunct populations around the Amazon (BirdLife International 2014). There are also some recent records along the coastline of northeast Brazil (França 2008, Holderbaum 2012, Sonntag 2012, Beleza 2013, Jones 2014a). Our observations widen the knowledge on species distribution and indicate that it is resident in the study area.

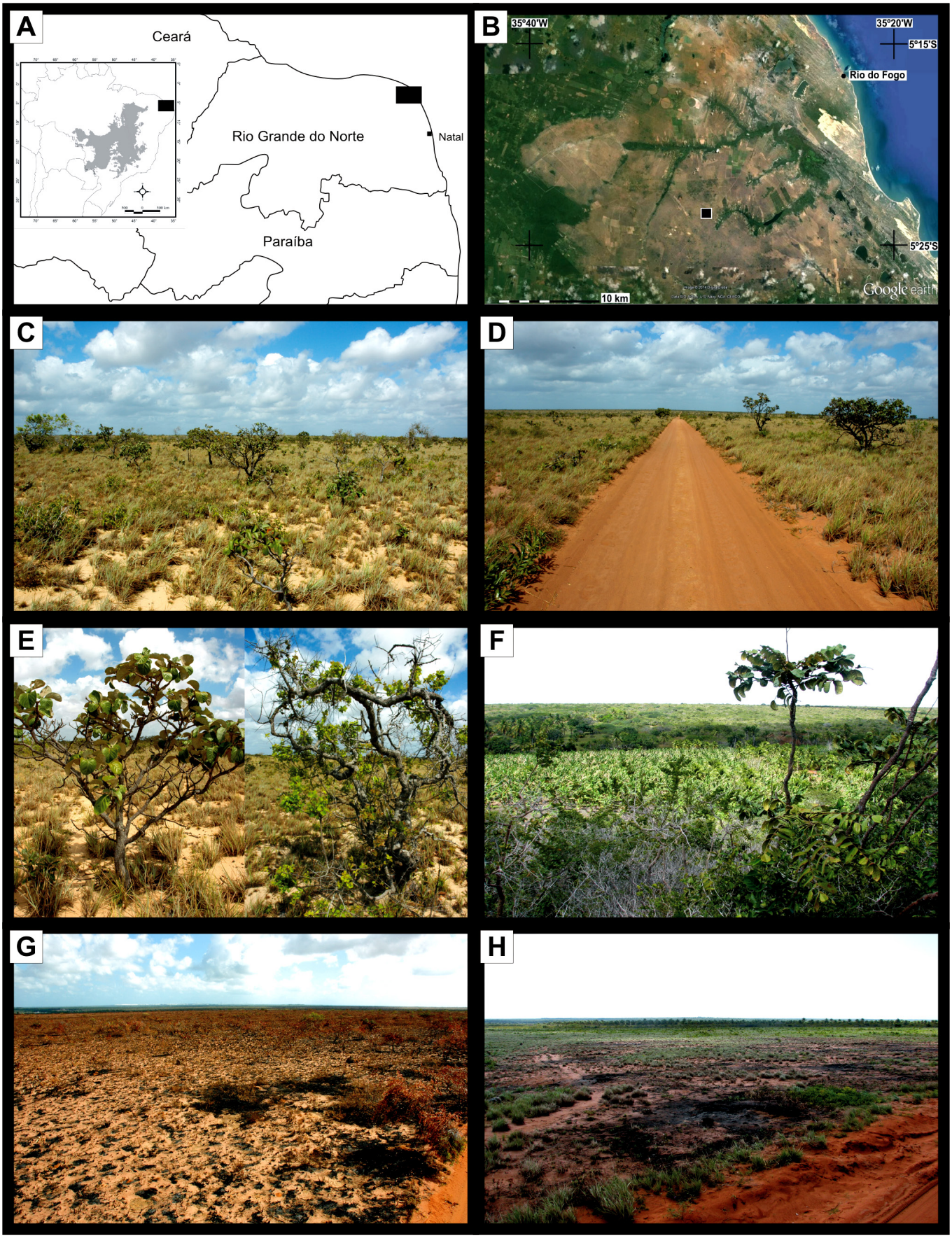

FIGURE 1. *Cerrado* area surveyed for birds in northeastern Brazil. A: localization in South America and northeastern Brazil (the grey polygon represents the core area of *Cerrado*). B: Aerial image of the studied site (the black square represents the core of the studied area, which was samples within a 10 km radius). C and D: general aspects of the vegetation. E: some typical tree species. F: Gallery forest vegetation impacted by agriculture. G: recent burned areas. H: impacted area by fire and coconut plantation in the background. Photos by Mauro Pichorim.

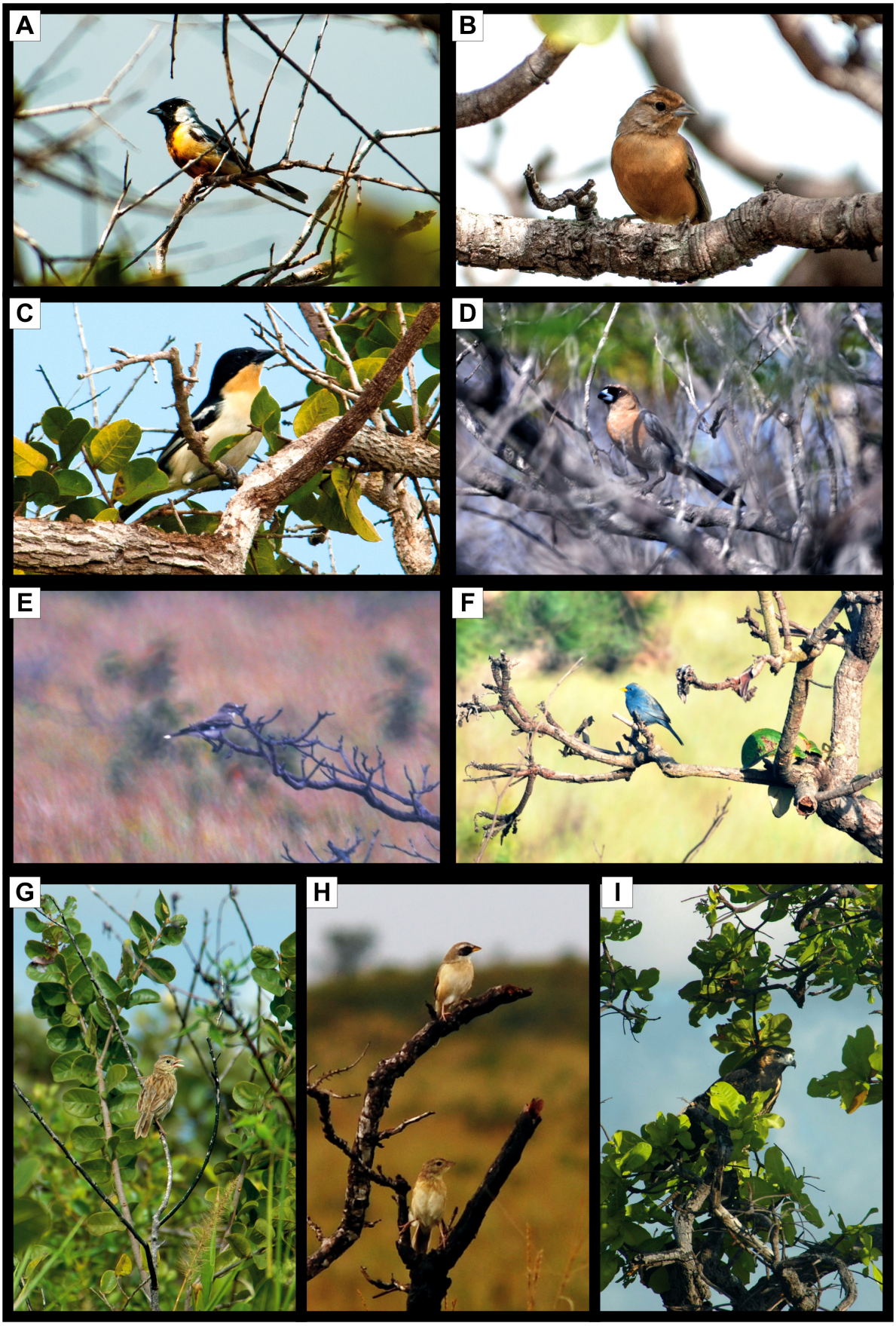

FIGURE 2. Some bird species recorded at the study site between 2006 and 2013. A and B: Male and female of the Near Threatened Coal-crested Finch - *Charitospiza eucosma*. C: White-rumped Tanager - *Cypsnagra hirundinacea*. D: Cinnamon Tanager - *Schistochlamys ruficapillus*. E: Grey Monjita - *Xolmis cinereus*. F and G: Male and female of the Near Threatened Blue Finch - *Porphyrospiza caerulescens*. H: Male and female of the Vulnerable Black-masked Finch - *Coryphaspiza melanotis*. I: White-tailed Hawk - *Geranoaetus albicaudatus* (young). Photos by Ricardo Duarte de Araújo, Bruno Rodrigo de Albuquerque França and Mauro Pichorim.

Lesser Elaenia - *Elaenia chiriquensis*. Visual and sound records were made on 12 November and 21 December 2006, 11 November 2007, 16 August 2008, 1 May 2009 and 10 June 2012. This species seems to undertake seasonal movements in the region since it occurs from late spring through fall. We saw no sign of reproduction during our observations, perhaps because the species is only transient in the study area. This species is common in the *Cerrado* of central Brazil and Bolivia, and in northern South America with well-known south-north movements (Stotz *et al.* 1996, BirdLife International 2014). It is poorly known in the *Caatinga* and the northeastern portion of the Atlantic Rainforest. The records nearest to our area were in Paraíba (Medcraft 2009, Holderbaum 2013), but the photographs and songs shown by these authors are more similar to *Elaenia chilensis*. Our records extend the knowledge on this species' distribution and the time of occurrence in the northernmost portion of northeastern Brazil.

Gray Monjita - *Xolmis cinereus*. Single individuals were recorded on 29 October and 21 December 2006, 16 August 2008 and 16 November 2013 in recently burned areas. This species is common in central and southeastern Brazil, and open areas of Argentina, Paraguay, Uruguay and Bolivia (Ridgely & Tudor 1994, BirdLife International 2014). It has recently been observed on the west coast of Ceará (Lopes 2012, Teixeira 2012), and the north coast of Bahia (Lima 2006). Our records are noteworthy because they extend species distribution at least 650 km to the northeast. The short period of occurrence in our area may indicate some movement, perhaps as a result of winter migration to the south.

Cinnamon Tanager - *Schistochlamys ruficapillus*. A common resident species recorded in 16 expeditions with more than three specimens per day observed (Appendix). This species is common in the *Cerrado*, but also occurs at the edge of the *Caatinga* and Atlantic Forest (BirdLife International 2014). In northeastern Brazil it is known in the south of Ceará, south coast of Paraíba, eastern Pernambuco, Alagoas and Bahia (Lima 2006, Albano 2009, Hilty 2011, Fernandes 2013, Jones 2014b). Recent records in Rio Grande do Norte state extend this species' distribution ~200 km northward. The individuals observed had light plumage in line with the subspecies *S. r. capistrata*. Additional morphological studies are needed to determine possible differences between coastal and inland specimens.

White-rumped Tanager - *Cypsnagra hirundinacea*. Pairs were recorded on 14 expeditions between 2006 and 2013 in January, March, April, May, June, August, October, November and December (Appendix, Figure 2). On 2 March 2008 and 1 May 2009, we observed groups of four specimens possibly involving family groups, since they were flying and foraging together. Thus, the breeding period of the species in the region may occur from summer to fall. This species is common in the *Cerrado* of central Brazil, but it was also recorded on the north coast of Bahia (Lima 2006, Cedraz 2012) and cited without any information on the south coast of Sergipe (Bencke *et al.* 2006), the nearest point to our records (~650 km). The specimens observed were tape recorded and photographed, exhibiting a pale chin and throat, similar to *C. h. pallidigula* (Figure 2). We have captured a number of individuals to measure and record their songs to determine possible taxonomic differences in the Rio Grande do Norte population. These analyses are currently underway and the results will be released shortly.

Blue Finch - *Porphyrospiza caerulescens*. A common resident species recorded in all surveys conducted between 2006 and 2013 (Appendix, Figure 2). We sighted lone individuals, pairs and family groups. On 1 May 2007 we recorded a pair and a fledgling with low flight capacity. On 16 August 2009 we observed a couple with one offspring and on 10 August 2013 we sighted two immature males, four males and six females. Thus, the local breeding period likely occurs from March to August. There is probably no species movement in the area since it was observed during all seasons. This species was also recorded on the north coast of Bahia and in southern Sergipe (Lima 2006, Lima & Buzzetti 2006, Sousa 2011). Our observations are ~650 km north of the nearest previously known location. The specimens observed were quite similar to those from other sites, but we are investigating possible morphological and biological differences in this new population. This near threatened species has become rare in many areas, owing to the conversion of its *Cerrado* habitats to agriculture (Jaramillo 2011a, BirdLife International 2014).

Coal-crested Finch - *Charitospiza eucosma*. Recorded in 15 surveys conducted between 2006 and 2013 (Appendix, Figure 1). The species seems relatively abundant in the area, and is normally encountered in flocks of 4-10 individuals (possibly involving family groups). On some occasions we observed lone individuals and on 21 December 2006 we recorded a group of 15 individuals. On 1 May 2007 and on 10 August 2013 we recorded pairs with one offspring each. The breeding period in the area likely occurs from March to August. Local migrations do not occur since specimens were observed during all seasons. This is a near threatened species that occurs mainly in the *Cerrado* of Brazil (BirdLife International 2014). It was also recently recorded in the *Caatinga* in northern Bahia and eastern Piauí (Nascimento 2011, Mota 2012, Santos 2012, Melo 2013, Caranha 2013). These are the nearest records to our observations (~650 km). There are no apparent morphological differences between the specimens from Rio Grande do Norte and central Brazil, but this deserves further investigation. This species is declining due to

habitat loss (conversion of *Cerrado* to agriculture) and the illegal bird trade (Jaramillo 2011b).

Black-masked Finch - *Coryphaspiza melanotis*. This species was observed mainly in couples and is relatively abundant in the area, since it was observed in all surveys (Appendix, Figure 2). On 16 August 2008, 1 May 2009 and 10 August 2013 we recorded three, four and five pairs respectively, and on each of these occasions one pair had a fledgling. The breeding period in the area likely occurs from March to August. Species movement does not occur given that it was observed in all seasons. This is a vulnerable species that occurs mainly in the *Cerrado* of Brazil, Peru, Bolivia, Paraguay and Argentina (BirdLife International 2014). In Brazil there is an isolated population at the mouth of the Amazon River described as *C. m. marajoara* (Sick 1967), with recent photographic records in eastern Pará (Lees 2011, Thompson 2011). The northernmost records of *C. m. melanotis* are from northern Goiás (Braz 2008, Cavalcante 2013, Timm 2013). These previous distribution limits are more than 1,600 km from our records. We are studying the morphology and ecology of this new population, focusing on possible geographic variations. This species is uncommon to rare and has experienced habitat destruction (Jaramillo 2011c).

DISCUSSION

Our results broaden the knowledge on the distribution of various species, indicate the seasonality and reproduction of some and reveal a lack of information on the composition of the communities in little or unstudied areas of Brazil. Birds from the *Cerrado* have been studied in the core region and a number of Amazon enclaves (*e.g.,* Henriques & Oren 1997, Silva *et al.* 1997, Tubelis & Cavalcanti 2000, Aleixo & Poletto 2007, Mittermeier *et al.* 2010), but little or no attention has been given to *Cerrado* enclaves in the *Caatinga* and Atlantic Forest. Distribution projections using niche modeling show low or medium probability of the occurrence of a number of *Cerrado* birds (*e.g.*, *C. hirundinacea*, *Neothraupis fasciata*, *Saltatricula atricollis*, *Melanopareia torquata*, *Cyanocorax cristatellus*) for part of the northeast coast of Brazil (Leite 2006, Corrêa *et al.* 2010). Our records confirm the presence of at least one of these species in the region. Even though these projections have been considered flaws in the models generated (see Corrêa *et al.* 2010), we believe that there are concrete indications of environmental similarities among the open areas on the northeast coast and the *Cerrado* of central Brazil. The lack of records for some species may be due to inadequate samplings of these formations on the northeastern coast. It is important to underscore that a number of species that we recorded have been linked to highland areas of central Brazil (Parker *et al.* 1996, Sick 1997). *P. caerulescens* is recognized as a riparian species from highland areas (BirdLife International 2014). The occurrence of these species on the coast of northeastern Brazil reveals they have a higher niche range that previously thought. Thus, it is important to reconstruct these potential distribution models with the addition of all the occurrence points on the northeastern coast of Brazil. These techniques are essential for optimizing the search effort of new occurrence areas for the species, as well as for understanding the biogeographic processes that led to their current distribution.

Considering the five structural types of *Cerrado* recognized by botanists (see Eiten 1972, 1993), the species we recorded are more common in open physiognomies known as "*campo limpo*" (grassland with few or no shrubs or tall woody plants) and "*campo sujo*" (grassland with scattered shrubs). Elements of "*Cerrado sensu stricto*", "*cerradão*" and "*matas de galeria* (riparian forests)" are lacking (*e.g.*, *Cyanocorax cristatellus*, *Antilophia galeata*, *Myiothlypis leucophrys*, *Herpsilochmus longirostris*). This is likely due to the fact that our study site has a physiognomy with a low density of typical *Cerrado* trees (Oliveira *et al.* 2012), decreasing the availability of structure and resources for a number of birds, in addition to the absence of gallery forests, border streams and lagoons in the region with typical "*veredas*" (tall gallery forests with stands of a species of palm, *Mauritia flexuosa*). In the study area the forests near rivers and lagoons are different from those of Central Brazil, in that they are mainly tropical semideciduous forests associated with the Atlantic Forest. Moreover, they are significantly affected by subsistence agriculture or coconut plantations. Thus, the lack of birds typical of *Cerrado* forest areas may be a result of environmental restrictions, due to differences in composition and/or local extinctions caused by the use of these areas.

We also did not found birds typical of open areas (*e.g.*, *M. torquata*, *N. fasciata*, *S. atricollis* and *Poospiza cinerea*). The reasons for this are difficult to ascertain at the moment, and more field surveys and increased knowledge of species biology are needed. In general, the study area seems to be relictual, representing the distribution limit of the *Cerrado* formation with low richness, likely related to historical extinction processes. However, this characteristic does not diminish the importance of the area, since it reveals clues of evolutionary processes in central and northeastern Brazil, in addition to harboring endemic species and those near or threatened with extinction. It is also important to consider that open physiognomies of the *Cerrado* must be more protected due to their increased vulnerability to agriculture, pastures and biological invasions (Tubelis & Cavalcanti 2000). The conservation of open habitats is essential in protecting threatened or little known Brazilian grassland birds (Marini & Garcia 2005, Lopes *et al.* 2010).

These *Cerrado* formations along the coast of Brazil seem to be distributed from the north coast of Bahia to Rio Grande do Norte. Some typical species of the *Cerrado*, such as *C. hirundinacea* and *P. caerulescens*, were previously cited for this narrow strip in the states of Bahia and Sergipe (Bencke *et al.* 2006, Lima & Buzzetti 2006, Sousa 2011). These formations occur on sandy soils originating in the *Arenito Barreira* outcrop, which extends over a large part of northeastern Brazil.

Considering the sea-level variation through the Late Pleistocene and Holocene, these areas may have undergone a series of expansion and coalescence. Most biogeographic patterns of the biotic diversity of the *Cerrado* occurred during the Pleistocene (Cracraft 1985, Silva 1995a, b, Silva 1997, Silva & Bates 2002). It is known that the sea level in the Late Pleistocene was ~100 m below current levels (Hearty 1998). For the coast of Rio Grande do Norte state, which is shallow and has a wide continental shelf, these events may have expanded the shoreline 50 km to the east, widening the coastal strip of open formations. The biogeography of savannas in the northern and southern Amazon has been studied in recent years (Haffer 1967, 1974, Webb 1991, Silva 1995b, c, Henriques & Oren 1997, Silva *et al.* 1997, Silva 1998), suggesting an Atlantic coast savanna corridor (Silva & Bates 2002). A similar process may have occurred on the northeast coast of Brazil. This process and the age of these *Cerrado* relicts need to be better understood and these areas must be protected, since they preserve the memory of the evolution of these biotas and the dynamics of the environments involved.

We observed that the study area has been affected by fire, agriculture and military activities. Although fires are uncommon, they must be controlled, since several *Cerrado* grassland species are highly sensitive to regular fires (Tubelis & Cavalcanti 2000). Agriculture has had a greater impact, completely altering the local physiognomy. At the margins of watercourses vegetation has been almost completely altered. Moreover, in recent years a number of monocultures have been established in the northern portion of the area, including irrigated agriculture (Figure 1). Some extensive coconut plantations (*Cocus nucifera*) have recently appeared (Figure 1). The major threats to Brazilian birds are habitat loss, degradation and fragmentation (Marini & Garcia 2005). Controlling these impacts is essential in maintaining the threatened endemic species that we found in the area. Therefore, new agriculture projects should be temporarily banned until their impacts on the flora and fauna can be assessed and conservation measures implemented. Furthermore, an Integral Protection Conservation Unit (ICU) must be urgently established to guarantee effective conservation. This ICU should be large (~20,000 ha) in order to protect viable populations, given that it is an open isolated area where species have low density and occupy an extensive area. There are still areas available to create an ICU of this size, including a section used as a military area and other conserved areas. However, decisions must be made immediately, since this situation will not continue for long. The parks and ecological stations in the *Cerrado* are vital to the conservation of this habitat (Silva & Bates 2002).

It is unknown whether the species found are totally isolated from the central areas of Brazil. Isolation is most likely be taking place since there is no indication of seasonal displacement, with most species found throughout the year. The time of this possible isolation cannot be estimated yet. For this reason, and considering the distance of these records, some geographic variation (morphological and/or genetic) probably occurred in these populations from the northernmost portion of the northeast. We observed some plumage variation in *C. hirundinacea* and *C. melanotis* and are acquiring more data on the subject. However, extensive morphological, bioacoustics and molecular studies are needed for these species, in order to clarify all the taxonomic and phylogeographic aspects in the region. Some of these initiatives are underway and we will present more information on *Cerrado* fragments on the northeast coast shortly. However, we cannot wait for this information to protect these *Cerrado* fragments on the northeastern coast; conservation measures must be immediate.

With respect to endemism in the *Cerrado*, we found *C. eucosma* and *P. caerulescen*s (following Silva & Bates 2002, Silva & Santos 2005). However, the criteria adopted by Silva & Santos (2005) to define endemism in this region were the overlap between geographic distribution of the species and the central region of the *Cerrado* (minimum of 95%) and isolated populations in savanna-like habitats up to 430 km from the *Cerrado*. Considering this last criterion, these species must no longer be considered endemic to the *Cerrado*, given that new records presented here are farther than those previously established. Vasconcelos (2008) considered the "430-km rule" inaccurate and biased and its application can create unrealistic or obscure biogeographic patterns. We agree with this idea mainly due to the peculiarities of species distribution in open areas and the fragmented pattern of the relictual occurrence of *Cerrado* patches in the Amazon, Atlantic Forest and *Caatinga* at large distances from the central region. As such, we suggest adopting only distribution overlapping with the central area as criterion, that is, the first criterion proposed by Silva & Santos (2005). Therefore, the aforementioned species are endemic and others have regained this status (*e.g.*, *N. fasciata* and *C. hirundinacea*). It is important to underscore that Vasconcelos (2008) also suggested not considering some species restricted to the eastern Brazilian highlands as endemic to the *Cerrado* (*e.g.*, *Augastes scutatus*,

Asthenes luizae, *Polystictus superciliaris*, and *Embernagra longicauda*) because rupestrian field vegetation seems to have been subjected to an independent evolutionary process. Thus, considering these proposals, the *Cerrado* currently has 28 endemic birds (*Nothura minor*, *Taoniscus nanus*, *Penelope ochrogaster*, *Columbina cyanopis*, *Pyrrhura pfrimeri*, *Alipiopsitta xanthops*, *Hydropsalis candicans*, *H. longirostris*, *Cercomacra ferdinandi*, *M. torquata, Scytalopus novacapitalis*, *Geositta poeciloptera*, *Clibanornis rectirostris*, *Syndactyla dimidiata*, *Synallaxis simoni*, *A. galeata*, *Suiriri islerorum*, *Phyllomyias reiseri*, *Knipolegus franciscanus*, *C. cristatellus*, *M. leucophrys*, *S. atricollis*, *C. hirundinacea*, *N. fasciata*, *Paroaria baeri*, *P. caerulescens*, *P. cinerea*, and *C. eucosma*).

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APPENDIX

Birds recorded in the *Cerrado* area near Punaú, Rio do Fogo, Rio Grande do Norte, Northeastern Brazil between 2006 and 2013. The taxonomy follows CBRO (2014).

Families and species	**Records (date and between parentheses the amount of individuals observed in each occasion)**
TINAMIDAE	
Crypturellus parvirostris Small-billed Tinamou	17Jan2007(2), 02Mar2008(2), 01May2007(2), 01May2009(3), 10Aug2013(1)
Nothura maculosa Spotted Nothura	17Jan2007(1), 02Mar2008(2), 16Aug2008(1), 01May2009(3), 16Nov2013(1)
ANATIDAE	
Dendrocygna viduata White-faced Whistling-duck	21Oct2006(~500), 10Aug2013(5)
ARDEIDAE	
Butorides striata Striated Heron	21Oct2006(1)
CATHARTIDAE	
Cathartes aura Turkey Vulture	21Oct2006(2), 12Nov2006(2), 01May2007(2), 01May2009(1), 15Aug2009(2), 15Aug2009(2), 10Jun2012(1), 21Apr2013(2), 10Aug2013(2)
Cathartes burrovianus Lesser Yellow-headed Vulture	21Oct2006(5), 16Aug2009(1), 16Aug2009(1), 10Aug2013(2), 16Nov2013(1)
Coragyps atratus Black Vulture	09Oct2006(2), 21Oct2006(5), 17Jan2007(2), 01May2007(5), 11Aug2007(1), 11Nov2007(2), 15Aug2009(10), 15Aug2009(3), 10Jun2012(5), 21Apr2013(6), 10Aug2013(5), 16Nov2013(2)
ACCIPITRIDAE	
Heterospizias meridionalis Savanna Hawk	15Aug2009(1)
Rupornis magnirostris Roadside Hawk	21Oct2006(3), 01May2007(1), 01May2009(2)
Geranoaetus albicaudatus White-tailed Hawk	21Oct2006(2), 29Oct2006(3), 29Oct2006(1), 12Nov2006(2), 21Dec2006(1), 17Jan2007(2), 01May2007(3), 11Aug2007(3), 10Nov2007(2), 11Nov2007(1), 02Mar2008(3), 01May2009(2), 10Jun2012(2), 10Aug2013(1), 16Nov2013(1)
Buteo brachyurus Short-tailed Hawk	15Aug2009(2)
CHARADRIIDAE	
Vanellus chilensis Southern Lapwing	21Oct2006(1)
COLUMBIDAE	
Columbina passerina Common Ground-dove	01May2009(2), 10Aug2013(3)

Families and species	Records (date and between parentheses the amount of individuals observed in each occasion)
Columbina minuta Plain-breasted Ground-dove	09Oct2006(2), 21Oct2006(9), 29Oct2006(2), 12Nov2006(6), 01May2007(2), 11Nov2007(1), 02Mar2008(2), 16Aug2009(1), 10Jun2012(1), 16Nov2013(1)
Columbina squammata Scaled Dove	11Nov2007(2)
Patagioenas picazuro Picazuro Pigeon	21Oct2006(1), 29Oct2006(1), 10Aug2013(1)
Zenaida auriculata Eared Dove	21Apr2013(2)
CUCULIDAE	
Piaya cayana Squirrel Cuckoo	21Oct2006(1), 10Aug2013(1)
Crotophaga ani Smooth-billed Ani	21Oct2006(1)
STRIGIDAE	
Glaucidium brasilianum Ferruginous Pygmy-owl	10Aug2013(1)
Athene cunicularia Burrowing Owl	09Oct2006(3), 01May2007(2), 10Jun2012(1), 10Aug2013(2)
CAPRIMULGIDAE	
Hydropsalis parvula Little Nightjar	21Oct2006(2), 21Dec2006(1), 17Jan2007(1), 11Aug2007(1), 16Nov2013(1)
Hydropsalis torquata Scissor-tailed Nightjar	16Aug2009(1)
Chordeiles pusillus Least Nighthawk	21Dec2006(1), 17Jan2007(20), 01May2007(8), 11Aug2007(3), 10Nov2007(1), 11Nov2007(3), 02Mar2008(7), 16Aug2008(2), 01May2009(5), 15Aug2009(2), 16Aug2009(4), 10Aug2013(8)
TROCHILIDAE	
Eupetomena macroura Swallow-tailed Hummingbird	21Dec2006(3), 17Jan2007(1), 01May2007(2), 11Nov2007(1), 02Mar2008(3), 16Aug2008(1), 15Aug2009(3), 16Aug2009(1), 10Aug2013(1)
Polytmus guainumbi White-tailed Goldenthroat	21Apr2013(1), 10Aug2013(1)
Heliactin bilophus Horned Sungem	21Oct2006(1), 12Nov2006(1), 17Jan2007(1)
ALCEDINIDAE	
Megaceryle torquata Ringed Kingfisher	21Apr2013(2)
BUCCONIDAE	
Nystalus maculatus Spot-backed Puffbird	21Oct2006(7), 12Nov2006(2), 11Nov2007(2), 02Mar2008(2), 15Aug2009(2), 16Aug2009(2), 21Apr2013(2), 10Aug2013(1)
PICIDAE	
Veniliornis passerinus Little Woodpecker	10Aug2013(2)

Families and species	Records (date and between parentheses the amount of individuals observed in each occasion)
CARIAMIDAE	
Cariama cristata Red-legged Seriema	21Oct2006(3), 21Dec2006(6), 01May2007(3), 11Aug2007(1), 11Nov2007(2), 02Mar2008(2), 01May2009(2), 16Aug2009(4), 10Jun2012(2), 21Apr2013(1), 10Aug2013(4)
FALCONIDAE	
Caracara plancus Southern Caracara	21Dec2006(8), 17Jan2007(2), 02Mar2008(1), 01May2009(2), 15Aug2009(1), 16Aug2009(1), 10Jun2012(5), 21Apr2013(3), 10Aug2013(2)
Milvago chimachima Yellow-headed Caracara	29Oct2006(1), 12Nov2006(1), 21Dec2006(1), 02Mar2008(1), 21Apr2013(1), 10Aug2013(1)
Falco sparverius American Kestrel	09Oct2006(1), 02Mar2008(1)
Falco femoralis Aplomado Falcon	01May2007(3), 15Aug2009(2), 16Aug2009(1), 21apr2013(1)
PSITTACIDAE	
Eupsittula aurea Peach-fronted Parakeet	29Oct2006(2), 21Dec2006(2), 11Nov2007(2)
Eupsittula cactorum Cactus Parakeet	10Aug2013(2)
THAMNOPHILIDAE	
Formicivora grisea White-fringed Antwren	21Oct2006(2), 01May2007(2), 11Aug2007(1), 11Nov2007(2), 02Mar2008(2), 16Aug2008(2), 16Aug2009(1)
Formicivora melanogaster Black-bellied Antwren	15Aug2009(1)
Formicivora rufa Rusty-backed Antwren	09Oct2006(4), 21Oct2006(4), 12Nov2006(2), 17Jan2007(4), 01May2007(2), 11Nov2007(1), 02Mar2008(6), 16Aug2008(3), 01May2009(3), 15Aug2009(1), 16Aug2009(3), 10Jun2012(1), 10Aug2013(1)
Thamnophilus torquatus Rufous-winged Antshrike	21Oct2006(4), 17Jan2007(1), 11Nov2007(1), 16Aug2008(2), 15Aug2009(1), 16Aug2009(2), 10Jun2012(1), 10Aug2013(1)
FURNARIIDAE	
Synallaxis frontalis Sooty-fronted Spinetail	11Nov2007(1)
Synallaxis albescens Pale-breasted Spinetail	01May2007(6), 10Nov2007(2), 11Nov2007(1), 02Mar2008(1), 16Aug2008(1), 16Aug2009(3), 10Aug2013(1)
Synallaxis scutata Ochre-cheeked Spinetail	21Apr2013(1)
RHYNCHOCYCLIDAE	
Todirostrum cinereum Common Tody-flycatcher	12Nov2006(1), 01May2007(2), 11Nov2007(1), 10Aug2013(1)
Hemitriccus margaritaceiventer Pearly-vented Tody-tyrant	21Oct2006(2), 11Nov2007(2), 02Mar2008(3), 16Aug2008(3), 01May2009(2), 15Aug2009(1), 10Jun2012(1), 21Apr2013(3), 10Aug2013(1)
TYRANNIDAE	
Stigmatura napensis Lesser Wagtail-tyrant	12Nov2006(1), 17Jan2007(1), 11Nov2007(4), 02Mar2008(2), 01May2009(2), 15Aug2009(2), 16Aug2009(1)

Families and species	Records (date and between parentheses the amount of individuals observed in each occasion)
Euscarthmus meloryphus Tawny-crowned Pygmy-tyrant	11Nov2007(1)
Camptostoma obsoletum Southern Beardless-tyrannulet	21Oct2006(2)
Elaenia flavogaster Yellow-bellied Elaenia	21Oct2006(2), 21Dec2006(1), 01May2007(2), 11Aug2007(3), 10Nov2007(1), 11Nov2007(4), 02Mar2008(3), 01May2009(4), 15Aug2009(1), 10Aug2013(2)
Elaenia spectabilis Large Elaenia	21Oct2006(1), 11Nov2007(1), 16Aug2008(2), 16Aug2009(2), 10Aug2013(3)
Elaenia chilensis Chilean Elaenia	17Jan2007(1), 10Aug2013(1)
Elaenia cristata Plain-crested Elaenia	12Nov2006(1), 21Dec2006(4), 11Nov2007(3), 02Mar2008(4), 16Aug2008(1), 01May2009(4), 15Aug2009(1), 16Aug2009(8), 21Apr2013(5), 10Aug2013(8), 16Nov2013(3)
Elaenia chiriquensis Lesser Elaenia	12Nov2006(4), 21Dec2006(1), 11Nov2007(1), 16Aug2008(2), 01May2009(2), 10Jun2012(2)
Myiopagis viridicata Greenish Elaenia	11Nov2007(1)
Pitangus sulphuratus Great Kiskadee	21Oct2006(1)
Tyrannus melancholicus Tropical Kingbird	21Oct2006(9), 12Nov2006(3), 21Dec2006(1), 17Jan2007(3), 01May2007(4), 10Nov2007(3), 11Nov2007(2), 02Mar2008(4), 16Aug2008(2), 01May2009(3), 15Aug2009(2), 16Aug2009(2), 10Jun2012(2), 21Apr2013(2), 10Aug2013(3)
Tyrannus savana Fork-tailed Flycatcher	29Oct2006(5), 12Nov2006(1), 21Dec2006(1), 21Apr2013(1)
Sublegatus modestus Southern Scrub-flycatcher	11Nov2007(1)
Cnemotriccus fuscatus Fuscous Flycatcher	21Oct2006(3)
Xolmis cinereus Gray Monjita	29Oct2006(2), 21Dec2006(1), 16Aug2008(1), 16Nov2013(1)
VIREONIDAE	
Cyclarhis gujanensis Rufous-browed Peppershrike	21Oct2006(2), 29Oct2006(1), 11Nov2007(2)
HIRUNDINIDAE	
Stelgidopteryx ruficollis Southern Rough-winged Swallow	21Apr2013(1)
Progne chalybea Gray-breasted Martin	02Mar2008(2)
Tachycineta albiventer White-winged Swallow	21Oct2006(2), 10Aug2013(2)
Hirundo rustica Barn Swallow	29Oct2006(4)
TROGLODYTIDAE	
Troglodytes musculus Southern House Wren	21Oct2006(2), 12Nov2006(1), 17Jan2007(1), 01May2007(1), 10Jun2012(1)
Cantorchilus longirostris Long-billed Wren	21Oct2006(1)

Families and species	Records (date and between parentheses the amount of individuals observed in each occasion)
POLIOPTILIDAE	
Polioptila plumbea Tropical Gnatcatcher	09Oct2006(2), 21Oct2006(4), 12Nov2006(1), 21Dec2006(1), 01May2007(2), 11Aug2007(3), 11Nov2007(1), 01May2009(2), 21Apr2013(2)
TURDIDAE	
Turdus leucomelas Pale-breasted Thrush	09Oct2006(1), 21Oct2006(2), 11Nov2007(2)
MIMIDAE	
Mimus saturninus Chalk-browed Mockingbird	21Oct2006(1), 12Nov2006(2), 21Dec2006(1), 15Aug2009(3), 15Aug2009(3), 10Jun2012(5), 10Aug2013(2)
MOTACILLIDAE	
Anthus lutescens Yellowish Pipit	10Jun2012(1)
PASSERELLIDAE	
Ammodramus humeralis Grassland Sparrow	09Oct2006(5), 21Oct2006(5), 12Nov2006(1), 21Dec2006(5), 17Jan2007(2), 01May2007(6), 11Nov2007(2), 02Mar2008(1), 01May2009(4), 15Aug2009(3), 16Aug2009(1), 10Jun2012(4), 10Aug2013(8)
ICTERIDAE	
Procacicus solitarius Solitary Black Cacique	17Jan2007(1), 11Nov2007(1)
Molothrus bonariensis Shiny Cowbird	21Apr2013(1)
THRAUPIDAE	
Coereba flaveola Bananaquit	21Dec2006(1), 02Mar2008(2), 01May2009(2), 15Aug2009(2)
Cypsnagra hirundinacea White-rumped Tanager	21Oct2006(7), 12Nov2006(7), 21Dec2006(3), 17Jan2007(2), 01May2007(6), 11Aug2007(4), 11Nov2007(4), 02Mar2008(4), 16Aug2008(2), 01May2009(4), 16Aug2009(4), 10Jun2012(2), 21Apr2013(2), 10Aug2013(4)
Tachyphonus rufus White-lined Tanager	21Oct2006(2), 10Jun2012(1)
Tangara cayana Burnished-buff Tanager	21Oct2006(4), 12Nov2006(1), 21Dec2006(3), 11Aug2007(1), 10Nov2007(2), 11Nov2007(2), 02Mar2008(1), 16Aug2008(1), 16Aug2009(2), 10Jun2012(1), 21Apr2013(1), 10Aug2013(4), 16Nov2013(2)
Schistochlamys ruficapillus Cinnamon Tanager	09Oct2006(4), 21Oct2006(5), 29Oct2006(3), 12Nov2006(3), 21Dec2006(3), 17Jan2007(4), 01May2007(3), 11Aug2007(3), 11Nov2007(5), 02Mar2008(5), 16Aug2008(3), 01May2009(5), 16Aug2009(3), 10Jun2012(3), 21Apr2013(3), 10Aug2013(4), 16Nov2013(1)
Porphyrospiza caerulescens Blue Finch	09Oct2006(2), 21Oct2006(8), 29Oct2006(1), 12Nov2006(3), 21Dec2006(1), 17Jan2007(1), 01May2007(3), 11Aug2007(1), 11Nov2007(2), 02Mar2008(2), 16Aug2008(2), 01May2009(3), 15Aug2009(3), 16Aug2009(6), 10Jun2012(1), 21Apr2013(2), 10Aug2013(12), 16Nov2013(1)
Sicalis luteola Grassland Yellow-finch	21Dec2006(14), 17Jan2007(15), 01May2007(25), 11Aug2007(3), 11Nov2007(2), 02Mar2008(5), 01May2009(5), 16Aug2009(1), 16Aug2009(1), 21Apr2013(5), 10Aug2013(6)

Families and species	**Records (date and between parentheses the amount of individuals observed in each occasion)**
Emberizoides herbicola Wedge-tailed Grass-finch	29Oct2006(5), 12Nov2006(2), 21Dec2006(2), 01May2007(3), 11Aug2007(2), 10Nov2007(2), 01May2009(3), 16Aug2009(1), 10Jun2012(3), 21Apr2013(2), 10Aug2013(1)
Volatinia jacarina Blue-black Grassquit	02Mar2008(1), 01May2009(3), 10Jun2012(1), 10Aug2013(5)
Charitospiza eucosma Coal-crested Finch	09Oct2006(8), 21Oct2006(15), 29Oct2006(1), 12Nov2006(4), 21Dec2006(15), 17Jan2007(5), 01May2007(3), 11Aug2007(3), 11Nov2007(2), 02Mar2008(1), 16Aug2008(1), 01May2009(3), 15Aug2009(1), 16Aug2009(14), 21Apr2013(1), 10Aug2013(13), 16Nov2013(2)
Coryphaspiza melanotis Black-masked Finch	09Oct2006(1), 21Oct2006(4), 29Oct2006(1), 12Nov2006(1), 21Dec2006(2), 17Jan2007(3), 01May2007(3), 11Aug2007(3), 11Nov2007(2), 02Mar2008(2), 16Aug2008(7), 01May2009(9), 15Aug2009(1), 16Aug2009(10), 10Jun2012(6), 21Apr2013(1), 10Aug2013(10), 16Nov2013(3)
FRINGILLIDAE	
Euphonia chlorotica Purple-throated Euphonia	09Oct2006(1), 01May2009(2), 16Aug2009(1), 21Apr2013(2), 10Aug2013(1)

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ARTICLE

Rivers acting as barriers for bird dispersal in the Amazon

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ABSTRACT: Morphological, vocal and genetic studies have shown that the Madeira River and its right bank tributaries delimit populations of primates and birds. We sequenced the cytochrome *b* gene (approx. 950 bp) for individuals of three suboscine passerine bird species, *Glyphorynchus spirurus* (Furnariidae), *Willisornis poecilinotus* (Thamnophilidae) and *Schiffornis turdina* (Tityridae), on opposite banks of the Madeira River and two of its right-bank tributaries, the Aripuanã and Jiparaná rivers. Phylogenetic hypotheses (parsimony, maximum likelihood and Bayesian analysis) revealed clades that have over 3.1% genetic differentiation on opposite banks of the Madeira River for *G. spirurus*, *W. poecilinotus* and *S. turdina*, suggesting that this river restricts gene flow among populations of these three species. The Jiparaná and Aripuanã rivers apparently separate distinct populations of *G. spirurus*, the smallest species we examined, but not those of the other two heavier bodied species, *W. poecilinotus* and *S. turdina*. In *G. spirurus* four clades with high levels of genetic differentiation (3.2–5.5%) were found to be delimited by the three rivers evaluated, whereas in *W. poecilinotus* and *S. turdina* no genetic structure across the Jiparaná and Aripuanã rivers was detected. In general, birds that are known to show population structure across the Madeira tributaries (*Glyphorynchus spirurus, Hemitriccus minor, Hypocnemis rondoni, Herpsilochmus stotzi*, and *Hylophylax naevius*) have body masses smaller than those of both *Willisornis poecilinotus* and *Schiffornis turdina*, but some exceptions are discussed. Future studies controlling for several variables are necessary to determine the extent to which body mass is a useful predictor of genetic population structure in understory suboscine passerines.

KEY-WORDS: Areas of endemism, body mass, comparative phylogeography, conservation, dispersal rate, suboscine birds.

INTRODUCTION

Avian distribution patterns are reasonably well known and influential in studies of evolutionary processes. Jürgen Haffer was one of the first authors to compile bird distribution data to describe biogeographic patterns in South America (Haffer 1974). His work made a great contribution to evolutionary studies and to the formulation of speciation hypotheses in Amazonia. The "centres of species endemism" he described remain largely unchanged in analyses of distribution patterns for many avian groups. They have been generally accepted in subsequent works, and in the Amazon basin these regions are often delimited by large rivers (Haffer 1974; Cracraft 1985; da Silva & Oren 1996). Bird species are usually separated by the Amazon River and its major tributaries such as the Negro, Madeira, Tapajós and Tocantins rivers (Cohn-Haft 2000; Ribas *et al*. 2012; D'Horta *et al*. 2013; Fernandes *et al*. 2012, 2013, 2014). Similar patterns are also found in other Amazonian vertebrate taxa, including primates and butterflies (Wallace 1852; van Roosmalen *et al*. 1998; Hall & Harvey 2002), suggesting that rivers are important barriers to dispersal.

Recent studies of primates and birds in the Madeira-Tapajós interfluvium (M-T), also known as the Rondônia area of endemism (Cracraft 1985), have suggested that smaller rivers also limit the distributions of some taxa, thus forming smaller areas of endemism in what was referred to as "mini-interfluvia" (Cohn-Haft *et al*. 2007). Willis (1969), in a study of birds of the genus *Rhegmatorhina*, was one of the first to document complex patterns of bird distributions in this area. He discussed the parapatric occurrence of *Rhegmatorhina berlepschi* and *R. hoffmannsi* within the M-T and suggested that the Madeira and Tapajós rivers have occasionally changed their courses, resulting in the separation of populations and subsequent speciation. Van Roosmalen and collaborators (1998) described geographic substitutions of species in primates of the genera *Callithrix* and *Callicebus* on opposite banks of small rivers within this interfluvium and described a new species of marmoset, *Callithrix humilis*, that occurs only on the west bank of the Aripuanã River. Subsequently, several other bird species in this region have been found to contain vocally, morphologically or genetically distinct populations, with restricted distributions and geographic substitution

on opposite banks of Madeira tributaries, such as the Aripuanã and Jiparaná (or Machado) rivers (Cohn-Haft *et al*. 2007; Isler *et al*. 2007; Tobias *et al*. 2008; Fernandes *et al*. 2012, 2013, 2014; Whitney *et al*. 2013a, b, c, d, e). Similar geographic patterns, with different races being separated by small Amazonian rivers, have also been found for butterflies (Hall & Harvey 2002).

Sardelli (2005) found genetic differentiation (cytochrome *b*, 500 bp) among morphologically indistinguishable populations of the Snethlage's Tody-Tyrant (*Hemitriccus minor*) apparently bounded by the Jiparaná and Aripuanã rivers. This study raised the possibility of the existence of cryptic endemism in mini-interfluvia, which was subsequently investigated for the other three species of passerine birds (*Myrmeciza hemimelaena*, *Glyphorynchus spirurus*, *Hylophylax naevius* (Fernandes *et al*. 2012, 2013, 2014). Fernandes (2013) cited in a review a number of publications corroborating the importance of the mini-interfluvia, highlighting that these diversity patterns are a key (and possibly unique) Amazonian feature and that despite the fact that this fine-scale endemism is well known and recognized among systematists working in the Amazon, it is not taken into account in conservation plans. Fernandes (2013) pointed out that many taxa in this region, including those yet to be given formal scientific names, may now be endangered or even extinct. Thus it is of utmost importance to consider species that present this kind of fine scale differentiation in future conservation proposals. The objective of our study was threefold: 1) describe phylogeographic patterns for three species of suboscine passerines across the Rondônia area of endemism; 2) compare these patterns to those of other species know to have populations delimited by the Madeira, Aripuanã and Jiparaná rivers; and 3) investigate the relationship between degree of phylogeographic structure and ecological attributes in the light of the riverine barrier hypothesis.

MATERIAL AND METHODS

Species studied and sampling design

We studied three species of passerine birds belonging to three different families: *Glyphorynchus spirurus* (Furnariidae), *Willisornis poecilinotus* (Thamnophilidae), and *Schiffornis turdina* (Tityridae). We sampled birds at 12 sites between the Tapajós and Madeira rivers and five sites on the left bank of the Madeira River (LM; Figure 1), with the final number of localities sampled per species differing among the three species (see Results). Individuals were collected along the Madeira, Aripuanã, Jiparaná and Roosevelt (the latter representing the largest tributary of the Aripuanã) rivers; the widths of these rivers along their lower courses are roughly 3.0, 0.8, 0.4 and 0.3 km, respectively. Each collection point had a corresponding point located on the opposite bank and therefore in a different interfluvium. For purposes of sampling and analyses, we suggest the existence of three mini-interfluvia within the M-T: Madeira-Jiparaná (MJ), Aripuanã-Jiparaná (AJ) and Aripuanã-Tapajós (AT) (Fig. 1). A maximum of 5 individuals per species were collected at each sampling point, with the total sample as follows: *Willisornis poecilinotus* (*n* = 45), *Schiffornis turdina* (*n* = 23), and *Glyphorynchus spirurus* (*n* = 25) (see Appendix). Specimens were deposited in the bird collection of the National Institute for Amazonian Research (INPA), Manaus, Brazil, where tissue samples (muscle, heart and liver) were stored in liquid nitrogen for molecular analyses.

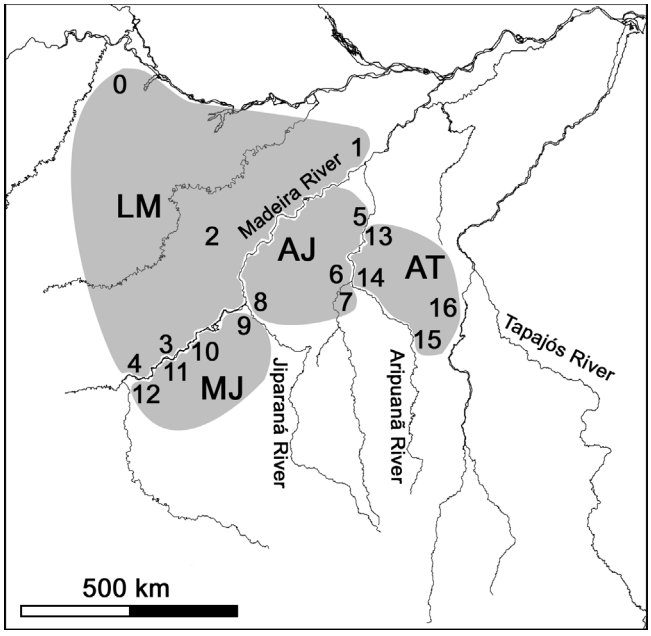

FIGURE 1. Collection points and the interfluvia sampled. Madeira-Jiparaná (MJ), Aripuanã-Jiparaná (AJ), Aripuanã-Tapajós (AT) and Left bank of the Madeira River (LM).

We chose to study these three target species primarily because they are common, easy to collect, and widely distributed across the entire Amazon basin. Although all three are suboscine passerines, they represent three distinct families and, as such, the results obtained in this study can be assumed to be instances of independent evolution, and, thus, support the generality of our conclusions. All three species can be found in the same habitat (*terra firme* forest) but they differ in a variety of ecological attributes:

Glyphorynchus spirurus – This is a polytypic species widely distributed in Neotropical lowland forests, occurring in Amazonia, Central America and along the Atlantic coast of Brazil (Ridgely & Tudor 1994). Marantz *et al*. (2003) recognized thirteen subspecies, six of which occur in the Brazilian Amazon. Three of these occur

within or adjacent to the Madeira basin: *G. s. castelnaudii* (west of the Madeira River to the Andes), *G. s. albigularis* (south-eastern Bolivia and Peru), and *G. s. inornatus*, which occurs throughout the Brazilian portion of the Madeira-Tapajós interfluvium (Peters 1951; Marantz *et al*. 2003). With a body mass ranging from 10.5 to 21g (typically 12.6-14.8 g in central Amazonia; Bierregaard, 1988), this is the smallest woodcreeper (Marantz *et al.* 2003), and it is the smallest of the three species we studied. It occurs in both *terra firme* and seasonally flooded forests (*várzea* and *igapó*) (Marantz *et al.* 2003) and it is moderately sensitive to environmental perturbation (Ferraz *et al.* 2007). Recently, Fernandes *et al*. (2013) found that populations of *G. s. inornatus* are delimited by the Aripuanã and Jiparaná rivers.

Willisornis poecilinotus – A species endemic to the Amazon basin, with seven subspecies recognized (Peters 1951; Zimmer & Isler 2003). Only one subspecies (*W. p. griseiventris*) is recognized from the middle and upper Madeira River basin; and there is no evidence of vocal or morphological differentiation across the Madeira, Aripuanã and Jiparaná rivers (Isler & Whitney 2011), although Bates (2000) found genetic differentiation (based on analyses of isozymes) across the Madeira River. Occurs in the understory of *terra firme* forest, where it is a regular follower of army ant swarms (Zimmer & Isler 2003). It is larger on average than *Glyphorynchus*, with a body mass ranging from 15 to 19 g (Zimmer & Isler 2003).

Schiffornis turdina – Nyári (2007), with no samples from the middle or lower Madeira River basin described close geographic proximity in the upper Madeira of two genetically distinct forms, showing no obvious vocal or plumage differences; the author proposed recognizing them as distinct species (*S. amazona* and *S. turdina*), as adopted by the Brazilian Ornithological Records Committee (2014). *Schiffornis turdina* (in the polytypic sense used here) occurs in the understory of *terra firme* and sandy-belt *campinarana* forests. Body mass averages 31 g (Snow 2004). This species is sensitive to forest fragmentation, disappearing from small forest fragments (Ferraz *et al*. 2007).

Extraction, amplification and sequencing of DNA

DNA was extracted from breast muscle (approximately 0.2 g) using a standard phenol chloroform protocol (Sambrook *et al*. 1989). The mitochondrial cytochrome *b* was amplified via the polymerase chain reaction (PCR) using the primers: *forward* H16064 5′-ATCTCARCCTGATGAAAYTTYGG-3′, reverse L14993 5′-AAGTGGTAAGTCTTCAGTCTTTGGTT-3′, both of which were designed exclusively for this project. All amplification reactions were performed in 25 µl volumes using a Thermo Hybaid PCR Express thermal cycler under the following conditions: (1) an initial denaturing step at 94°C for 5 min; (2) 35 cycles of the following: 1 min at 92°C, 1 min at 48°C, and 1 min at 72°C; (3) a 10-min extension step at 72°C. Following PCR, correct fragment size and the presence of a single amplification product was confirmed via electrophoresis on 1% agarose gel. After amplification, the PCR products were purified using a salt protocol (Sambrook *et al.* 1989). Sequencing was performed by the chain termination method (Sanger *et al*. 1977), using a Big Dye Termination Kit (Applied Biosystems) following the manufacturer's specifications. The products of the sequencing reaction were precipitated with Tris-HCl and alcohol, and resuspended in formamide and resolved by capillary electrophoresis in an ABI 3130xl automatic sequencer (Applied Biosystems). All sequences have been deposited in GenBank (accession numbers: HM164938 – HM165034).

Alignment

Sequences of DNA were visualized and edited using the Bioedit program (Hall, 1999). Alignments were performed in Clustal X within Bioedit (Hall, 1999). We used recommended precautions and are confident that all sequences represent mitochondrial DNA for the following reasons: (1) DNA was extracted only from tissue samples, which have high ratios of mitochondria to nuclei relative to blood or skin samples; (2) no stop codons occurred within the cytochrome *b* of any of the sequences; (3) sequences contain no insertions or deletions relative to one another or to other known avian cytochrome *b* sequences; (4) sequences in both DNA fragments from each individual were identical and unambiguous in their region of overlap; (5) in phylogenetic analyses, no samples appeared in unexpectedly basal portions of the tree or had exceptionally short or long branch lengths, both of which, if present, would indicate a fast evolving gene or an early diverged gene (a pseudogene, for example).

Phylogenetic analyses

Phylogenetic analysis of DNA sequence data was performed using maximum parsimony (MP) and maximum likelihood (ML) via PAUP* 4.0b10 (Swofford 2002) and Bayesian inference (BI) implemented in MRBAYES 3.0b4 (Hulsenbeck & Ronquist 2001). Maximum parsimony analysis was performed using a heuristic search with the following options: TBR branch-swapping with 10 trees held at each step. Support for nodes was assessed using 1000 bootstrap replicates. Maximum likelihood was performed using the model parameters determined in the program Modeltest

(Posada & Crandall 1998). The support for nodes in the likelihood tree was assessed using 500 bootstrap iterations. For BI analyses, two independent runs of 8,000,000 generations each were performed; for each run four Markov chains were simulated. Trees were sampled every 500 generations and the first 4,000 samples were discarded as burn-in.

Because there is strong evidence that geographic distributions of Amazonian birds are bounded by large rivers that form areas of Neotropical endemism, we used individuals from populations from other interfluvia as outgroups for the three species studied. For the analysis of *Glyphorynchus spirurus* we used two individuals collected in the headwaters of the Negro River (Appendix) as the outgroup. For *Willisornis poecilinotus*, we used one individual collected in the Solimões-Negro River interfluvium and for *Schiffornis turdina*, we used as outgroups one individual collected north of Manaus and also one sequence of *Schiffornis virescens* from GenBank (accession number AF453816; Appendix).

Phylogenetic divergence analyses

Phylogenetic divergence was estimated in the program BEAST v1.6.1 (Drummond & Rambaut 2007) using the coalescent constant population size tree prior (Drummond *et al*. 2002), the uncorrelated lognormal relaxed molecular clock model (Drummond *et al*. 2006), and the HKY (Hasegawa *et al*. 1985) models of molecular evolution, including gamma-distributed rate heterogeneity among sites and invariant sites. After preliminary runs, we adjusted priors and MCMC operators to assure optimum performance. To assess the robustness of estimates and investigate the influence of the tree prior, we also performed analyses under the exponential (Drummond *et al*. 2002) and the Bayesian skyline (Drummond *et al*. 2005) tree priors. To convert divergence time estimates into units of millions of years, we used the mean substitution rate of 0.01105 substitutions/site/lineage/million years as proposed by Weir & Schluter (2008).

For each set of priors, two independent MCMC analyses were run for 100 million generations, sub-sampling every 100 thousand generations. After a 10% burn-in, convergence of parameter estimates was assessed using the Gelman-Rubin statistic implemented in the module *coda* in the statistical package R (R Development Core Team 2011). Independent chains were combined, and marginal posterior parameter means and their associated 90% highest probability density intervals (90% HPD) together with effective sample size (ESS) for each divergence time estimate were calculated in the statistical package R (R Development Core Team 2011).

RESULTS

We found significant phylogeographic structure among populations within all three study species. The Madeira River clearly separates genetically distinct populations in all of them. Within the Madeira-Tapajós interfluvium, the degree of structure varied among species (see below). In each species, tree topologies were identical for all four tree-building algorithms, thus we only show the tree resulting from the Bayesian inference analyses. The pair-wise genetic p-distance between individuals from opposite banks of the three rivers ranged from 3.1 to 5.5% but the variation within interfluvia was low (0.0–0.09%). Results for each species were as follows:

Glyphorynchus spirurus

We sequenced a total of 946 bp for 27 individuals of *G. spirurus*. Parsimony, maximum likelihood, and Bayesian inference analyses suggested a genetic structure in the form of monophyletic groups on opposite banks of the Madeira, Aripuanã and Jiparaná rivers, each supported by high bootstrap values (MP = 100, ML = 100, BI = 1.00). No barrier effect was found on opposite banks of the Roosevelt River. Parsimony analysis yielded two equally parsimonious trees (length = 170, CI = 0.8235, RI = 0.9504). From 130 variable sites, 110 were parsimony informative. Maximum likelihood (-ln L = 2012.00097) and Bayesian inference resulted in a topology very similar to that of the parsimony analysis. Levels of genetic divergence (uncorrected p-distance) between individuals of different clades ranged from 3.2% (populations of AJ versus MJ) to 5.5% (populations of LM versus AT) and levels of divergence between individuals within the same interfluvium ranged from 0.0–0.03% (Figure 2). Coalescent analyses in the program BEAST indicate a 6.5 mya (1.9 – 32.7, 90% HDP) divergence between populations on the left and right banks of the Madeira River.

Willisornis poecilinotus

We sequenced a total of 956 bp for 46 *Willisornis poecilinotus* individuals. The results of parsimony, maximum likelihood, and Bayesian inference analyses were concordant, thus indicating a strong phylogenetic signal supported by high bootstrap values (MP = 100, ML = 100, BI = 1.00) (Figure 3). Parsimony analysis yielded 100 equally parsimonious trees (length = 94, CI = 0.8723, RI = 0.9634). From 71 variable sites, 41 were parsimony informative. Maximum likelihood (-ln L = 1757.25307) and Bayesian inference resulted in a topology very similar to that of the parsimony analysis. The level of genetic divergence (uncorrected p-distance)

between individuals of the two clades separated by the Madeira River, RM (right bank of Madeira River) versus LM (left bank of Madeira River), was 3.4% (Figure 3). Levels of divergence between individuals in the same interfluvium ranged from 0.0–0.09%. Coalescent analyses in the program BEAST indicate a 2.6 mya (0.8 – 13.8, 90% HDP) divergence between populations on the left and right banks of the Madeira River.

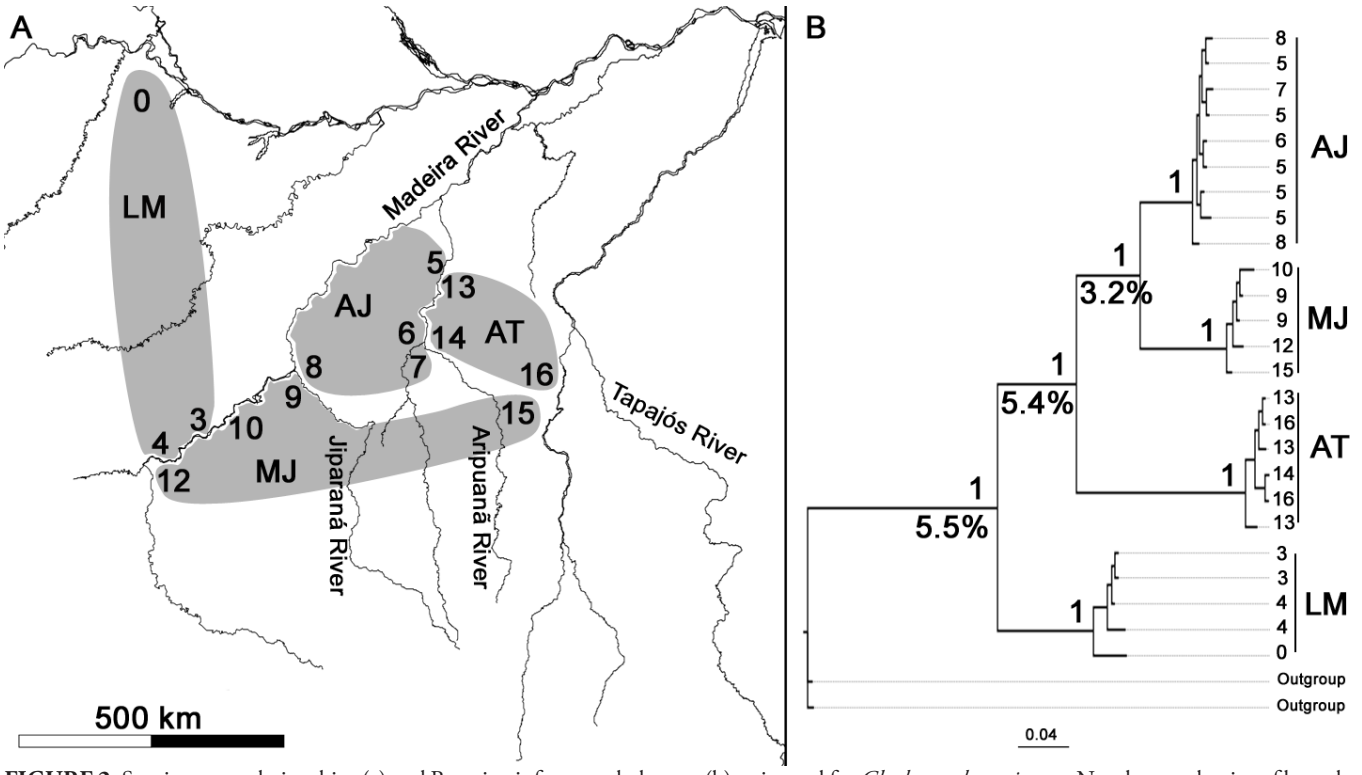

FIGURE 2. Species–area relationships (a) and Bayesian inference phylogeny (b) estimated for *Glyphorynchus spirurus*. Numbers at the tips of branches refer to localities where individuals were sampled. Bayesian inference (BI) posterior probabilities and genetic distance (uncorrected p-distance) values are indicated in the branches. Note grouping of a sample from the Aripuanã-Tapajós interfluvium (location 15) with those of the Madeira-Jiparaná interfluvium (see Discussion).

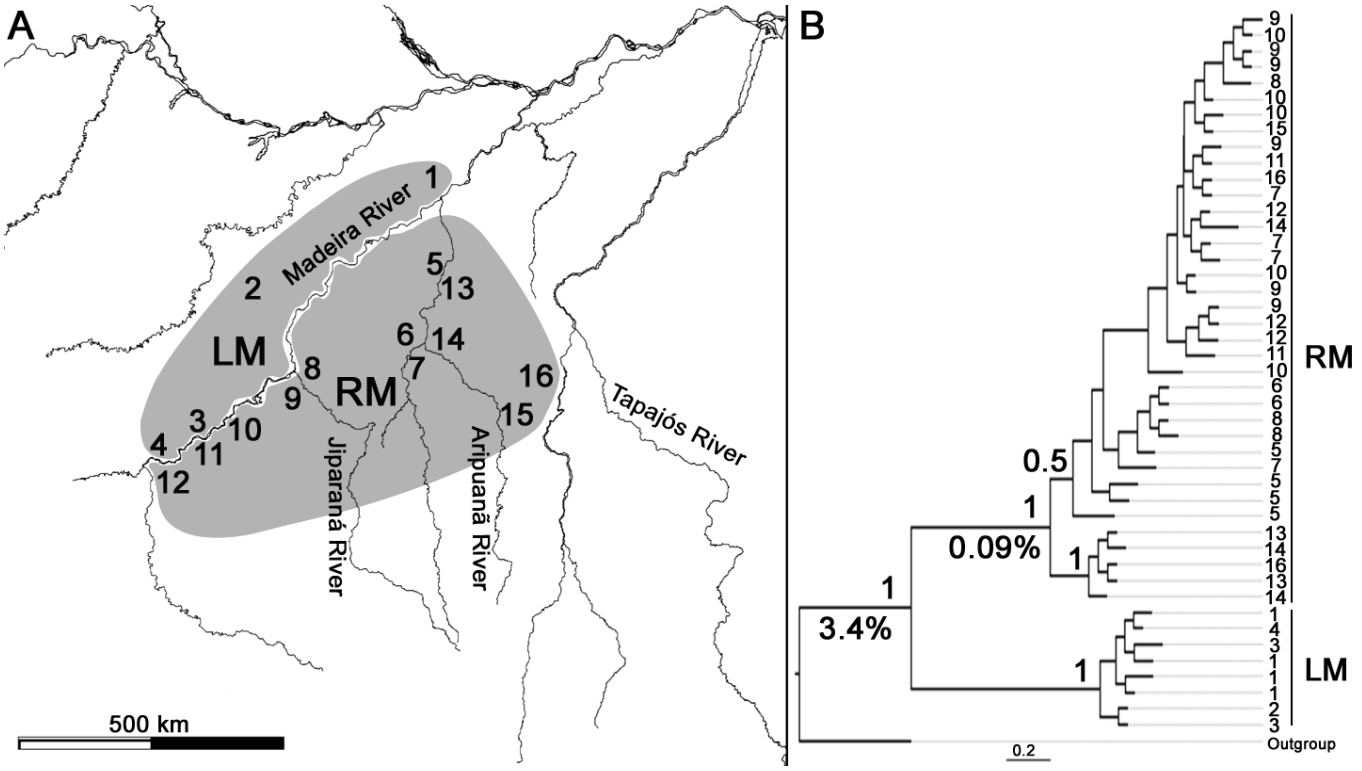

FIGURE 3. Species–area relationships (a) and Bayesian inference phylogeny (b) estimated for *Willisornis poecilinotus*. Numbers at the tips of branches refer to localities where individuals were sampled. Bayesian inference (BI) posterior probabilities and genetic distance (uncorrected p-distance) values are indicated in the branches.

Schiffornis turdina

We sequenced a total of 968 bp for 25 *Schiffornis turdina* individuals. Parsimony, maximum likelihood and Bayesian inference analyses suggested genetic structure on opposite banks of the Madeira River supported by high bootstrap values (MP = 100, ML = 98, BI = 1.00) (Figure 4). Parsimony analysis yielded 48 equally parsimonious trees (length = 175, CI = 0.9371, RI = 0.9214). From 159 variable sites, 67 were parsimony informative. Maximum likelihood (-ln L = 2043.26577) and Bayesian inference resulted in a topology very similar to that of the parsimony analysis consensus topology. The maximum divergence (uncorrected p-distance) between individuals of the RM and LM clades was 3.1% (Figure 4). Levels of divergence among individuals of the same interfluvium ranged from 0.0–0.3%. Coalescent analyses in the program BEAST indicate a 3.1 mya (1.0 – 15.2, 90% HDP) divergence between populations on the left and right banks of the Madeira River.

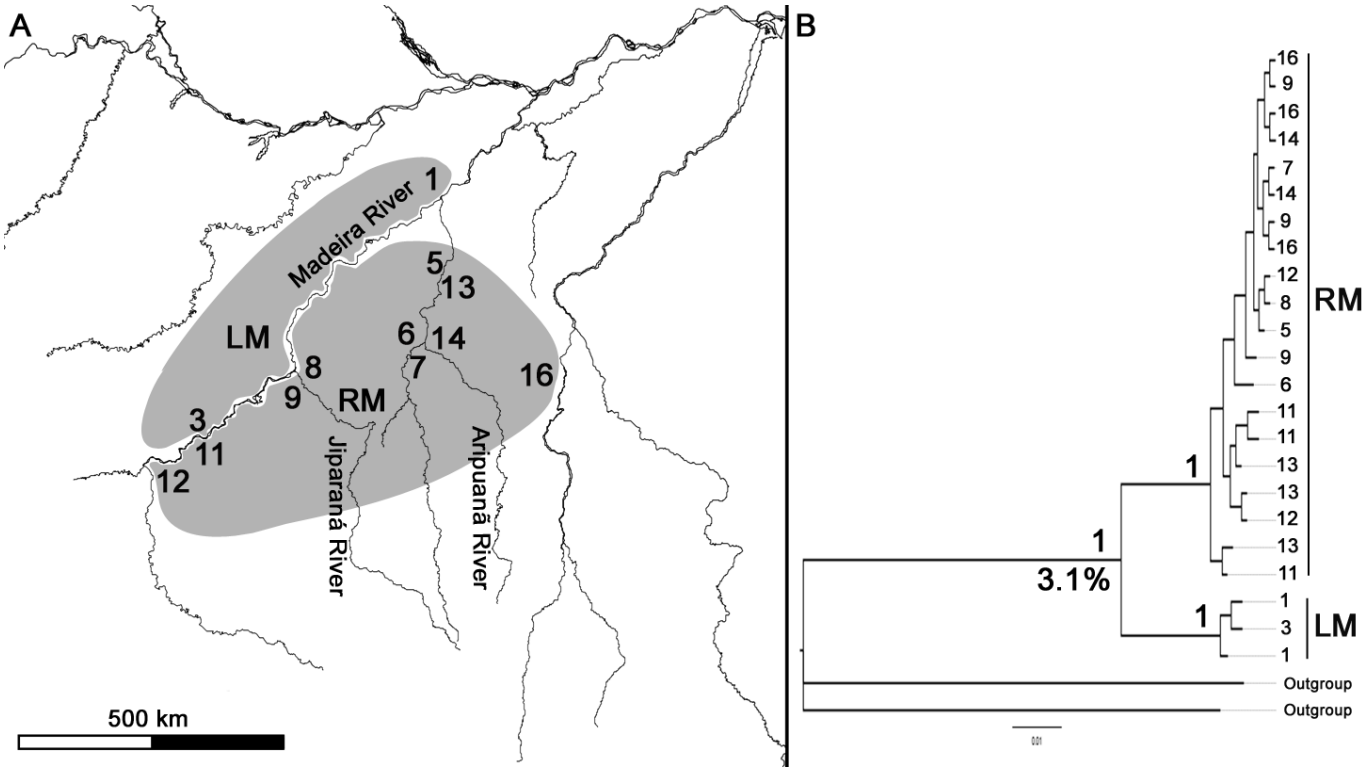

FIGURE 4. Species–area relationships (a) and Bayesian inference phylogeny (b) estimated for *Schiffornis turdina*. Numbers at the tips of branches refer to localities where individuals were sampled. Bayesian inference (BI) posterior probabilities and genetic distance (uncorrected p-distance) values are indicated in the branches.

DISCUSSION

Strong genetic differentiation in the face of highly conserved phenotype is at the heart of numerous descriptions of "cryptic species" in recent years (Whitney *et al*. 2013a, b, c, d, e) and appears to be a frequent phenomenon in the Amazon. In *S. turdina*, differentiation on opposite banks of the middle and lower reaches of the Madeira River is consistent with that detected earlier in the upper Madeira (Nyári 2007) and associated with species level taxa. In all three studied species, the observed molecular groups are monophyletic and parapatrically distributed, their geographic distributions are delimited by rivers, and the observed phylogenetic divergence between clades on opposite banks of the Madeira River (3.1–5.5%) is consistent with interspecific divergences in other avian taxa separated by the same geographic barrier (Ribas *et al*. 2012). Based on coalescent analyses (see Methods), we estimated mean divergences of 6.5 mya, 2.6 mya and 3.1 mya between populations on left and right banks of the Madeira River for *G. spirurus*, *W. poecilinotus* and *S. turdina*, respectively. The separation of the lineages in all three species of passerines are clearly ancient, all lineages are diagnosable by multiple molecular synapomorphies, and all lineages are parapatrically distributed and likely represent phylogenetic species. However, it is also clear that a more detailed analysis evaluating species status and establishing species boundaries is necessary.

Irrespective of taxonomy, the pattern of geographic variation delimited by rivers is clear for all three taxa studied. Our results indicate genetically distinct populations on opposite banks of the Madeira River. For all three species analyzed in this study we found sister

clades on opposite banks of the Madeira River, and for *G. spirurus*, as documented previously (Fernandes *et al*. 2013), the data further indicated sister clades on opposite banks of the smaller Aripuanã and Jiparaná rivers. Our data therefore reinforce the importance of rivers as geographic barriers, and suggest a hierarchical effect in which larger rivers divide older clades whereas smaller rivers are associated with more recent divergences. For *G. spirurus*, an individual collected on the right bank of the Aripuanã River that grouped in the clade Madeira/Jiparaná (MJ) provides evidence of upstream gene flow across both of the same rivers (Jiparaná and Aripuanã) that delimit differentiated populations in their lower reaches. Since rivers naturally tend to be narrower in the upper reaches, this result suggests that river width is important in determining a river's likelihood of delimiting distributions and further strengthens the hypothesis of a hierarchical effect of river width in structuring populations (Haffer 1974, 1997).

Assuming roughly equal rates of substitution, then *Willisornis poecilinotus* and *Schiffornis turdina* populations may have differentiated across the Madeira River at about the same time; however, *Glyphorynchus spirurus* would appear to have differentiated much earlier. This implies that not all sympatric bird taxa necessarily share the same evolutionary scenario. Although the Madeira River currently delimits the distributions of the left- and right-bank clades of all three species, the Madeira River might not necessarily be the primary agent that has driven the observed divergence. It may simply represent current limits of distribution for clades that have diverged due to other abiotic or biotic forces, independent of the formation of the Madeira River itself. Another non-exclusive possibility is that rates of molecular substitutions are 2–3 times faster in *G. spirurus* than in *W. poecilinotus* and *S. turdina*; however, such an elevated substitution rate appears to be a rare phenomenon in passerine birds, and has been suggested only for one case of an Old World species (*Nectarinia humbloti*; Warren *et al*. 2003). Finally, a third explanation suggested previously (Willis 1969, Fernandes *et al*. 2012, 2014) is that changes in the courses of rivers might confuse the phylogenetic pattern. There is evidence that the course of rivers in the Madeira basin changed throughout history, but remained stable for long periods of time (Latrubesse 2002). The period of stability could be enough to cause differentiation until their course was modified again and became stable for another long period of time thus causing both spatial and temporal incongruences among phylogenies of co-distributed species (Fernandes 2013). A comparative analysis including additional species and sampling nuclear markers is likely to shed more light on this issue, but at least three other studies have found populations separated by the Madeira River not to be reciprocally monophyletic (Aleixo 2004, Patané *et al*. 2009, Sousa-Neves *et al*. 2013), as recovered herein for *G. spirurus*, *W. poecilinotus*, and *S. turdina*, hence supporting a more complex scenario of differentiation and a broad range of phylogeographic patterns for the same region.

Despite the importance of rivers for avian differentiation, even the largest Amazonian rivers are not barriers for all species and smaller rivers are less likely to be barriers than larger rivers. There are several potential explanations for this phenomenon. Molecular studies suggest that populations of canopy species are less structured than those of understory birds (Capparella 1988; Burney & Brumfield 2009). The latter authors showed that genetic divergence is significantly smaller across the Andes and two Amazonian rivers (Amazon and Madeira rivers) in canopy birds than in understory species. Burney & Brumfield (2009) further suggested that there is a negative relationship between dispersal propensity and genetic structure. Species that occupy the understory are supposed to be less effective dispersers, which may be one reason why there are more species of understory birds, and that they are more locally distributed.

However, we found differences in genetic structure among understory species, suggesting that other factors may also influence the diversification of birds. One might also expect the degree of sensitivity to disturbance or habitat specialization on primary *terra firme* forest to predict the importance of rivers in driving or maintaining allopatric differentiation. Ferraz *et al*. (2007) analyzed thirteen years of capture/recapture data for birds in the reserves managed by the Biological Dynamics of Forest Fragmentation Project (BDFFP), located in the Brazilian state of Amazonas north of Manaus. These authors derived measures of the vulnerability of a species to isolation and sensitivity due to fragment size. These two measures reflect sensitivity to environmental change. Among the 54 species examined by Ferraz *et al*. (2007), *G. spirurus* was the least sensitive to the size of the fragment and one of the ten species least vulnerable to isolation. By contrast, *S. turdina* was among the most vulnerable and most sensitive species. *Willisornis poecilinotus* was not included in the analysis. One would therefore expect *G. spirurus*, the species least affected by isolation and fragmentation, to have lower genetic divergence across the rivers than the other two species; however, our results contradict the expected pattern. *Glyphorynchus spirurus*, although occurring in different types of forests and not being especially sensitive to disturbance, has populations that are much more strongly structured than are those of the other two species. In this case, sensitivity to disturbance and degree of specialization on primary *terra firme* forest were not good predictors of the degree of population genetic structure.

The Jiparaná and Aripuanã rivers separate populations of *G. spirurus*, the smallest species we examined (average body mass 13.7 g), but not the populations of two other species, *W. poecilinotus* (15–19 g) and *S. turdina* (30–35.5 g). The Jiparaná and Aripuanã rivers also appear to limit the distributions of populations in other very small birds, including *Hemitriccus minor* (Sardelli 2005), *Hypocnemis rondoni* (Isler *et al*. 2007; Tobias *et al*. 2008; Whitney *et al*. 2013a), *Herpsilochmus stotzi* (Whitney *et al*. 2013b), *Hylophylax naevius* (Fernandes *et al*. 2014) and *Picumnus aurifrons* (Cohn-Haft *et al*. 2007), all of which weigh on average less than 13 g each. In other parts of the world, tiny birds make spectacular long-distance migrations and even in Amazonia, where most species tend to be sedentary (Stotz *et al*. 1996), certain species, such as those adapted to river islands (Remsen & Parker, 1983; Rosenberg, 1990), are likely to be excellent dispersers, independent of size. However, there is evidence that at least two other heavier bodied species have structured populations delimited by the Aripuanã and Jiparaná rivers as well: *Thamnophilus aethiops* (23-30g; Thom & Aleixo 2015) and *Malacoptila rufa* (36-44g; Ferreira 2013). As discussed by Smith *et al.* (2014) differences in life history attributes, effective population sizes, lineage ages, and dispersal rates can together account for highly disparate responses of avian lineages across important physical barriers in the Neotropics such as the Andes and some large Amazonian rivers, including the Madeira River. Further tests, controlling for phylogeny, habitat, wing shape and loading, and behavioral responses to open spaces, will be necessary to determine the extent to which body mass is a useful predictor of genetic population structure in suboscine passerines.

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APPENDIX

Information on the specimens analyzed.

Population/Locality	Taxon: Voucher/Genbank accession numbers
0/ AM: right bank of lower Juruá, RESEX Baixo Juruá, comunidade Socó. 3°36'S; 66°4'W	*G. spirurus*: INPA A 808/HM164938
1/ AM:"Campo do Lago Preto", left bank of Madeira river, 39 km W Novo Aripuanã. 5°09'S; 60°44'W	*W. poecilinotus*: INPA A 420/HM164985,421/HM164980, 422/HM164994, 424/HM164975. *S. turdina*: INPA A 395/ HM165029, 413/HM165028
2/ AM: right bank Purús river, Ussuá stream, tributary of Mucuim river (right bank). 7°13'S; 64°10'W	*W. poecilinotus*: INPA A 101/HM164978
3/ RO: left bank of the Madeira river, near Jacy Paraná, ca. 45 km southwest Porto Velho. 9°10'S; 64°23'W	*G. spirurus*: INPA A 349/HM164942, 359/HM164941. *W. poecilinotus*: INPA A 345/HM164983, 347/HM164999, *S. turdina* INPA A 348/HM165032
4/ RO: left bank of the Madeira river, ca. 20 km N Abunã. 9°31'S; 65°21'W	*G. spirurus*: INPA A 173/HM164943, 191/HM164960. *W. poecilinotus*: 182/HM164984
5/ AM: left bank of Aripuanã river, Arauazinho stream, 130 km S Novo Aripuanã. 6°18'S; 60°24'W	*G. spirurus*: INPA A 461/HM164951, 466/HM164950, 510/HM164952, 553/HM164963, 562/HM164962. *W. poecilinotus*: INPA A 465/HM164974, 472/HM164967, 475/HM165009, 504/HM164971. *S. turdina*: INPA A 533/ HM165014
6/ AM: left bank of lower Roosevelt river, confluence with Aripuanã river. 7°35'S; 60°43'W	*G. spirurus*: INPA A 906/HM164945. *W. poecilinotus*: INPA A 902/HM164976, 904/HM164992. *S. turdina*: INPA A 903/ HM165017.

7/ AM: right bank of lower Roosevelt river, confluence with Aripuanã river. 7°38'S; 60°40'W	*G. spirurus*: INPA A 895/HM164948. *W. poecilinotus*: INPA A 894/HM164997, 896/HM165007, 900/HM165003, 898/HM165001. *S. turdina*: INPA A 893/HM165015
8/ RO: right bank lower Jiparaná river, comunidade Demarcação, ca. 20 km southeast Calama. 8°09'S; 62°47'W	*G. spirurus*: INPA A 875/HM164946, 877/HM164958. *W. poecilinotus*: INPA A 876/HM164989, 884/HM164990, 907/HM165008. *S. turdina*: INPA A 885/HM165016
9/ RO: left bank of lower Jiparaná river, opp. Comunidade Demarcação, ca. 20 km southeast Calama. 8°14'S; 62°46'W	*G. spirurus*: INPA A 870/HM164964, 886/HM164940. *W. poecilinotus*: INPA A 871/HM164982, 872/HM164996, 873/HM165000, 878/HM164988, 881/HM165010, 882/HM164977. *S. turdina*: INPA A 874/HM165034, 880/HM165021, 883/HM165018
10/ RO: right bank of Madeira river, 9.5 km southeast Porto Velho. 8°52'S; 64°0'W	*G. spirurus*: INPA A 329/HM164959. *W. poecilinotus*: INPA A 307/HM164966, 308/HM164970, 326/HM164968, 327/HM164973, 334/HM164972
11/ RO: right bank of Madeira river, near Jacy Paraná, ca. 45 km southwest Porto Velho	*W. poecilinotus*: INPA A 367/HM165002, 368/HM164969. *S. turdina*: INPA A 371/HM165030, 372/HM165025, 374/HM165026
12/ RO: right bank of Madeira river, ca. 20 km N Abunã. 9°35'S; 65°21'W	*G. spirurus*: INPA A 208/HM164949. *W. poecilinotus*: INPA A 248/HM165005, 264/HM165006, 265/HM164993. *S. turdina*: INPA A 249/HM165031, 266/HM165012
13/ AM: right bank of Aripuanã, Extremo stream, 135 km S Novo Aripuanã. 6°18'S; 60°20'W	*G. spirurus*: INPA A 536/HM164944, 559/HM164947, 561/HM164955. *W. poecilinotus*: INPA A 478/HM164987, 479/HM164979. *S. turdina*: INPA A 525/HM165027, 527/HM165023, 538/HM165024
14/ AM: right bank of middle Aripuanã, confluence with Roosevelt river. 7°37'S; 60°40'W	*G. spirurus*: INPA A 890/HM164954. *W. poecilinotus*: INPA A 887/HM164995, 888/HM164981, 891/HM165004. *S. turdina*: INPA A 892/HM165033, 889/HM165019
15/ AM: Floresta Estadual do Sucunduri, right bank of upper Sucunduri river. 8°34.5'S; 59°08.5'W	*G. spirurus*: INPA A 845/HM164957. *W. poecilinotus*: INPA A 849/HM164998. *S. turdina*: INPA A 846/HM165013, 848/HM165022, 850/HM165020
16/ AM: Parque Estadual do Sucunduri; right bank of Bararati river. 8°21'S; 58°37'W	*G. spirurus*: INPA A 852/HM164953, 855/HM164956. *W. poecilinotus*: INPA A 856/HM164986, 857/HM164991
Outgroup/ AM: right bank of upper Negro river, 3 km SW São Gabriel da Cachoeira. 0°8'S; 67°5'W	*G. spirurus*: INPA A 1153/HM164939
Outgroup/ AM: left bank upper Negro river, 10 km east São Gabriel da Cachoeira. 0°10'S; 66°59'W	*G. spirurus*: INPA A 1118/HM164961
Outgroup/ AM: left bank middle Solimões river; RDS Amanã, Comunidade Nova Canaã, Centro Grande stream. 2°36'S; 64°52'W	*W. poecilinotus*: INPA A 398/HM164965
Outgroup/ AM: ca. 60 km N Manaus; highway BR-174, km 43; Campina reserve/INPA	*S. turdina*: INPA A 777/HM165011

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ARTICLE

Core and transient species in an Amazonian savanna bird assemblage

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ABSTRACT: In this paper, we report the number of core and transient bird species in an Amazonian savanna site and assess their ecological differences. We conducted our study at Campo Experimental do Cerrado (CEC) da Embrapa–Amapá, 48 km north of Macapá (0°2'5" N / 51°2'2" W), Amapá, Brazil. Forty points were monitored on a monthly basis over the course of one year, using the unlimited-distance point counts in a plot of 360 hectares of well-preserved and relatively homogeneous upland savanna from September 2006 to August 2007. Species were classified in core (recorded in the area in nine or more months), transient (recorded in the area in four or less months) and intermediate (the ones recorded between five and eight months). Species were also classified according to feeding guilds and habitat preferences. Statistical analyses were made to compare core and transient species. We recorded 72 species in the plot, of which 36 were transients, 12 were intermediates, and 22 were core. Core species have higher abundances than transient species. Core species are found mostly in the savanna while transient species also occur in other habitats within the landscape. Both core and transient groups presented well-marked seasonal variation in abundance. Recruitment explains abundance variation for core species, while differences in the availability of food resources in the site explains variation of the abundance in transient species. We predict that plot-level (not more than 500 hectares) bird assemblages in South American savannas will be composed of a small number of abundant and habitat-restricted species that occupy the site almost year round, combined with a high number of low abundant transient species that are habitat generalists and use the plot only during limited periods of their annual life cycle.

KEY-WORDS: conservation biogeography, landscape dynamics, local assemblages, South America, tropical savannas.

INTRODUCTION

The most common approach to biodiversity conservation is to identify and protect natural features such as ecosystems and threatened species, whose distributions can be mapped and targeted through conservation management activities (Watson *et al.* 2011). While such an approach is important, the conservation of species and ecosystems cannot be achieved unless the ecological and evolutionary processes that sustain them are understood and maintained (Cowling *et al*. 1999, Fuller *et al*. 2001).

One of the most important ecological processes to be documented for any conservation plan is the movement of organisms (Bennett *et al*. 2009). Organisms move at different scales and for many purposes: to find food and shelter, for social interactions, to track resources that vary irregularly over space and time, for seasonal migration, and to disperse and establish in new locations (Bennett *et al*. 2009).

Movements of populations and species link habitat patches within a landscape, landscapes within a region, and entire regions (Wiens 1992). Therefore, a thorough understanding of the major patterns of biological movements from the local to the regional scales is a critical step towards the design of conservation systems that maintain ecological flows and enable the resilience of populations against the effects of global changes (Watson *et al.* 2011).

One concept that has not yet been fully explored in conservation biogeography is the important distinction between core and transient species (Grinnell 1922, Magurran & Henderson 2003). Core species are those that persist in a habitat patch (or site) through time and transient species are those that occur intermittently in a habitat patch (or site) as a result of dispersal from surrounding habitats or regions (Coyle *et al*. 2013).

Core and transient species usually differ in their ecological requirements as well as their abundance patterns (Magurran & Henderson 2003, Magurran 2007). Core species are predicted to be locally abundant,

habitat-restricted, and follow a lognormal abundance distribution, whereas transient species are predicted to be rare, habitat generalist, and follow the log series abundance distribution model (Magurran 2007, Belmaker 2009).

Core and transient species arise in local assemblages through different mechanisms. Core species are influenced mostly by local-scale factors that allow the persistence of the species in a habitat patch, whereas transient species are influenced mostly by regional factors that govern the number of species that potentially could move into the habitat patch from the surrounding landscape (Coyle *et al*. 2013).

Tropical avian assemblages are well known to exhibit temporal and spatial variation in their species' richness and abundance at the site scale (Karr 1976, Loiselle 1988, Poulin *et al*. 2001). These variations are usually correlated with the availability of fruit, flowers, seeds, and insects that are, in turn, impacted by seasonal changes in rainfall and associated soil moisture cycles (Karr 1976). In regions with long dry seasons, resource availability is low during the dry season and high during the wet season (Poulin *et al*. 2001, Blendiger 2005). Resource scarcity during the dry season can create ecological 'crunches' or 'bottlenecks' that limit species' abundances and biotic interactions and processes (Wiens 1977, 1992).

Temporal variance in abundances of tropical birds at the site scale can be caused by population recruitment and mortality (Blake & Loiselle 1991) but short-term (e.g., < 3 months) variations in abundance can be caused by movements of individuals into or out of a site (Martin & Karr 1986). Movements by individuals have been suggested as an important cause of the variance in tropical bird abundances (Martin & Karr 1986, Silva *et al*. 2011), but very few studies have evaluated the contribution of core and transient species on the richness and abundance of local assemblages (Karr & Freemark 1983, Poulin *et al*. 2001).

Here we report for the first time the numbers of core and transient bird species in a 360-ha plot of relatively uniform Amazonian upland savanna. We assessed the variation of the bird assemblages in this plot over a one-year period. Then we identified the core and transient species and evaluated how these two groups of species differ in their species richness, abundance, feeding habitats, and habitat use. In addition, we evaluated how species richness and abundance of the core and transient groups vary over time. We used our findings to propose some general predictions on the contribution of the core and transient species for site-level bird assemblages in South American upland savannas.

STUDY AREA

Our field research was conducted at Campo Experimental do Cerrado (CEC) of Embrapa–Amapá, 48 km north of Macapá (0°2'5" N / 51°2'2" W), Amapá, Brazil. The CEC protects 796 ha of well-managed South American upland savannas.

The CEC landscape has four major habitat types: upland savannas, wet grasslands, gallery forests, and anthropic areas. Upland savannas compose the matrix of the landscape. They occupy nutrient-poor soils, with strong to medium acidity, low in organic matter and with frequent iron concretions. Savanna vegetation is low, with few (usually no more than 100 per hectare) short (up to 4-6 m) trees (Silva *et al*. 2011). The grass *Trachypogon plumosus* and the sedge *Bulbostylis spadicea* dominate the ground (Sanaiotti *et al*. 1997). Wet grasslands are found in narrow valleys where soils are shallow and permanently inundated. Narrow belts of *Mauritia martiniana* palms can be used to identify the position of these wet grasslands. Gallery forests are linear formations (usually 15-25 m tall) that are restricted to wide valleys formed by the permanent streams that cut the landscape. Tree species such as *Jacaranda copaia* and *Symphonia globulifera* as well as palms such as *Euterpe oleracea* are the most common species in these gallery forests. Anthropic areas used for agriculture and agro-forestry experiments are small in size and are located near the CEC's housing and laboratory facilities.

The climate is hot (average temperature of 27ºC) and humid (average relative humidity of 81%). Average annual precipitation from 1961 to 1990 is around 2,700 mm with a well-marked dry season from August to November, when total monthly rainfall is below 50 mm.

METHODS

We set 40 sampling points within a plot of 360 hectares of well-protected and relatively homogeneous upland savanna located at 0°2'5" N / 51°2'2" W. We set points at least 300 m apart to maintain sample independence and at least 300 m from any habitat edge. We used this distance because Tubelis *et al*. (2004) found that forest birds do not move more than 200 m within the savannas in central Brazil. Our goal with this approach was to sample the avifauna in the most homogenous savanna area possible, avoiding the influence of other habitats in the landscape as well as edges or transitional vegetation.

To study the bird assemblages within the plot, we used the unlimited-distance point count method (Blondel *et al*. 1970). For 10 min we noted all birds seen or heard in each point. For species that travel in groups, when we heard but did not see the birds, we assumed that the group size was the average from when we did see and count a group of the same species. We noted the species seen while the observer walked between points, but these sightings were not included in the quantitative analyses. The order of point sampling changed every month to eliminate any

bias. RB conducted all monthly censuses from September 2006 to August 2007, always between 06h00 and 08h00. She used a Pentax 8X40 binocular and a Sony TCD5 PRO II tape-recorder with a Sennheiser ME67 microphone.

Following Coyle *et al*. (2013), we classified each species as core if it was present in the plot for at least two-thirds of the period of time that was surveyed (nine months or more) and transient if it was present in no more than one-third of the surveyed period (four months or less), regardless of whether the species was recorded or not breeding in the plot. Intermediate are those species that were neither classified as core nor as transients. We used this pragmatic approach to minimize misclassification at the expense of excluding a small fraction of intermediate species from analyses.

Species were also classified as habitat-restricted if they were recorded in the landscape only in the upland savannas; they were classified as habitat non-restricted when they were also found in other natural habitats within the landscape. Our classification is based on qualitative data collected by RB during our study period in other habitats as well as the information reported by Silva *et al*. (1997) for our study area.

We classified bird species into six major guilds based on their diet. These feeding guilds are: (RS) raptors + scavengers (including families of Cathartidae, Accipitridae and Falconidae); (IN) insectivores; (IF) insectivore-frugivore; (FG) frugivore-granivore; (GR) granivore; and (NE) nectarivore. We used personal field experience and literature (Silva 1995, Silva *et al*. 1997, Sick 1997) to classify species into feeding guilds.

We calculated the monthly richness for core and transient groups as well as for each feeding guild by summing up the number of species of each group recorded monthly in the plot. We calculated the monthly abundance for each species, summing up its number of detections in all 40 points (Maron *et al*. 2005). By summing up monthly abundances of species, we were able to calculate monthly abundances for the entire core and transient species groups as well as the annual abundance for each species.

We used the Kolmogorov-Smirnov test to test if the species abundance distributions of core and transient groups were different. We used the Median Test to determine if species classified as core and transient differed in their annual abundances. We used the G-Test to evaluate if proportions of core and transient species among feeding guilds as well as habitat use categories were different. We used the G-Test for goodness-of-fit to a uniform distribution to determine whether abundances and species richness of core and transient groups showed any variation over time. We used Biostat 5.0 (Ayres *et al*. 2007) for all statistical analyses. Latin and English names of the bird species follow Remsen *et al*. (2014).

RESULTS

We recorded 72 species in the plot, corresponding to 37.2% of all species recorded in the entire site until now (Boss 2009). The presence of species in the plot over the year follows the expected bimodal pattern (Figure 1) with 36 transients, 12 intermediates and 22 core species. Intermediate species were *Colinus cristatus*, *Columbina passerina, Thalurania furcata*, *Amazilia fimbriata*, *Heliactin bilophus, Caracara cheriway, Milvago chimachima, Amazona ochrocephala*, *Amazona amazonica, Myiarchus ferox*, *Cyclarhis gujanensis*, *Piranga flava*, *Thraupis palmarum*, *and Sporophila plumbea.*

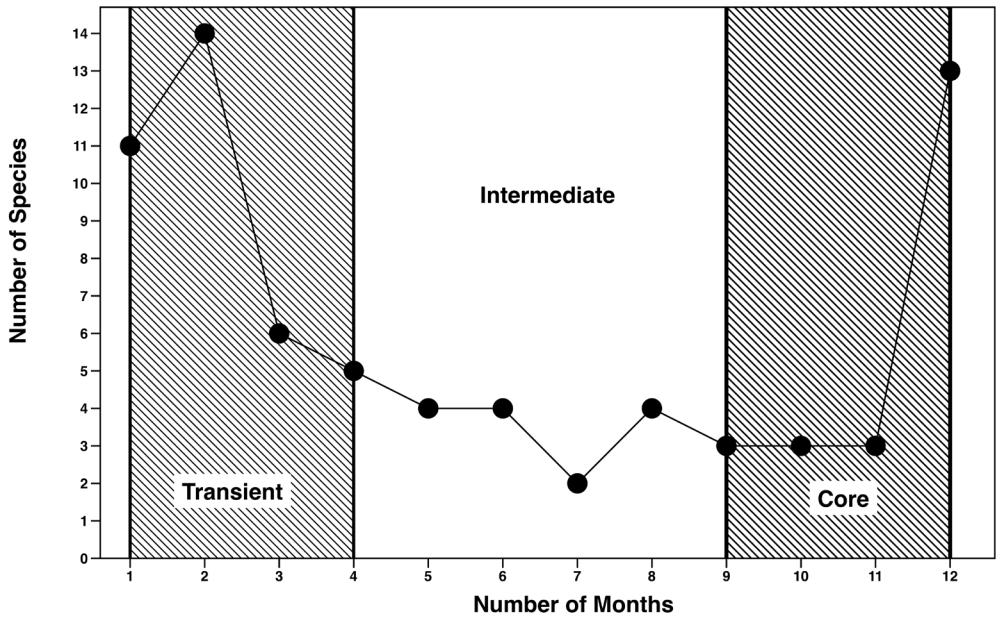

FIGURE 1. Temporal occupancy of bird species in the 360-ha plot of upland savanna in Amapá, Brazil. The temporal occupancy of a species is the number of surveyed months in which the species was recorded as present. Core species were those recorded in nine or more months and transient species were those recorded in four our less months.

The abundance distribution patterns of core and transient groups (Figure 2) are significantly different (KS, Dmax = 0.91, $p < 0.001$). Core species are significantly more abundant than transient species (Median Test, $\chi^2 = 36.6$, $p < 0.001$). The frequencies of core and transient species among the five guild categories (Figure 3) are not different (G = 3.97, $df = 5$, $p < 0.55$). In contrast, core and transient species are very different in their habitat use (G = 27.2, $df = 1$, $p < 0.0001$) because most of the core species (68.2%) are found only in savannas, whereas most of the transient species (94.4%) occur in two or more habitats (Table 1).

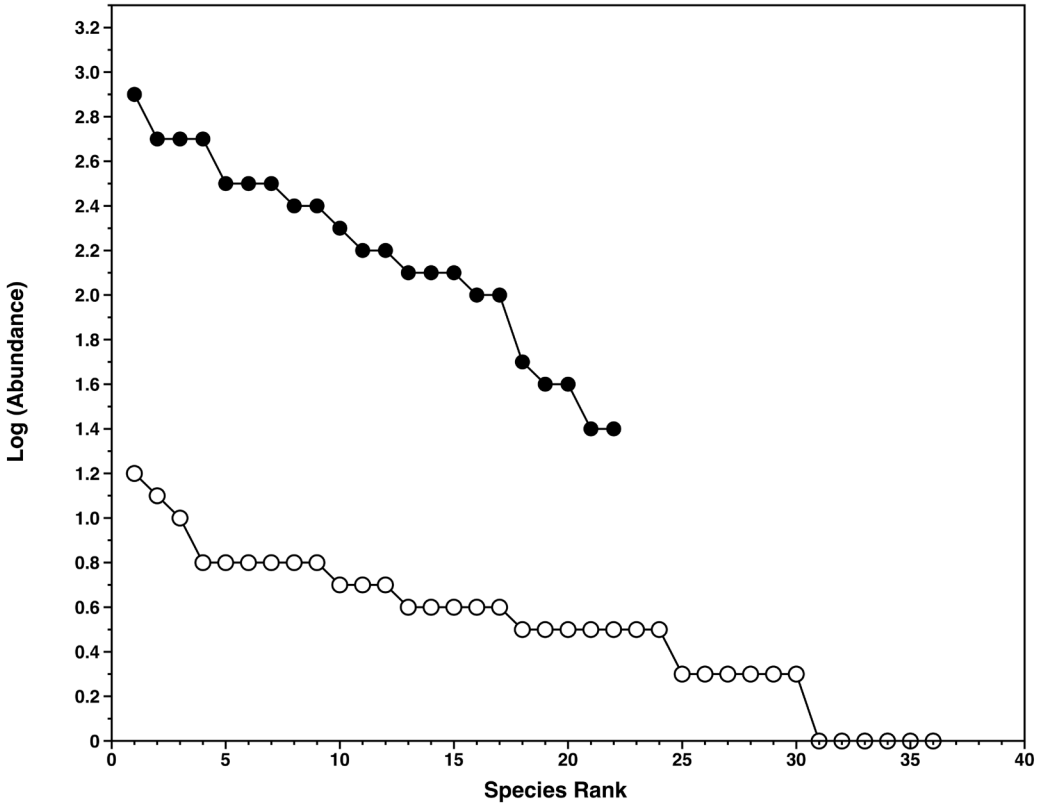

FIGURE 2. Abundance distributions patterns of core (black) and transient (white) bird species recorded in a 360-ha plot of an upland savanna in Amapá, Brazil.

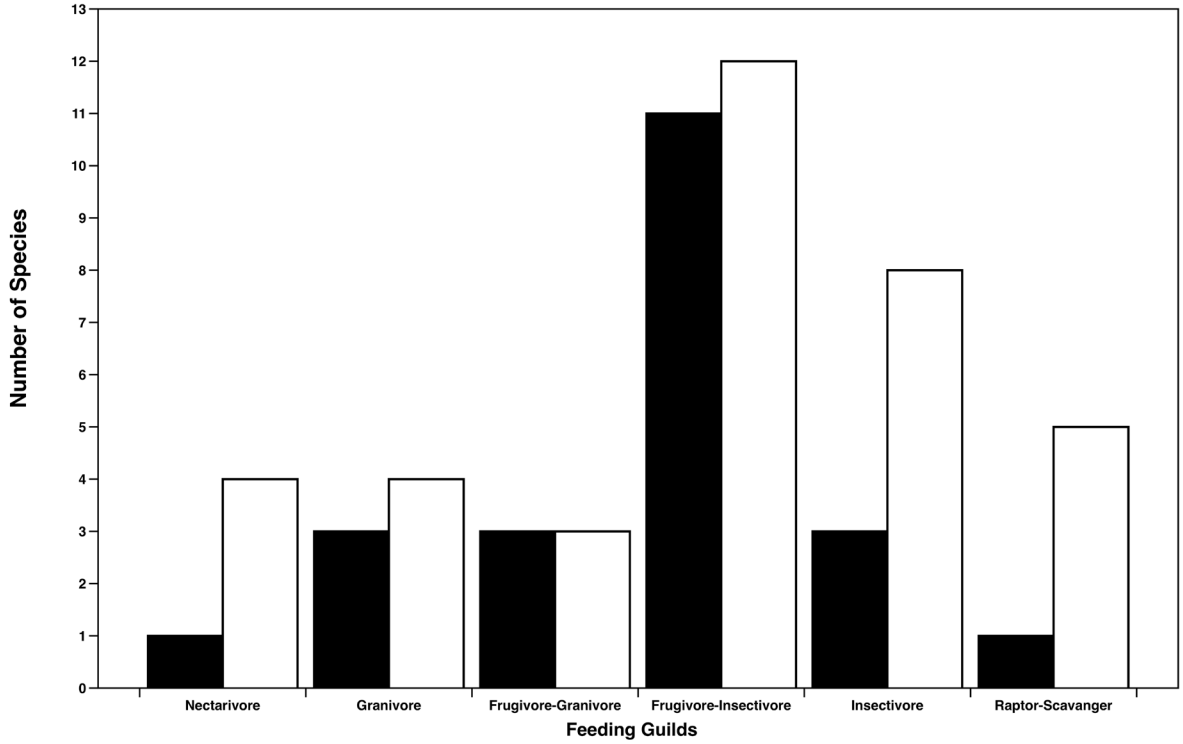

FIGURE 3. Numbers of core (black) and transient (white) species among five feeding guilds recorded in a 360-ha plot of an upland savanna in Amapá, Brazil.

TABLE 1. List of bird species recorded during one year in a 360 hectares of savanna upland at Campo Experimental do Cerrado, Embrapa-Amapá, Amapá, Brazil. Core species are those found during at least nine months while transient species were reported in less than four months. Feeding guilds are: RS (raptors + scavangers), IN (insectivores), IF (insectivore-frugivore), FG (frugivore-granivore), GR (granivore), and NE (nectarivore). Habitat categories are: (1) restricted to upland savanna; (2) recorded in other habitats in the broad landscape. Annual abundance is the total number of detections of the species over one year.

Species	English Name	Feeding Guild	Habitat	Annual Abundance
CORE SPECIES				
Geranoaetus albicaudatus	White-tailed Hawk	RS	2	27
Patagioenas cayennensis	Pale-vented Pigeon	FG	2	129
Zenaida auriculata	Eared Dove	FG	1	103
Aratinga aurea	Peach-fronted Parakeet	FG	1	161
Eupetomena macroura	Swallow-tailed Hummingbird	NE	2	38
Colaptes campestris	Campo Flicker	FI	1	23
Lepidocolaptes angustirostris	Narrow-billed Woodcreeper	IN	1	153
Elaenia flavogaster	Yellow-bellied Elaenia	FI	2	331
Elaenia chiriquensis	Lesser Elaenia	FI	1	185
Suiriri suiriri	Suiriri Flycatcher	FI	1	332
Xolmis cinereus	Gray Monjita	IN	1	327
Tyrannus albogularis	White-throated Kingbird	FI	1	131
Tyrannus melancholicus	Tropical Kingbird	FI	2	102
Tyrannus savana	Fork-tailed Flycatcher	FI	1	816
Myiarchus swainsoni	Swainson's Flycatcher	FI	1	256
Troglodytes aedon	House Wren	IN	2	38
Mimus saturninus	Chalk-browed Mockingbird	FI	2	134
Neothraupis fasciata	White-banded Tanager	FI	1	552
Cypsnagra hirundinacea	White-rumped Tanager	FI	1	486
Emberizoides herbicola	Wedge-tailed Grass-Finch	GR	1	273
Ammodramus humeralis	Grassland Sparrow	GR	1	554
Sturnella magna	Eastern Meadowlark	GR	1	56
TRANSIENT SPECIES				
Theristicus caudatus	Buff-necked Ibis	IN	2	6
Cathartes aura	Turkey Vulture	RS	2	1
Buteogallus meridionalis	Savanna Hawk	RS	2	2
Rupornis magnirostris	Roadside Hawk	RS	2	6
Burhinus bistriatus	Double-striped Thick-knee	IN	2	6
Columbina talpacoti	Ruddy Ground-Dove	GR	2	1
Patagioenas speciosa	Scaled Pigeon	FG	2	1
Leptotila verreauxi	White-tipped Dove	FG	2	6
Guira guira	Guira Cuckoo	IN	2	6
Chordeiles pusillus	Least Nighthawk	IN	2	4
Phaethornis ruber	Reddish Hermit	NE	2	3
Phaethornis superciliosus	Long-tailed Hermit	NE	2	3
Chrysolampis mosquitus	Ruby-topaz Hummingbird	NE	1	12
Anthracothorax nigricollis	Black-throated Mango	NE	2	3
Campephilus melanoleucos	Crimson-crested Woodpecker	FI	2	4
Herpetotheres cachinnans	Laughing Falcon	RS	2	5
Falco femoralis	Aplomado Falcon	RS	2	4
Forpus passerinus	Green-rumped Parrotlet	FG	2	2
Thamnophilus doliatus	Barred Antshrike	IN	2	1

Species	English Name	Feeding Guild	Habitat	Annual Abundance
Formicivora rufa	Rusty-backed Antwren	IN	2	2
Synallaxis albescens	Pale-breasted Spinetail	IN	2	5
Phaeomyias murina	Mouse-colored Tyrannulet	FI	2	4
Euscarthmus rufomarginatus	Rufous-sided Pygmy-Tyrant	IN	1	1
Tolmomyias flaviventris	Yellow-breasted Flycatcher	FI	2	1
Megarynchus pitangua	Boat-billed Flycatcher	FI	2	7
Myiarchus tyrannulus	Brown-crested Flycatcher	FI	2	5
Vireo olivaceus	Red-eyed Vireo	FI	2	2
Hylophilus pectoralis	Ashy-headed Greenlet	FI	2	15
Turdus leucomelas	Pale-breasted Thrush	FI	2	10
Schistochlamys melanopis	Black-faced Tanager	FI	2	2
Ramphocelus carbo	Silver-beaked Tanager	FI	2	3
Volatinia jacarina	Blue-black Grassquit	GR	2	2
Oryzoborus angolensis	Chestnut-bellied Seed-Finch	GR	2	3
Molothrus bonariensis	Shiny Cowbird	FI	2	4
Sturnella militaris	Red-breasted Blackbird	GR	2	3
Euphonia chlorotica	Purple-throated Euphonia	FI	2	3

Core species represented most (90.6%) of all detections over the year (Figure 4b). Monthly species richness of core (G = 6.36, df = 11, p = 0.84) and transient (G = 0.32, df = 11, p = 0.32) groups did not differ from a uniform distribution (Figure 4a). However, significant seasonal variation in abundance was found for both core (G = 309.5, df = 11, p < 0.0001) and transient (G = 26.25, df = 11, p < 0.0001) groups (Figure 4b). Both groups presented their highest abundance values from October to February, with a clear peak in November (Figure 4b).

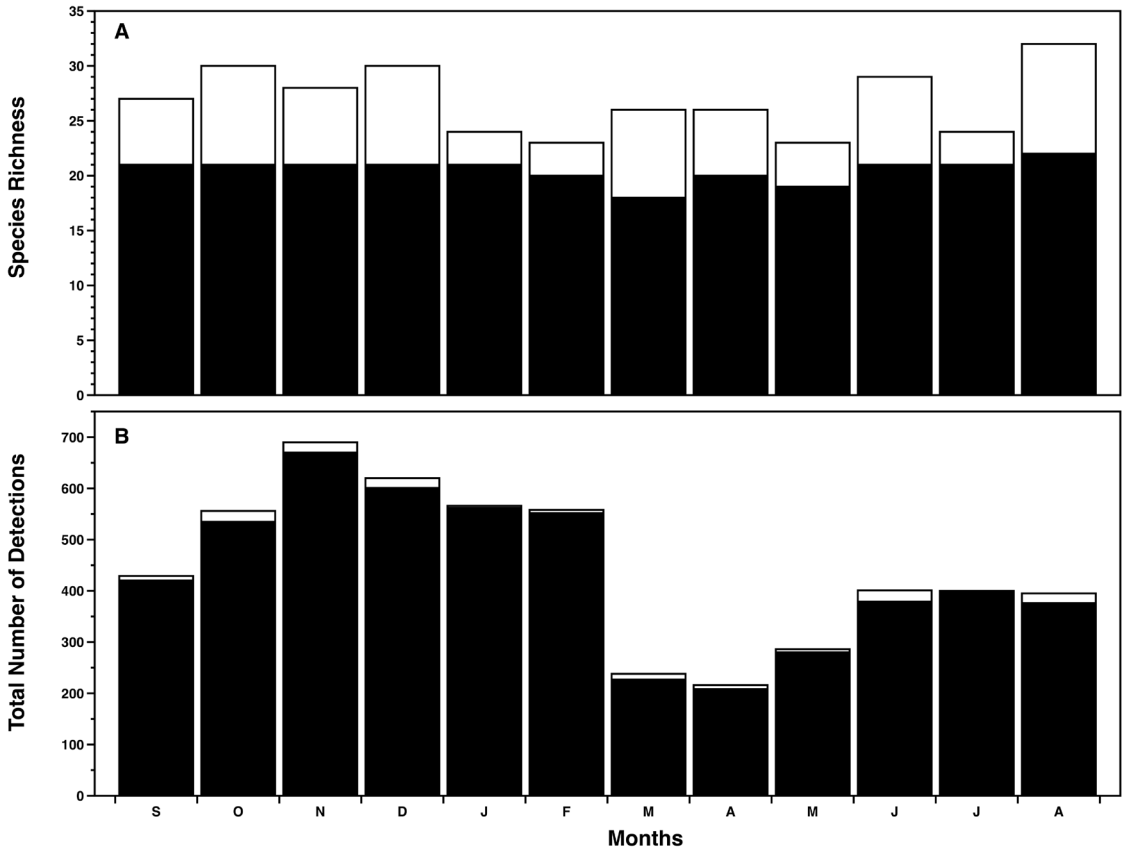

FIGURE 4. Monthly variations in the species richness (a) and total number of detections (b) of core (black) and transient (white) bird species recorded in a 360-ha plot of an upland savanna in Amapá, Brazil.

DISCUSSION

We recorded that only 22 species (30.5%) are core, with most of the species being transients. However, core species represented 90.6% of all detections in one year and are on average more abundant than transient species. Therefore, although species' richness in the site is mostly dominated by transient species, abundance is dominated by core species.

Core species are mostly restricted to savannas, while transient species occupy other habitats in the landscape. This finding is supported by findings in other tropical bird assemblages. For instance, Poulin *et al*. (2001) found that transient birds represented a large portion of the local assemblages of tropical arid and semi-arid habitats in northern Venezuela. Martin and Karr (1986) suggested that transients are an important component of tropical forest bird assemblages, but they did not present their proportions.

The core species recorded in our research site are also found frequently in other savannas in central South America and some of them are amongst the most abundant species (Silva 1995, Sick 1997, Tubelis & Calvacanti 2000, Cintra & Sanaiotti 2005, Aleixo & Poletto 2007). In addition, five core species (*Lepidocolaptes angustirostris*, *Suiriri suiriri*, *Mimus saturninus*, *Neothraupis fasciata*, and *Cypsnagra hirundinacea*) are considered as nuclear species in the mixed-species flocks that are found in most of the South American upland savannas (Tubelis 2007).

Combining our findings with general theories on bird assemblages, we can make some general predictions about the proportions of core and transient species in other South American upland savannas. At the local scale (up to 500 ha), we predict that savanna bird assemblages will be composed of a small number of abundant and habitat-restricted species that occupy the site almost year-round, combined with a high number of low abundant transient species that are habitat generalists and use the site only during some periods of their annual life cycle. Because local diversity is a consequence of regional diversity plus habitat selection (Ricklefs 2004), we can also predict that the number of core species in a given savanna site will increase with the structural complexity of the vegetation (Mac Arthur & Mac Arthur 1961, Karr & Roth 1971). In addition, because the number of transient species in a site is dependent on the pool of species in the landscape (Belmaker 2009) and because the landscape species richness correlates with landscape heterogeneity (Coyle *et al*. 2013), we can also predict that the richness of transient species in a savanna bird assemblage will increase with the heterogeneity of the landscape in which the savanna patch is located (Coyle *et al*. 2013). These predictions can be tested by carefully designed long-term seasonal studies on sites covering an array of landscapes that compose the South American savannas.

Populations of both core and transient species exhibited marked seasonality and followed roughly the same variation pattern. Overall, bird abundance is high from October to February and low from March to September. The five months in which bird abundance is higher coincides with the last two months of the dry season and the first three months of the rainy one. Although fruits and insects are available year-round in tropical savannas (Silvério & Lenza 2010, Silva *et al*. 2011), the availability of these resources peaks during the transition between dry and rainy seasons (Sanaiotti & Cintra 2001). It is also during this period that most of the species breed in the plot (Boss 2009), a pattern that has been observed in other tropical savannas as well (Sanaiotti & Cintra 2001, Silvério & Lenza 2010).

The overlap between breeding period and higher abundance indicates that recruitment is the simplest explanation for the increase of the detections of core species at the local level (Martin & Karr 1986). However, there are six species (*Elaenia flavogaster*, *Elaenia chiriquensis*, *Tyrannus albogularis*, *Tyrannus melancholicus*, *Tyrannus savanna*, and *Myiarchus swainsoni*) that have populations that breed in central South America and are known to migrate northwards during the austral migration (Chesser 1994). Therefore, it is also possible that individuals coming from migratory populations of those species and stopping by the site during some days or weeks may also contribute to the variation in abundance of these core species. Finally, core species might have been more abundant during the breeding period because they were more vocal and consequently their detectability increased. More studies are required to evaluate these hypotheses.

Because transient species are expected to track resources across the landscape more frequently than core species, the variation in the abundance observed for transient species can be explained by the high concentration of insects, fruits, and flowers during some periods of the year in the plot. The abundance of food resources during the end of the dry season and beginning of the rainy season possibly attracts several species from other habitats in the landscape to the study plot, leading to an increment of both richness and abundance of transient species (Martin & Karr 1986).

Our study also indicates that several species from gallery forests and wet grasslands are able to fly more than 300 meters into the upland savannas to use resources, indicating that possibly the intensity of the movements between habitats within landscapes dominated by upland savannas are greater than was originally expected (Tubelis *et al*. 2004). Because South American savannas' landscapes are heterogeneous landscapes subjected to

strong environmental variability (Furley 2006), their local bird assemblages are composed mostly of species that have a generalist feeding habit and a high capacity to exploit resources in the interfaces between open and forest physiognomies (Silva 1995, Tubelis *et al*. 2004). Understanding the dynamics of the avian assemblages over time and space will require focus along the boundaries of the different structural elements of the landscape because inter-habitat movements may have been underestimated in most of the studies so far (Dunning *et al*.1992, Silva *et al*. 1996).

Our results demonstrated that few core species were present in an upland savanna site over the entire year and that a considerable flow of individuals and species existed across the landscape as a consequence of the resource dynamics. The implications of these findings for the design of persistent conservation systems are clear. The conservation of South American savannas requires large protected areas covering representative entire landscapes integrated through large-scale multiple-use corridors designed to maximize the environmental heterogeneity of the region and thus ensure the maintenance of the ecological and evolutionary processes that have shaped their biota (Silva & Bates 2002, Cavalcanti & Joly 2002).

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ARTICLE

Continued bird surveys in southeastern coastal Brazilian Atlantic forests and the importance of conserving elevational gradients

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ABSTRACT: Although the Atlantic forest is the best-studied Brazilian phytogeographic domain, few coastal municipalities of the state of São Paulo can count on published and critically revised bird species list, which are important initial steps to organize conservation inniciatives. Here we present historical records from Bertioga, a northern coastline municipality of the state of São Paulo, as well as recent records obtained in surveys during the past years within the municipality. Surveying methods, carried out between 2008-2011, included point counts, 10-species lists, transect counts and mist nets. This compendium resulted in 330 documented species, 90 of which still await documentation. Of these 420 bird species, 85 (20.4%) are Atlantic forest endemic species and as many as eight, six and 23 are threatened at the global, national and state levels, respectively. Seventeen species are reported from Bertioga for the first time. Some records based exclusively on sightings must be carefully considered, whereas the species richness reflects the diversity of the habitats we visited, which varied from lowland and montane forests, to slopes and fluvial and tidal-influenced environments. We highlight that every habitat of the region should be continuously inventoried and that the absence of legal protection of lowland forests (which are not considered under the elevational threshold of the Serra do Mar State Park) must be reevaluated, as they harbor a greater number of endemic and threatened species than do other elevational bands.

KEY-WORDS: Bird species richness, Bertioga, *restingas*, species lists, survey methods.

INTRODUCTION

The Brazilian Atlantic forest occupies a vast heterogeneous region (1,481,946 km^2, approximately 17.4% of the Brazilian territory). It includes a large variety of forest physiognomies and compositions distributed throughout > 3,300 km along the Brazilian Atlantic coast, within latitudes from 3º S to 30º S, and elevations from sea level up to 2,700 m. These forests are distributed in different topographical and climatic conditions, encompassing lowlands and coastal mountains with high levels of rainfall, as well as interior high plateaus with seasonally dry seasons (Câmara 2003).

The Atlantic forest is recognized worldwide for its high diversity (1-8% of the world's total species, Silva & Casteleti 2003) and high rates of endemism (Myers *et al.* 2000). A recent assessment highlighted the large number of endemic species in several groups, such as 8,000 tree species (40% of the total species richness within the phytogeographic domain), 199 birds (16%), 71 mammals (27%), 94 reptiles (31%), and 286 amphibians (60%, Mittermeier *et al.* [2005]). Despite this biological richness, the Atlantic forest is probably one of the most threatened tropical forests, within the hottest of hotspots (Laurance 2009). Almost 90% of the original Atlantic forest has been lost, and less than 12% of the original vegetation remains. The best preserved biogeographical sub-region of this phytogeographic domain is the Serra do Mar Mountain Range, which runs in parallell with the Atlantic Ocean and encompasses 36.5% of its original vegetation (Ribeiro *et al.* 2009). This mountainous complex also holds the highest levels of bird endemism in the Atlantic forest (Haffer 1985). In the state of São Paulo, lowland forests, which lie in narrow bands at the base of coastal mountains, are unprotected throughout most of their extension because the Serra do Mar State Park rarely includes forests below a 100 m elevational threshold. Due to the absence of protection as well as real-state speculation, lowland

forests are probably the most threatened Atlantic forest habitats in the state (Câmara 1991). As a consequence of a long history of deforestation, more than 80% of the 199 endemic bird species are threatened or endangered (Goerck 1997, IUCN 2012).

Although the Serra do Mar has a stunning diversity, we still know little about its birds. Since the first investigations carried out at the Serra do Mar at the turn of the 20th century by Helmuth Pinder in Alto de Paranapiacaba (Camargo 1998), as well as Luederwaldts's (1925) scientific expeditions to Ilhabela (both localities in São Paulo), and later Davis' (1946) in Teresópolis, state of Rio de Janeiro, several bird inventories conducted along this region have been published (*e.g.* Willis & Oniki 1981, Olmos 1996, Goerck 1999, Naka & Rodrigues 2000, Willis & Oniki 2003, Develey 2004, Nores *et al.* 2005, Straube & Urben-Filho 2005, Cunha & Rajão 2007, Alves & Vecchi 2009, Lima 2010, Cavarzere *et al.* 2010, Mallet-Rodrigues *et al.* 2010), especially in the states of São Paulo and Rio de Janeiro. Recently a paper gathered all documented records of bird species from the municipality of Ubatuba (Simpson *et al.* 2012), but entire municipalities of São Paulo's northern shore, which primarily constitute the Serra do Mar, remain without published and critically revised checklists, such as Bertioga, São Sebastião and Caraguatatuba. These lists represent an important means of gathering data that will initially organize and eventually lead to conservation inniciatives. Here we present a birdlist for the municipality of Bertioga, São Paulo, based on museum specimens, published literature and recent field expeditions, highlighting noteworthy records, endemic and endangered species and the importance of continued surveys in order to document and produce the most updated and reliable bird checklist for this municipality. We further discuss about the need of extending conservation priority to lowland forests, which remain mostly unprotected although harboring extremely high bird richness and endemism.

MATERIAL AND METHODS

Study site

We carried out bird censuses and observations in Bertioga (centered at 23°51' S / 46°08' W), a northern coastline municipality in the state of São Paulo, southeastern Brazil (Figure 1). Bertioga has about 480 km^2 of evergreen Atlantic forest, 85% of which constitutes areas under

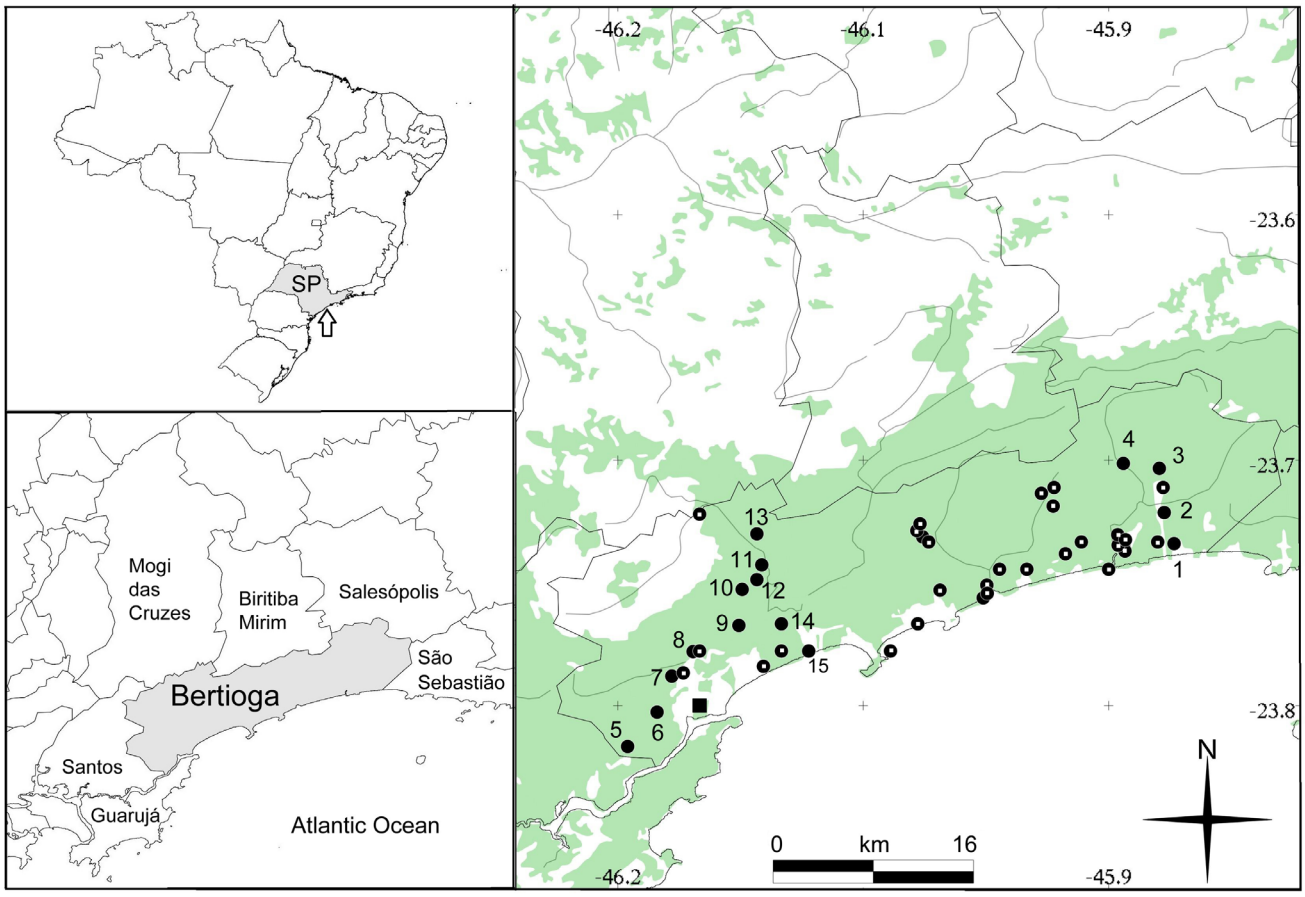

FIGURE 1: Map showing the remaining Atlantic forest (green) in the municipality of Bertioga, southeastern Brazil, where recent bird surveys have been carried out (numbered black circles, cross-referenced with Table 1). Locations where records of birds have been made within Bertioga by several other sources are depicted as un-numbered black circles with white dots. A black square shows the city of Bertioga.

protection (Maia *et al*. 2008). According to Köppen's classification, the climate of the region is Af, humid or super humid tropical, with rains distributed throughout the year (Nascimento & Pereira 1988). Climatologic data monitored between 1941 and 1970, indicates mean annual temperatures of 24.8°C, with lowest and highest monthly means of 20.7°C in July and 28.3°C in February, respectively. Bertioga is one of the most humid regions in Brazil, with mean annual rainfall of more than 3,200 mm, with lowest mean rainfalls in July (111 mm) and highest, in February (410 mm, Martins *et al*. 2008).

We cleared up existing (sometimes quite steep) narrow (< 1 m wide) trails in distinct zones within the municipality. At lower elevations they presented signs of human disturbance, such as selective logging (especially the palm tree *Euterpe edulis*) and hunter trails, while elevations above 300 m constituted of mature secondary forests (≥ 20 m canopy) and seemed slightly disturbed, with scarce understory. We surveyed sites at several latitudes along elevational transects: (1) habitats around the Guaratuba River (hitherto Guaratuba), which included 15 point counts distributed along five elevational bands between 0 and 400 m; (2) habitats around the Itatinga River (hitherto Itatinga) between 0 and 500 m, surveyed with 10-species lists; and (3) restingas between da Prata River (hitherto Prata), one of the tributaries of the Itapanhaú River, as well as the adjacent Bertioga beach, between 0 and 50 m. These latter locations were surveyed with point counts and mist nets. For coordinates and locations refer to Table 1 and Figure 1, respectively.

TABLE 1: List of locations where recent bird surveys have been carried out within the municipality of Bertioga, São Paulo, Brazil. Dates of surveys (detailed in methods) are indicated for each site, to which decimal latitude and longitude are given. The main vegetation types are shown, including mean elevations and type of surveying method and effort. Total sampling effort for mist nets are represented in h.m^2, while the effort for other methods are indicated in hours. *Ad* = *ad libitum*, L = 10-species lists, MN = mist nets, PC = point counts, T = transect counts.

Location number	Sampling period	Location name	Habitat	Latitude	Longitude	Altitude	Method	Total sampling effort
1	2008-2009	Boraceia beach	Beach	-23.751	-45.860	4	*Ad*	32
2	2008-2009	Condomínio Morada da Praia I	Lowland forest	-23.732	-45.866	20	PC	30
3	2008-2009	Condomínio Morada da Praia II	Submontane forest	-23.705	-45.869	98	PC	20
4	2008-2009	Condomínio Morada da Praia III	Submontane forest	-23.702	-45.891	290	PC	10
5	2010	Segunda Estrada	Lowland forest	-23.875	-46.194	31	L	5
6	2010	Alambique road	Lowland forest	-23.854	-46.176	35	L	5
7	2010	Vicente's road	Lowland forest	-23.832	-46.167	9	L	5
8	2010	Mangue road	Mangrove	-23.817	-46.154	4	L	5
9	2010	K3 trail	Lowland forest	-23.801	-46.126	10	L	5
10	2010	Restinga trail	*Restinga*	-23.779	-46.124	109	L	5
11	2010	Rio trail	Lowland forest	-23.764	-46.112	46	L	5
12	2010	Pedra trail	Submontane forest	-23.773	-46.115	189	L	5
13	2010	Represa trail	Submontane forest	-23.745	-46.115	491	L	5
14	2010-2011	Prata river	Lowland forest	-23.8	-46.1	5	MN,T	2,304/5
15	2010-2011	Bertioga beach	*Restinga*	-23.82	-46.08	12	MN,T	2,304/5

Bird counts

We surveyed birds with auditory-visual methods and mist nets. VC conducted unlimited-distance 10-min point counts (Bibby *et al*. 2000, Vielliard & Silva 1990). There were three points 200 m apart in each of the four elevational bands, which were separated vertically by *ca.* 100 m. Each point was visited for six non-continuous days and the observer managed to intersperse the sequence of conducting points so that each point was the first to be sampled. Complementarily, TVVC used 10-species lists, in which case 10 species were noted in a list, without repeating the same species in the same list; it was possible to mark a repeated species again only in a subsequent one. The observer took descriptions or sound recordings of any bird not immediately identified but that was seen or heard sufficiently well for identification. These individuals were later identified using standard reference works (Herzog *et al*. 2002, MacKinnon & Phillips 1993). GAB and LML surveyed birds with unlimited-distance transect counts during mornings and afternoons. All observations began 15 min before sunrise, while afternoon counts usually took place after 15h00. Bird records consisted of individuals heard and/or seen with the help of 8 x 20 and 8 x 40 binoculars. We avoided surveying birds on rainy or windy days. Individuals were recorded with tape (Panasonic RQ-L31) and digital (Zoom H4n) recorders with a Sennheiser ME-66 directional microphone. Recordings were deposited at the Seção de Aves do Museu de Zoologia da Universidade de São Paulo (MZUSP).

Mist nets were also used to complement our inventories. Eight mist nets (12 x 3 m x 30 mm) were placed in six 100 m trails, one trail for each of the six sites located at the Prata restingas. Nets touched bottom and were kept open from 05h00-12h00 for two consecutive mornings and one afternoon (15h00-17h00). We also conducted pre-dawn observations (03h00-05h00) and walked randomly in different elevations around our study areas and distinct habitats such as restingas and nearby marshes and reed beds, while including stops at flowering and fruiting trees to observe hummingbirds and canopy-dwelling frugivores, many of which are difficult to detect, especially during point counts (Robinson 1999). On many occasions we conducted afternoon counts ca. 2 h before sunset until nightfall. We surveyed sites during four reproductive seasons: 31 August-1 September 2008; 24 October-8 November 2008; 25-28 November 2008; 14-29 November 2009 (Guaratuba), 11, 15-22 December 2010 (Itatinga) and 8-12 September 2010, 31 March, 2 and 5 April 2011 (Prata), accumulating a total of 90 point counts (15 h), 42 10-species lists (~ 12 km), 58 h of transect counts (~ 10 km) and a net effort (E) of 4,608 h.m^2. The net effort was calculated according to $E = area.h.n$, where *area* is the area of each mist net (height multiplied by width), h is the time of exposure and n is the number of mist nets (Roos 2010). Free observations summed up 87 h and another 110 h were spent walking in nearby marshes and restingas, for a total of 197 hours and *ca.* 190 km of quantitative and *ad libitum* observations.

For a complete compendidium we searched for Bertioga bird records in the literature in Web of knowledge (http://wokinfo.com/) and Google Scholar (http://www.scholar.google.com/), and for "Santos" (which encompassed this municipality in past decades), "Bertioga", and "Varjão do Rio Guaratuba" specimens in the MZUSP bird collection. Santos specimens were critically examined individually regarding their precise location, and only those unequivocally collected within the current Bertioga municipality were considered. In addition, skins deposited at the Instituto Adolfo Lutz (IAL) and Museu de Zoologia da Universidade Estadual de Campinas (ZUEC) and recordings available at the Fonoteca Neotropical Jacques Vielliard (FNJV) were accessed in http://www.splink.org.br/. Specialized World Wide Web sites were consulted for additional documented records within the municipality (http://www.xeno-canto.org and http://www.wikiaves.com.br), bearing in mind some questionable identifications. Therefore, all records based on these websites were critically examined . We are aware that many species recorded from the literature and that we considered as undocumented may have documentation. However, because we had no access to these vouchers (photographs and recordings), we treated them as such. Taxonomic arrangements follow the Comitê Brasileiro de Registros Ornitológicos (CBRO 2014) and Atlantic forest endemic species are according to Moreira-Lima (2013). Threatened species are reported for global (IUCN 2012), national (Silveira & Straube 2008) and state (Silveira *et al*. 2009) levels.

RESULTS

Over a total of 71 non-continuous days of surveys and random observations we documented 217 bird species of 22 orders and 61 families. Another 30 species were recorded aurally and/or seen only, lacking further documentation. The use of mist nets resulted in 215 individuals captured. These corresponded to 21 species, which were also detected with other surveying methods, belonging,to three orders and 14 families.

The first published account on Bertioga birds was Camargo's (1946) who mentioned six species from Varjão do Guaratuba, which consists of mangroves and marshes adjacent to that river. Lopes *et al*. (1980) mist netted 18 species in lowland forests around the Guaratuba River and later, Bennett & Lopes (1980) mist netted birds at Varjão do Rio Guaratuba, as well as other municipalities

in the state (Itapetininga and Salesópolis) without teasing apart species recorded by individual locality. The Bertioga Polygon avifauna inventory yielded 87 species, for none of which Beyer (2008) mentioned the type of documentation obtained. The SESC Bertioga bird project recorded 135 species, most of them documented with photographs (Sanfilippo & Demétrio 2004). Willis & Oniki (2003), in which Stotz & Willis' (1992) records in Guaratuba are included, mentioned 233 species from Bertioga. The most recent published avifaunal inventory conducted in Bertioga surveyed birds with point counts in montane Atlantic forests at the Parque das Neblinas, lying on 700-1,200 m terrains (Donatelli *et al*. 2011). This list included 221 species. The authors, however, did not specify the types of documentation for each species, except for the Hangnest Tody-Tyrant *Hemitriccus nidipendulus*, the identification of which consisted of its diagnosable nest.

The MZUSP collection accounted for 116 specimens of 64 species whereas the IAL and ZUEC collections accounted for 20 species each, although the IAL specimen of an *Elaenia* sp. was omitted here since its identification was not provided and could not be personally examined. Recordings from xeno-canto included 17 species, and from the 2,806 photographs and 51 recordings as of 22 October 2014 on the Wiki Aves database (261 species), we excluded two single photographed individuals because of the following: *Myiarchus tyrannulus* is a poor-quality photograph of a ferrugineous-tailed *Myiarchus*. As no comments by the photographer reffered to its vocalization, but rather to its ferrugineous wing and tail feathers, we decided to exclude this record because this genus is not easily recognizable by plumage alone. In addition, VC photographed a ferrugineous-tailed singing *M. ferox* at Emas National Park on 27 November 2013, rendering the feature used to identify this *M. tyrannulus* from Bertioga unreliable. *Sula leucogaster* were photographed during a boat crossing from Bertioga to Guarujá, so their precise locality (municipality) cannot be assumed.

All documented records (including literature, museum specimens, recordings and photographs) from Bertioga accounted for 330 species of 25 orders and 73 families. Of these, 55 are endemic to the Atlantic forest (including another 11 "almost endemic" species, Moreira-Lima 2013), and six are considered globally endangered or vulnerable, whereas six are endangered in Brazil and another 23 in the state, including the critically endangered *Aburria jacutinga* (Appendix I). Seventeen species are reported from Bertioga for the first time (Appendix I and II). Should we consider elevational bands separetly, the lowest band (0-99 m) accounts for three times (or even more) the number of species recorded in any other elevational band (Table 2).

TABLE 2: Number of species recorded per elevational band within the municipality of Bertioga, São Paulo, Brazil.

Elevation	Documented species	Undocumented species	Total
0-99	177	21	198
100-199	60	6	66
200-299	60	9	69
300-399	41	5	46
400-499	47	3	50

DISCUSSION

Novel species added to the municipality of Bertioga are mostly represented by conspicuous, yet vagrant species, or those, which have recently colonized the area due to habitat alterations. Some common forest species should be recorded and documented with continued surveys.

Some 90 undocumented records (of which 28 are Atlantic forest endemics) include many species found at higher elevations of the Serra do Mar, not surveyed by us. Among these there are three vulnerable and two critically endangered species in the state, as well as 30 species, which can be found at the nearby Boraceia Biological Station (Appendix II, Cavarzere *et al*. 2010). While the Scaled Woodcreeper *Lepidocolaptes squamatus* represents a misidentification (in Bertioga its southern counterpart Scalloped Woodcreeper *L. falcinellus* should occur in montane forests) there are many other sightings that must be fully documented either due to their unlikely range within the Serra do Mar or discrete plumage to be identified only by sight. Species such as the Planalto Slaty Antshrike *Thamnophilus pelzelni*, Pale-breasted Spinetail *Synallaxis albescens*, Southern Antpipit *Corythopis delalandi* and Mouse-coloured Tyrannulet *Phaeomyias murina* (Donatelli *et al*. 2011) are not found along the coast or in highland evergreen Atlantic forests in the state (Willis & Oniki 2003). They may have been misidentified since these records relied on sightings only (Donatelli *et al*. 2011).

VC saw on two consecutive days (25 and 26 October 2008) one lone, quite striated *Tigrisoma* standing on large rocks in the middle of the river while crossing the

Guaratuba River deep in lowland forest in a point where it bears characteristc features (fast-flowing small- to medium-sized clear water rivers surrounded by undisturbed vegetation) of the habitat of the Fasciated Tiger-Heron *T. fasciatum*, a critically endangered species in São Paulo. There was no time to observe the diagnosable characters that dintinguish it from its congenier's youngsters as the bird flew away to the forest on both occasions at the moment it was sighted. However, we strongly believe it was not a young Rufescent Tiger-Heron *T. lineatum*, for this latter species was commonly and only observed, in adult and juvenile plumage, in marshes bordering, or even completely isolated from, forest edges. VC also heard the Rusty-barred Owl *Strix hylophila* on 3 November 2008 at *ca.* 200 m at a steep slope at Guaratuba. This owl is more common at higher elevations at the Serra do Mar and especially at the Serra da Mantiqueira (Antunes *et al.* 2006). This undocumented record illustrates how some typical high-elevation species move along elevational gradients as long as the vegetation is continuous between lowland and montane forests (Simpson *et al.* 2012).

Noteworthy records

Our compilation resulted in 420 bird species (93, or 22.6%, Atlantic forest endemics), 324 of which are documented in the form of skins, photographs or recordings. Some of these records are quite interesting and we briefly comment on them below.

Solitary Tinamou ***Tinamus solitarius***. Vulnerable in São Paulo and sought after by poachers. The species was perhaps less common in the lowlands, but regularly found along the entire elevational gradient at Guaratuba, even in the steepest terrains, indicating low hunting pressure in that area (Sick 1997). Its vocalization was heard on every survey, apparently with no temporal or seasonal correlation. On few occasions when birds were seen, only one individual was sighted.

Black-fronted Piping-Guan ***Aburria jacutinga***. Critically endangered in São Paulo and globally endangered. This species is extremely rare outside protected areas, especially in the Serra do Mar, due to hunting and palm harvesting (Galetti *et al.* 1997). We saw two individuals around the 100 m elevational band at Guaratuba, which is the limit threshold of the Serra do Mar State Park boundaries. One individual flew away the moment it was sighted, but the other remained calm on a canopy branch for several minutes. Residents reported the species as somewhat regularly seen in the area, and although it is not common at all at the Boraceia Biological Station (contiguous higher elevation forests on the same elevational gradient), the species has also been recently recorded there at 830 m (Cavarzere *et al.* 2010). There is a record of breeding activity in Bertioga (Casadei 2013), where a bird in young plumage was seen besides an adult individual. This elevational gradient may be a promising location for studying *A. jacutinga* at the Serra do Mar.

Hook-billed Kite ***Chondrohierax uncinatus***. Near threatened in São Paulo. An uncommon hawk in the state, especially in coastal areas (Willis & Oniki 2003). At least nine individuals were reported from three different localities at the Baixada Santista, a southern coastal locality in São Paulo (Silva & Olmos 2007), suggesting a resident population which commonly form conspecific groups. Here it is reported for Bertioga (Itatinga) for the first time, but we saw no indications of social aggregations.

Mantled Hawk ***Pseudastur polionotus***. Vulnerable in São Paulo. This species is typically found at higher altitudes at the Serra do Mar, but we saw one bird soaring over the 200 m elevational band at Itatinga, just 100 m higher than our record of the White-necked Hawk *Amadonastur lacernulatus*, a coastal lowland species in the state.

Black-and-white Hawk-Eagle ***Spizaetus melanoleucus***. Critically endangered in São Paulo. A rare species in the state, it depends on large areas to hunt. We saw one bird soaring over a small fragment, which was not far from continuous lowland forests, near the city of Bertioga.

American Oystercatcher ***Haematopus palliatus.*** Vulnerable in São Paulo. New for the municipality, this species has no historical records in São Paulo northern coastlines. Because dogs are a menace to the nidification of the species, it would be important to control the entrance of such pets in protected environments (F. Olmos, pers. com.). In addition, the deforestation of restingas, as well as uncontrolled turism and pollution constitute a severe threat to this species (Barbieri 2009). Hopefully, recently protected restingas (see below) will warrant its constant presence in Bertioga.

Mearly Parrot ***Amazona farinosa***. Critically endangered in São Paulo. This represents one of the few populations in the state's northern coasts. The species is much more abundant in São Sebastião and Ilha Bela, immediately northeast of Bertioga (Olmos 1992), but can reach both Caraguatatuba (E. Pacífico pers. obs.) and Ubatuba (Simpson *et al.* 2012) to the north. The species is typically seen in small flocks of ca. six individuals, which fly from lower slopes to lowland forests during the mornings and to the opposite direction on late afternoons (São Sebastião, R. S. Marconde pers. obs.). Although common in lowlands, it can be also spotted above 700 m, in preserved montane forests at Ilha Bela, in the highest part of the dirt road to the Castelhanos beach (pers. obs.).

Salvadori's Antwren ***Myrmotherula minor***. Vulnerable in São Paulo and globally vulnerable. We saw one adult male in mature and tall forest at sea level at Guaratuba. Much less common than its congener *M.*

unicolor, this species may be easily overlooked because of its cryptic plumage and behavior. There is also a male collected at Varjão do Rio Guaratuba by E. Dente in 30 June 1971 (MZUSP 43457).

Tawny-throated Leaftosser ***Sclerurus macconnelli***. Vulnerable in São Paulo. The only record of the species for Bertioga is a mist netted male (MZUSP 62446) on 24 October 1972 around Varjão do Rio Guaratuba. Uncommon at the northward coastal municipality of Ubatuba (Simpson *et al*. 2012), no other records have been made for this species in Bertioga since then, nor has the species been recorded in Caraguatatuba (between Bertioga and Ubatuba), where we suspect the species will be found with increasing surveying efforts. There is also a record from Saibadela/Sete Barras, within the Serra de Paranapiacaba (Aleixo & Galetti 1997), which is supposedly the southernmost range of this species in eastern Brazil.

Wren-like Rushbird ***Phleocryptes melanops***. Vulnerable in São Paulo. One of three records for the state. There is a female specimen in MZUSP (61066) from Rio Guaratuba. Like *S. macconnelli*, no other record of the species has been made in Bertioga, although it has been recorded in Cubatão (Olmos & Silva 2001).

Shrike-like Cotinga ***Laniisoma elegans***. Vulnerable in São Paulo. A species hard to detect, with only a few records in the state, most of them at higher elevations (Boraceia Biological Station, Cavarzere *et al*. [2010]). A previous undocumented sighting at the Varjão do Rio Guaratuba lowlands by Camargo (1946) is now confirmed by a recent photograph (Balieiro 2012).

Chestnut-bellied Seed-Finch ***Sporophila angolensis***. Vulnerable in São Paulo. A sought-after cage bird found especially in Coco-grass *Cyperus rotundus* and Cattail *Typha* ssp. dominated marshes in the interior of the state (Willis & Oniki 2003). Apparently its populations are recovering in some parts of São Paulo, becoming more common even in disturbed areas. We saw and heard a singing adult male at Itatinga.

Correlates of species richness

The high species richness detected at Bertioga clearly reflects the environmental diversity in our study areas, such as lowland and montane forests, and riverine and marine habitats. There are other species that will eventually be encountered within the municipality as additional surveys and observations are carried out. Recently, the successful implementation of a 9,264 ha restinga protected area (Restinga de Bertioga State Park) has been achieved, although this excluded Itaguaré beach, an important resting area for sea and shorebirds. The adjoining Hércules Florence Private Natural Reserve adds another 1,440 ha to this large restinga *continuum*, making this area one of the last large protected restingas remaining in the country. Despite these initiatives, we caution about the conservation of lowland forests along other coastline municipalities within São Paulo. As the Serra do Mar State Park does not protect lowland habitats, we strongly believe these forests will be destined for real-state speculation and, as already seen in Bertioga and elsewhere, occupation by slums in the near future.

Although some species seem restricted to lowlands, such as the Yellow-legged Tinamou *C. noctivagus*, Glittering throated Emerald *Amazilia fimbriata*, Tawny-throated Leaftosser *S. macconnelli*, Whiskered Flycatcher *Myiobius barbatus*, Black-headed Berryeater *Carpornis melanocephala*, the conservation of complete elevational gradients are just as important. As fully documented, there are cases of elevational replacements and migrations at both the Serra do Mar and Serra de Paranapiacaba (*e.g.* Rajão & Cerqueira 2006, Simpson *et al*. 2012). Migrations exist in some high elevation species which can descend to sea level, or species that have been suggested to depend on the palm heart *E. edulis*, which fruits at different times and elevations, during periods of general fruit scarcity (Laps 1996, but see Galetti & Aleixo 1998). Therefore, such communities can only thrive in entire Atlantic forest elevational gradients, from lowlands to montane forests.

Recently, the polytypic species *Sclerurus mexicanus* was proven paraphyletic (d'Horta *et al*. 2012), meaning that the subspecies *S. m. maconelli* should eventually be regarded as a full species ranging from the Guiana Shield to the Atlantic forest in eastern Brazil (CBRO 2014). The Yellow-legged Tinamou *Crypturellus n. noctivagus* may also prove to be a separate species (endemic of the Atlantic forest) from its northern counterpart, *C. n. zabele*, of drier caatinga and semideciduous forests (B. Tamotami pers. com.). For harboring a greater species richnes than other elevational band, exclusive and threatened species as well as several Atlantic forest endemics, we highlight the importance of continuous efforts to study and survey low elevation forest and restinga habitats, suggesting their immediate inclusion within the Serra do Mar State Park, a Category II protected area (see IUCN protected area categories).

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APPENDIX I

List of 330 bird species documented within the municipality of Bertioga, state of São Paulo, southeastern Brazil. Evidence: A = aural, N = nest, P = photograph, R = recording, Sk = skin, V = visual. Sources: Skins - Museu de Zoologia da Universidade de São Paulo (MZUSP), Museu de Zoologia da Universidade Estadual de Campinas (ZUEC) and Instituto Adolfo Lutz (IAL); Recordings - Fonoteca Neotropical Jacques Vielliard (FNJV), xeno-canto database (XC) and Wiki Aves (Wk*, exclusively registered on Wiki Aves as recordings); Literature - A = this study, C = Camargo (1946), D = Donatelli *et al.* (2011), L = Lopes *et al.* (1980), P = Beyer (2008), S = Sanfilippo & Demétrio (2004), W = Willis & Oniki (2003); on line photographs - Wk = Wiki Aves. Elevation: B = 0-99 m, 1 = 100-199 m, 2 = 200-299 m, 3 = 300-399 m, 4 = 400-499 m. Threats: GL = global (IUCN 2012), BR = Brazil (Silveira & Straube 2008), SP = state of São Paulo (Silveira *et al.* 2009). AE = species almost endemic to the Atlantic forest (Moreira-Lima 2013).

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Tinamiformes								
Tinamidae (3)								
Tinamus solitarius	Solitary Tinamou	A,P,Sk,V	1234	A,D,P,W,Wk			VU	E
Crypturellus obsoletus	Brown Tinamou	A,R	B	A,D,P,Wk				
Crypturellus noctivagus	Yellow-legged Tinamou	A,R,Sk	B	A,MZUSP,W,Wk*		EN	EN	
Anseriformes								
Anatidae (5)								
Dendrocygna viduata	White-faced Whistling-Duck	P		S,Wk				
Dendrocygna autumnalis	Black-bellied Whistling-Duck	P,V	B	A				
Cairina moschata	Muscovy Duck	P,V	B	A,W,Wk				
Amazonetta brasiliensis	Brazilian Teal	V,P	B	A,S,Wk				
Nomonyx dominica	Masked Duck	V,P	B	A,Wk			NT	
Galliformes								
Cracidae (2)								
Penelope obscura	Dusky-legged Guan	A,P,R,Sk,V	B	A,C,D,MZUSP,P,S,W,Wk			NT	
Aburria jacutinga	Black-fronted Piping-Guan	P,V	13	A,Wk	EN	EN	CR	E
Podicipediformes								
Podicipedidae (1)								
Podilymbus podiceps	Pied-billed Grebe	V,P	B	A,Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Sphenisciformes								
Spheniscidae (1)								
Spheniscus magellanicus	Magellanic Penguin	Sk		W				
Procellariiformes								
Procellariidae (3)								
Pachyptila belcheri	Slender-billed Prion	Sk		W				
Procellaria aequinoctialis	White-chinned Petrel	Sk		W	VU	EN	VU	
Calonectris borealis	Cory's Shearwater	Sk		W				
Suliformes								
Fregatidae (1)								
Fregata magnificens	Magnificent Frigatebird	P,Sk,V	B	A,D,S,W,Wk				
Phalacrocoracidae (1)								
Phalacrocorax brasilianus	Neotropic Cormorant	P,V	B	A,D,P,S,W,Wk				
Pelecaniformes								
Ardeidae (13)								
Tigrisoma lineatum	Rufescent Tiger-Heron	P,Sk,V	B	A,MZUSP,W,Wk				
Cochlearius cochlearius	Boat-billed Heron	P		S				
Ixobrychus exilis	Least Bittern	P		Wk				
Nycticorax nycticorax	Black-crowned Night-Heron	P,V	B	A,S,W,Wk				
Nyctanassa violacea	Yellow-crowned Night-Heron	P		W,Wk				
Butorides striata	Striated Heron	P,V	B	A,S,W,Wk				
Bubulcus ibis	Cattle Egret	P,V	B	A,S,Wk				
Ardea cocoi	Cocoi Heron	P,V	B	A,D,W,Wk				
Ardea alba	Great Egret	P,V	B	A,P,S,W,Wk				
Syrigma sibilatrix	Whistling Heron	P,V	B	A,S,Wk				
Pilherodius pileatus	Capped Heron	V,P	B	A,Wk			VU	
Egretta thula	Snowy Egret	P,V	B	A,P,S,W,Wk				
Egretta caerulea	Little Blue Heron	P		P,W,Wk				
Threskiornithidae (2)								
Theristicus caudatus	Buff-necked Ibis	P		S				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Platalea ajaja	Roseate Spoonbill	P		Wk				
Cathartiformes								
Cathartidae (3)								
Cathartes aura	Turkey Vulture	P,Sk,V	B	A,D,C,MZUSP,P,S,W,Wk				
Cathartes burrovianus	Lesser Yellow-headed Vulture	P		Wk				
Coragyps atratus	Black Vulture	P,V	B	A,D,P,S,W,Wk				
Accipitriformes								
Pandionidae (1)								
Pandion haliaetus	Osprey	P		W,Wk				
Accipiridae (12)								
Leptodon cayanensis	Gray-headed Kite	A,P,V	B	A,W,Wk				
Chondrohierax uncinatus	Hook-billed Kite	P,V	B	A,Wk			NT	
Harpagus diodon	Rufous-thighed Kite	P,Sk,V	B	A,W,Wk				
Accipiter superciliosus	Tiny Hawk	P		Wk				
Accipiter bicolor	Bicolored Hawk	P		W,Wk				
Rostrhamus sociabilis	Snail Kite	A,P,R,V	B	A,Wk				
Geranospiza caerulescens	Crane Hawk	P,V	B	A,Wk				
Heterospizias meridionalis	Savanna Hawk	P		S				
Amadonastur lacernulatus	White-necked Hawk	P,V	1	A,Wk	VU	EN	VU	E
Urubitinga urubitinga	Great Black-Hawk	Sk	B	MZUSP,W				
Rupornis magnirostris	Roadside Hawk	A,P,R,V	B	A,D,FNJV,P,S,W,Wk				
Buteo brachyurus	Short-tailed Hawk	P,V		D,Wk				
Gruiformes								
Aramidae (1)								
Aramus guarauna	Limpkin	A,P,R,V	B	A,Wk				
Rallidae (8)								
Aramides cajaneus	Gray-necked Wood-Rail	P		W,Wk				
Aramides saracura	Slaty-breasted Wood-Rail	A,P,R,V	B	A,D,P				E
Laterallus melanophaius	Rufous-sided Crake	A,P,R	B	A,W,Wk				
Pardirallus maculatus	Spotted Rail	R		XC				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Pardirallus nigricans	Blackish Rail	A,P,R,V	B	A,D,P,Wk				
Gallinula galeata	Common Gallinule	A,P,R,V	B	A,Wk				
Porphyrio martinicus	Purple Gallinule	P,V	B	A,Wk				
Fulica armillata	Red-gartered Coot	P		Wk			NT	
Charadriiformes								
Charadriidae (4)								
Vanellus chilensis	Southern Lapwing	A,P,V	B	A,D,P,S,W,Wk				
Pluvialis dominica	American Golden-Plover	P		Wk				
Charadrius semipalmatus	Semipalmated Plover	P,V	B	A,W,Wk				
Charadrius collaris	Collared Plover	P,V	B	A,P,S,W,Wk				
Charadriiformes								
Haematopodidae (1)								
Haematopus palliatus	American Oystercatcher	P		Wk			VU	
Recurvirostridae (1)								
Himantopus melanurus	White-backed Stilt	P		Wk				
Scolopacidae (6)								
Actitis macularius	Spotted Sandpiper	P		P,W,Wk				
Tringa solitaria	Solitary Sandpiper	P		Wk				
Tringa melanoleuca	Greater Yellowlegs	P		W,Wk				
Tringa flavipes	Lesser Yellowlegs	P		Wk				
Calidris alba	Sanderling	P,Sk,V	B	A,MZUSP,W,Wk				
Calidris fuscicollis	White-rumped Sandpiper	P,V	B	A,W,Wk				
Jacanidae (1)								
Jacana jacana	Wattled Jacana	A,P,R,V	B	A,S,Wk				
Stercorariidae (1)								
Stercorarius longicaudus	Long-tailed Jaeger	P		Wk				
Laridae (1)								
Larus dominicanus	Kelp Gull	A,P,V	B	A,P,S,Wk				
Sternidae (5)								
Sterna hirundo	Common Tern	P		Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Sterna hirundinacea	South American Tern	P		W,Wk				
Thalasseus acuflavidus	Cabot's Tern	P		W,Wk				
Thalasseus maximus	Royal Tern	P		Wk		EN	VU	
Rynchopidae (1)								
Rynchops niger	Black Skimmer	P		Wk				
Columbiformes								
Columbidae (9)								
Columbina talpacoti	Ruddy Ground-Dove	A,P,Sk,V	B	A,D,IAL,S,W,Wk				
Claravis pretiosa	Blue Ground-Dove	Sk		S,W				
Columba livia	Rock Dove	P,V	B	A,S,Wk				
Patagioenas picazuro	Picazuro Pigeon	A,P,V	B	A,D,S,Wk				
Patagioenas cayennensis	Pale-vented Pigeon	P,V	1	A,P,S,W,Wk				
Zenaida auriculata	Eared Dove	A,P,V	B	A,S				
Leptotila verreauxi	White-tipped Dove	A,R	B	A,D,P,W				
Leptotila rufaxilla	Gray-fronted Dove	A,P,Sk	B	A,D,MZUSP,Wk				
Geotrygon montana	Ruddy Quail-Dove	A,P,R,Sk	234	A,D,W,Wk				
Cuculiformes								
Cuculidae (5)								
Piaya cayana	Squirrel Cuckoo	A,P,Sk,V	B	A,D,MZUSP,W,Wk				
Coccyzus melacoryphus	Dark-billed Cuckoo	Sk		W				
Crotophaga ani	Smooth-billed Ani	P,Sk,V	B	A,D,IAL,P,S,W,Wk				
Guira guira	Guira Cuckoo	A,P,V	B	A,P,S,Wk				
Tapera naevia	Striped Cuckoo	A,R,Sk,V	B	A,D,W				
Strigiformes								
Tytonidae (1)								
Tyto furcata	Barn Owl	P		S				
Strigidae (4)								
Megascops choliba	Tropical Screech-Owl	A,P		D,S				
Pulsatrix koeniswaldiana	Tawny-browed Owl	A,P	123	A,Wk				E
Athene cunicularia	Burrowing Owl	A,P,V	B	A,D,S,Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Asio stygius	Stygian Owl	P		S,Wk				
Nyctibiiformes								
Nyctibiidae (1)								
Nyctibius griseus	Common Potoo	A,P,R,V	B	A,D,S,W,Wk				
Caprimulgiformes								
Caprimulgidae (4)								
Lurocalis semitorquatus	Short-tailed Nighthawk	A,R,Sk,V	12	A,W				
Hydropsalis albicollis	Pauraque	A,P,V	B	A,D,S,Wk				
Hydropsalis forcipata	Long-trained Nightjar	Sk,V		D,W				E
Chordeiles acutipennis	Lesser Nighthawk	P	B	S,W				
Apodiformes								
Apodidae (4)								
Cypseloides fumigatus	Sooty Swift	P,V	B	A,W				
Streptoprocne zonaris	White-collared Swift	P,V	1	A,D,S,W,Wk				
Chaetura cinereiventris	Gray-rumped Swift	A,P,Sk,V	123	A,MZUSP,W,Wk,ZUEC				
Chaetura meridionalis	Sick's Swift	A,P,V	B	A,P,S,W,Wk				
Trochilidae (16)								
Ramphodon naevius	Saw-billed Hermit	A,P,R,Sk,V	1234	A,C,D,MZUSP,W,Wk,ZUEC				E
Phaethornis ruber	Reddish Hermit	A,P,R,Sk,V	B4	A,P,XC,W,Wk				
Eupetomena macroura	Swallow-tailed Hummingbird	P,V	B	A,D,P,S,Wk				
Aphantochroa cirrochloris	Sombre Hummingbird	P		S,Wk				AE
Florisuga fusca	Black Jacobin	A,P,Sk,V	B12	A,D,MZUSP,P,S,W,Wk				
Anthracothorax nigricollis	Black-throated Mango	P,V	B	A,S,Wk				
Lophornis chalybeus	Festive Coquette	P,Sk,V		W,Wk,ZUEC				
Chlorostilbon lucidus	Glittering-bellied Emerald	P,V	B	A,D,S,Wk				
Thalurania glaucopis	Violet-capped Woodnymph	A,P,Sk,V	B1	A,D,MZUSP,P,S,W,Wk				
Hylocharis cyanus	White-chinned Sapphire	A,P,Sk,V	B	A,MZUSP,S,W,Wk,ZUEC				
Leucochloris albicollis	White-throated Hummingbird	P	B	D,S				
Amazilia versicolor	Versicolored Emerald	P,V	B	A,D,S,Wk				
Amazilia fimbriata	Glittering-throated Emerald	P,Sk,V	B	A,S,W,Wk,ZUEC				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Amazilia lactea	Sapphire-spangled Emerald	P,R,Sk		FNJV,S,W,Wk				
Clytolaema rubricauda	Brazilian Ruby	V,Sk		D,W				E
Trogoniformes								
Trogonidae (2)								
Trogon viridis	White-tailed Trogon	A,P,R,Sk,V	134	A,MZUSP,P,W,Wk				
Trogon surrucura	White-tailed Trogon	A,P,V		D,W,Wk				
Coraciiformes								
Alcedinidae (5)								
Megaceryle torquata	Ringed Kingfisher	P,Sk,V	B	A,P,S,W,Wk				
Chloroceryle amazona	Amazon Kingfisher	P,Sk,V	B	A,D,S,W				
Chloroceryle aenea	American Pygmy Kingfisher	P,Sk	B	MZUSP,W,Wk				
Chloroceryle americana	Green Kingfisher	P,Sk,V		D,W,Wk				
Chloroceryle inda	Green-and-rufous Kingfisher	Sk		W,ZUEC				
Momotidae (1)								
Baryphthengus ruficapillus	Rufous-capped Motmot	A,R,Sk,V	1234	A,MZUSP,W				AE
Galbuliformes								
Bucconidae (2)								
Notharchus swainsoni	Buff-bellied Puffbird	P,Sk		W,Wk			NT	E
Malacoptila striata	Crescent-chested Puffbird	Sk		L,MZUSP,W				
Piciformes								
Ramphastidae (4)								
Ramphastos toco	Toco Toucan	P		Wk				
Ramphastos vitellinus	Channel-billed Toucan	A,P,R,Sk,V	12	A,D,P,W,Wk				
Ramphastos dicolorus	Red-breasted Toucan	P,V		D,S,Wk				E
Selenidera maculirostris	Spot-billed Toucanet	A,P,Sk,V	1	A,MZUSP,W,Wk			NT	E
Picidae (9)								
Picumnus cirratus	White-barred Piculet	A,Sk,V	B	A,MZUSP,W,Wk				
Picumnus temminckii	Ochre-collared Piculet	A,P,R,V	B	A,D,FNJV,L,P,S,Wk				E
Melanerpes flavifrons	Yellow-fronted Woodpecker	A,P,R,V	124	A,W,Wk				AE
Veniliornis spilogaster	White-spotted Woodpecker	A,P,R,V	B23	A,D,P,S,W,Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Piculus flavigula	Yellow-throated Woodpecker	A,P,Sk,V	1	A,MZUSP,W,Wk,ZUEC				
Colaptes campestris	Campo Flicker	P,V	B	A,D,S,Wk				
Celeus flavescens	Blond-crested Woodpecker	A,P,R,Sk,V	B1234	A,D,MZUSP,P,S,XC,W,Wk				
Dryocopus lineatus	Lineated Woodpecker	P,R,V	B	A,D,FNJV,S,W,Wk				
Campephilus robustus	Robust Woodpecker	Sk		MZUSP,W			NT	E
Falconiformes								
Falconidae (8)								
Caracara plancus	Southern Caracara	P,V	B	A,D,P,S,W,Wk				
Milvago chimachima	Yellow-headed Caracara	A,P,R,V	B	A,D,P,S,W,Wk				
Herpetotheres cachinnans	Laughing Falcon	A,P,V	B	A,D,W,Wk				
Micrastur ruficollis	Barred Forest-Falcon	A,R	1	A,D, FNJV				
Micrastur semitorquatus	Collared Forest-Falcon	A,R	B	A,W				
Falco sparverius	American Kestrel	P		S				
Falco femoralis	Aplomado Falcon	P		S,Wk				
Falco peregrinus	Peregrine Falcon	P		Wk				
Psittaciformes								
Psittacidae (9)								
Aratinga auricapillus	Golden-capped Parakeet	P		Wk	NT			
Pyrrhura frontalis	Maroon-bellied Parakeet	A,P,R,Sk,V	B1234	A,D,MZUSP,W,Wk				AE
Forpus xanthopterygius	Blue-winged Parrotlet	A,P,R,Sk,V	B12	A,S,P,S,XC,W,Wk				
Brotogeris tirica	Plain Parakeet	A,P,R,Sk,V	B134	A,D,MZUSP,P,S,W,Wk				
Pionopsitta pileata	Pileated Parrot	A,R,V	B	A,D,W				E
Pionus maximiliani	Scaly-headed Parrot	A,P,R,Sk,V	12	A,D,FNJV,MZUSP,P,S,W,Wk				
Amazona farinosa	Mealy Parrot	A,R,V	B	A,Wk*			CR	
Amazona amazonica	Orange-winged Parrot	P,V	B	A,Wk			NT	
Triclaria malachitacea	Blue-bellied Parrot	Sk		W			VU	E
Passeriformes								
Thamnophilidae (12)								
Terenura maculata	Streak-capped Antwren	A,Sk	2	A,MZUSP,W				E
Myrmotherula minor	Salvadori's Antwren	Sk,V	B	A,MZUSP,W	VU	EN	VU	E

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Myrmotherula unicolor	Unicolored Antwren	A,P,R,Sk,V	B13	A,MZUSP,XC,W,Wk,ZUEC			VU	E
Rhopias gularis	Star-throated Antwren	A,R,V	B123	A,W				E
Dysithamnus stictothorax	Spot-breasted Antvireo	A,R,V	1	A,W			NT	E
Dysithamnus mentalis	Plain Antvireo	A,P,R,V	B1234	A,D,Wk				
Herpsilochmus rufimarginatus	Rusty-backed Antwren	A,P,R,Sk,V	B12	A,D,FNJV,P,W,Wk				
Thamnophilus caerulescens	Variable Antshrike	A,P,R	B	A,D,W,Wk				
Hypoedaleus guttatus	Spot-backed Antshrike	A,R,V	1234	A,D,W,Wk*				E
Myrmoderus squamosus	Squamate Antbird	A,P,Sk	4	A,D,W,Wk				E
Pyriglena leucoptera	White-shouldered Fire-eye	A,R,Sk,V	234	A,D,FNJV,P,W,Wk*				
Drymophila squamata	Scaled Antbird	A,P,R,Sk,V	B134	A,L,MZUSP,P,XC,W,Wk				E
Conopophagidae (2)								
Conopophaga lineata	Rufous Gnateater	A,P,Sk,V		D,W,Wk				
Conopophaga melanops	Black-cheeked Gnateater	A,P,R,Sk,V	1234	A,MZUSP,P,XC,W,Wk				E
Rhinocryptidae (2)								
Merulaxis ater	Slaty Bristlefront	A,P,R,V	134	A,D,XC,W			NT	E
Eleoscytalopus indigoticus	White-breasted Tapaculo	A,R,Sk	B	A,D,XC,W,Wk*				E
Formicariidae (1)								
Formicarius colma	Rufous-capped Antthrush	A,P,R,Sk,V	B	A,C,MZUSP,S,W,Wk,ZUEC				
Scleruridae (2)								
Sclerurus macconnelli	Tawny-throated Leaftosser	A,P,R,Sk,V	B	MZUSP,W			VU	
Sclerurus scansor	Rufous-breasted Leaftosser	A,P,R,Sk	23	A,D,MZUSP,S,W,Wk				E
Dendrocolaptidae (5)								
Dendrocincla turdina	Plain-winged Woodcreeper	A,R,Sk,V	1234	A,L,MZUSP,P,XC,W,Wk				E
Xiphorhynchus fuscus	Lesser Woodcreeper	A,P,R,Sk,V	B234	A,D,MZUSP,P,W,Wk				AE
Lepidocolaptes angustirostris	Narrow-billed Woodcreeper	P		S,Wk				
Dendrocolaptes platyrostris	Planalto Woodcreeper	A,R,Sk,V	1234	A,D,W,Wk				
Xiphocolaptes albicollis	White-throated Woodcreeper	A,P,Sk	1234	A,D,MZUSP,W,Wk				AE
Xenopidae (2)								
Xenops minutus	Plain Xenops	A,P,R,Sk,V	2	A,D,MZUSP,P,S,W,Wk				
Xenops rutilans	Streaked Xenops	P		Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Furnariidae (13)								
Furnarius figulus	Wing-banded Hornero	P,V		D,Wk				
Furnarius rufus	Rufous Hornero	A,P,V	B	A,D,S,W,Wk				
Phleocryptes melanops	Wren-like Rushbird	Sk		MZUSP,W			VU	
Automolus leucophthalmus	White-eyed Foliage-gleaner	A,P,R,Sk,V	24	A,D,FNJV,L,W,Wk				AE
Anabacerthia lichtensteini	White-browed Foliage-gleaner	Sk,V	2	A,D,MZUSP,W				E
Philydor atricapillus	Black-capped Foliage-gleaner	A,P,R,Sk,V	1234	A,D,MZUSP,XC,W,Wk				E
Philydor rufum	Ochre-breasted Foliage-gleaner	A,Sk,V	12	A,C,D,MZUSP,W				
Cichlocolaptes leucophrus	Pale-browed Treehunter	A,R,V	1234	A,W				E
Phacellodomus erythrophthalmus	Red-eyed Thornbird	A,N,V		D				E
Phacellodomus ferrugineigula	Orange-eyed Thornbird	A,P,R,V	B	A				E
Certhiaxis cinnamomeus	Yellow-chinned Spinetail	A,P,R,V	B	A,Wk				
Synallaxis ruficapilla	Rufous-capped Spinetail	A,P,R,V	B	A,D,S,Wk				E
Synallaxis spixi	Gray-bellied Spinetail	A,P,R,Sk,V	B	A,D,FNJV,MZUSP,P,W,Wk				
Pipridae (2)								
Manacus manacus	White-bearded Manakin	A,P,R,Sk,V	B	A,D,FNJV,L,MZUSP,P,XC,W,Wk				
Chiroxiphia caudata	Blue Manakin	A,P,R,Sk,V	B24	A,D,FNJV,L,MZUSP,P,W,Wk				E
Oxyruncidae (1)								
Oxyruncus cristatus	Sharpbill	A,R	234	A,D,W				
Onychorhynchidae (2)								
Myiobius barbatus	Black-tailed Flycatcher	A,P,R,Sk,V	B	A,MZUSP,XC,W,Wk				
Myiobius atricaudus	Black-tailed Flycatcher	P		Wk				
Tityridae (7)								
Schiffornis virescens	Greenish Schiffornis	A,R,Sk,V	B	A,D,P,W				E
Laniisoma elegans	Shrike-like Cotinga	P,Sk		C,W,Wk			VU	
Tityra inquisitor	Black-crowned Tityra	P,V	1	A,D,S,Wk				
Tityra cayana	Black-tailed Tityra	A,P,R,Sk,V	2	W,Wk				
Pachyramphus polychopterus	White-winged Becard	A,R,Sk,V	2	A,D,P,W				
Pachyramphus marginatus	Black-capped Becard	A,P,R,Sk,V	2	A,FNJV,MZUSP,W,Wk			NT	
Pachyramphus validus	Crested Becard	A,P,R,Sk,V	1	A,D,FNJV,L,S,W,Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Cotingidae (2)								
Procnias nudicollis	Bare-throated Bellbird	A,P,R,Sk	B2	A,D,FNJV,J,P,S,W,WK	VU		VU	E
Pyroderus scutatus	Red-ruffed Fruitcrow	A,P,R,V	B	A,D,J,W,Wk			VU	AE
Platyrinchidae (1)								
Platyrinchus mystaceus	White-throated Spadebill	A,Sk,V	B	A,D,MZUSP,P,W				
Rhynchocyclidae (8)								
Mionectes rufiventris	Gray-hooded Flycatcher	A,P,R,Sk,V	B	A,D,L,P,S,W,Wk				AE
Leptopogon amaurocephalus	Sepia-capped Flycatcher	A,P,R,Sk,V	B4	A,D,FNJV,W,Wk				
Tolmomyias sulphurescens	Yellow-olive Flycatcher	A,P,R,V	B124	A,D,P,W,Wk				
Todirostrum poliocephalum	Yellow-lored Tody-Flycatcher	A,P,R,Sk	B	A,FNJV,MZUSP,P,S,W,Wk,ZUEC				E
Todirostrum cinereum	Common Tody-Flycatcher	P		S,Wk				
Poecilotriccus plumbeiceps	Ochre-faced Tody-flycatcher	R,V		D,FNJV				
Hemitriccus orbitatus	Eye-ringed Tody-Tyrant	A,P,R	124	A,D,P,XC,W,Wk				E
Hemitriccus furcatus	Fork-tailed Pygmy-Tyrant	A,R,V	B	A,XC,Wk*	VU		VU	E
Tyrannidae (33)								
Hirundinea ferruginea	Cliff Flycatcher	A,P,R,V	B	A,P,Wk				
Camptostoma obsoletum	Southern Beardless-Tyrannulet	A,P,R,V	B	A,D,FNJV,P,S,W,Wk				
Elaenia flavogaster	Yellow-bellied Elaenia	A,P,R,V	B	A,D,S,W,Wk				
Elaenia chilensis	Chilean Elaenia	Sk		W				
Elaenia mesoleuca	Olivaceous Elaenia	Sk		ZUEC				AE
Phyllomyias fasciatus	Planalto Tyrannulet	Sk		L,P,W,Wk,ZUEC				
Phyllomyias griseocapilla	Gray-capped Tyrannulet	Sk		W				E
Attila phoenicurus	Rufous-tailed Attila	A,R,V	1234	A,D,W				
Attila rufus	Gray-hooded Attila	A,P,R,Sk,V	B124	A,D,P,S,W,Wk				E
Legatus leucophaius	Piratic Flycatcher	A,P,R,Sk,V	B134	A,D,S,W,Wk				
Myiarchus swainsoni	Swainson's Flycatcher	A,P,R,Sk	B	A,D,IAL,P,S				
Myiarchus ferox	Short-crested Flycatcher	A,P,V	B	A,D,S,W,Wk				
Rhytipterna simplex	Grayish Mourner	A,P,R,Sk,V	B	A,P,W,Wk				
Pitangus sulphuratus	Great Kiskadee	A,P,R,Sk,V	B2	A,D,IAL,P,S,W,Wk				
Philohydor lictor	Lesser Kiskadee	P,V	B	A,D				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Machetornis rixosa	Cattle Tyrant	A,P,V	B	A,P,S,W,Wk				
Myiodynastes maculatus	Streaked Flycatcher	A,P,R,Sk,V	B1234	A,D,P,S,W,Wk				
Megarynchus pitangua	Boat-billed Flycatcher	A,P,V	B	A,D,W,Wk				
Myiozetetes similis	Social Flycatcher	A,P,R,Sk,V	B	A,D,IAL,P,S,W,Wk				
Tyrannus melancholicus	Tropical Kingbird	A,P,R,V	B	A,D,P,S,W,Wk				
Tyrannus savana	Fork-tailed Flycatcher	P,V	B	A,D,S,Wk				
Empidonomus varius	Variegated Flycatcher	A,P,R,Sk,V	B	S,W,Wk,ZUEC				
Conopias trivirgatus	Three-striped Flycatcher	R		FNJV,W				
Colonia colonus	Long-tailed Tyrant	A,P,V	B	A,W,Wk				
Myiophobus fasciatus	Bran-colored Flycatcher	A,P,R,Sk,V	B	A,D,FNJV,IAL,L,S,W,Wk				
Pyrocephalus rubinus	Vermilion Flycatcher	P,Sk,V	B	A,IAL,S,W,Wk				
Fluvicola nengeta	Masked Water-Tyrant	A,P,V	B	A,D,S,Wk				
Arundinicola leucocephala	White-headed Marsh-Tyrant	P,V	B	A,S,Wk				
Cnemotriccus fuscatus	Fuscous Flycatcher	A,P,Sk		D,P,W,Wk				
Lathrotriccus euleri	Euler's Flycatcher	A,P,R,Sk	B1234	A,D,P,W,Wk,ZUEC				
Contopus cinereus	Tropical Peewee	A,P,R,Sk,V		D,FNJV,MZUSP,W,Wk				
Hymenops perspicillatus	Spectacled Tyrant	P		Wk				
Satrapa icterophrys	Yellow-browed Tyrant	P,V	B	A,D,S,W,Wk				
Vireonidae (2)								
Cyclarhis gujanensis	Rufous-browed Peppershrike	A,P,V	234	A,D,W,Wk				
Vireo olivaceus	Red-eyed Vireo	A,P,V	12	A,D,S,W,Wk				
Corvidae (2)								
Cyanocorax caeruleus	Azure Jay	P,R		Wk,XC				E
Cyanocorax cristatellus	Curl-crested Jay	P		Wk				
Hirundinidae (5)								
Pygochelidon cyanoleuca	Blue-and-white Swallow	A,P,Sk,V	B	A,D,IAL,P,S,W,Wk				
Atticora tibialis	White-thighed Swallow	Sk		MZUSP,W				
Stelgidopteryx ruficollis	Southern Rough-winged Swallow	A,P,R,V	B	A,D,S,W,Wk				
Progne chalybea	Grey-breasted Martin	A,P,R,Sk,V	B	A,D,IAL,S,W,Wk				
Hirundo rustica	Barn Swallow	P		Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Troglodytidae (2)								
Troglodytes musculus	Southern House-Wren	A,P,R,Sk,V	B	A,D,IAL,P,S,W,Wk				
Cantorchilus longirostris	Long-billed Wren	A,P,R,Sk,V	B1	A,FNJV,IAL,L,MZUSP,P,S,XC,W,Wk				
Donacobiidae (1)								
Donacobius atricapilla	Black-capped Donacobius	A,P,V	B	A				
Polioptilidae (1)								
Ramphocaenus melanurus	Long-billed Gnatwren	A,Sk		D,W				
Turdidae (6)								
Turdus flavipes	Yellow-legged Thrush	A,P,R,Sk,V	B24	A,D,MZUSP,S,W,Wk				
Turdus leucomelas	Pale-breasted Thrush	A,P,R,Sk,V	B	A,D,IAL,Wk				
Turdus rufiventris	Rufous-bellied Thrush	A,P,R,Sk,V	B14	A,D,FNJV,L,P,S,W,Wk				
Turdus amaurochalinus	Creamy-bellied Thrush	A,P,R,Sk,V	B	A,D,MZUSP,P,S,W,Wk				
Turdus subalaris	Eastern Slaty Thrush	A		D				
Turdus albicollis	White-necked Thrush	A,P,R,Sk,V	B1234	A,D,IAL,L,W,Wk				
Mimidae (1)								
Mimus saturninus	Chalk-browed Mockingbird	P,V	B	A,D,S,Wk				
Motacillidae (1)								
Anthus lutescens	Yellowish Pipit	A,P,R,V	B	A,S,Wk				
Passerellidae (1)								
Zonotrichia capensis	Rufous-collared Sparrow	A,P,Sk,V	B	A,D,IAL,P,S,W,Wk				
Parulidae (5)								
Setophaga pitiayumi	Tropical Parula	A,P,R,Sk,V	B1234	A,D,FNJV,MZUSP,P,S,W,Wk,ZUEC				
Setophaga striata	Blackpoll Warbler	Sk		W				
Geothlypis aequinoctialis	Masked Yellowthroat	A,P,R,V	B	A,D,FNJV,P,S,W,Wk				
Basileuterus culicivorus	Golden-crowned Warbler	A,R,V	12	A,D,W,Wk*				
Myiothlypis rivularis	Neotropical River Warbler	A,P,R,Sk,V	B	A,D,MZUSP,XC,W,Wk,ZUEC				E
Icteridae (7)								
Cacicus haemorrhous	Red-rumped Cacique	A,P,R,Sk,V	B	A,P,S,W,Wk				
Gnorimopsar chopi	Chopi Blackbird	P,V		D,Wk				
Agelasticus cyanopus	Unicolored Blackbird	P,V	B	A,W			NT	

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Chrysomus ruficapillus	Chestnut-capped Blackbird	P		Wk				
Molothrus oryzivorus	Giant Cowbird	P,Sk		W,Wk				
Molothrus bonariensis	Shiny Cowbird	A,P,Sk,V	B	A,D,IAL,S,W,Wk				
Sturnella superciliaris	White-browed Blackbird	P		S,W				
Mitrospingidae (1)								
Orthogonys chloricterus	Olive-green Tanager	A,P,R,Sk,V	34	A,MZUSP,W,Wk				E
Thraupidae (30)								
Coereba flaveola	Bananaquit	A,P,R,Sk,V	B	A,D,IAL,L,MZUSP,P,S,W,Wk				
Saltator fuliginosus	Thick-billed Saltator	A,P,R,V	B1234	A,D,W,Wk				E
Thlypopsis sordida	Orange-headed Tanager	P,Sk,V		D,S,W,Wk				
Pyrrhocoma ruficeps	Chestnut-headed Tanager	Sk		W				AE
Tachyphonus coronatus	Ruby-crowned Tanager	A,P,R,Sk,V	124	A,D,FNJV,L,P,S,W,Wk				E
Ramphocelus bresilius	Brazilian Tanager	A,P,R,Sk,V	B	A,D,IAL,MZUSP,P,S,W,Wk				E
Lanio cristatus	Flame-crested Tanager	A,P,R,Sk,V	B	A,L,MZUSP,P,S,W,Wk				
Lanio cucullatus	Red-crested Finch	P		Wk				
Lanio melanops	Black-goggled Tanager	A,P,Sk,V	2	A,D,W,Wk				
Tangara seledon	Green-headed Tanager	A,P,R,Sk,V	B1	A,D,FNJV,MZUSP,P,S,W,Wk,ZUEC				E
Tangara cyanocephala	Red-necked Tanager	A,P,R,Sk,V	B234	A,D,MZUSP,P,W,Wk				E
Tangara sayaca	Sayaca Tanager	A,P,R,Sk,V	B	A,D,IAL,S,W,Wk				
Tangara cyanoptera	Azure-shouldered Tanager	P,Sk,V		D,MZUSP,W,Wk				E
Tangara palmarum	Palm Tanager	A,P,R,Sk,V	B	A,MZUSP,S,W,Wk				
Tangara ornata	Golden-chevroned Tanager	A,P,R,Sk,V	1234	A,D,P,S,W,Wk				E
Tangara peruviana	Black-backed Tanager	P		Wk				E
Tangara cayana	Burnished-buff Tanager	P,V	B	D,Wk				
Pipraeidea melanonota	Fawn-breasted Tanager	P,V		D,S,W				
Tersina viridis	Swallow Tanager	P,V		D,S,Wk				
Dacnis cayana	Blue Dacnis	A,P,Sk,V	B	A,D,P,S,W,Wk				
Chlorophanes spiza	Green Honeycreeper	P,Sk		MZUSP,P,W,Wk				
Hemithraupis ruficapilla	Rufous-headed Tanager	A,P,Sk,V	1234	A,D,W,Wk				E
Conirostrum bicolor	Bicolored Conebill	P		P,W,Wk				

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism
Sicalis flaveola	Saffron Finch	A,P		D,S,Wk				
Volatinia jacarina	Blue-black Grassquit	A,P,Sk,V	B	A,D,S,W,Wk				
Sporophila falcirostris	Temminck's Seedeater	P		Wk				E
Sporophila lineola	Lined Seedeater	P		S,Wk				
Sporophila caerulescens	Double-collared Seedeater	A,P,V	B	A,D,S,W,Wk				
Sporophila angolensis	Chestnut-bellied Seed-Finch	P,V	B	A,Wk			VU	
Tiaris fuliginosus	Sooty Grassquit	Sk		W				
Cardinalidae (3)								
Habia rubica	Red-crowned Ant-Tanager	A,P,R,Sk,V	B1234	A,D,MZUSP,P,W,Wk,ZUEC				
Cyanoloxia glaucocaerulea	Glaucous-blue Grosbeak	P,Sk,V	B	W,ZUEC				
Cyanoloxia brissonii	Ultramarine Grosbeak	P		Wk				
Fringillidae (5)								
Sporagra magellanica	Hooded Siskin	A,Sk		D,W				
Euphonia chlorotica	Purple-throated Euphonia	A,P		D,S				
Euphonia violacea	Violaceous Euphonia	A,P,R,Sk,V	B12	A,D,L,S,W,Wk,ZUEC				
Euphonia pectoralis	Chestnut-bellied Euphonia	A,P,R,Sk,V	B1234	A,D,FNJV,MZSUP,P,S,XC,W,Wk				E
Chlorophonia cyanea	Blue-naped Chlorophonia	Sk		W				
Estrildidae (1)								
Estrilda astrild	Common Waxbill	A,P,V	B	A,P,S,W,Wk				
Passeridae (1)								
Passer domesticus	House Sparrow	A,P,Sk,V	B	A,D,IAL,S,W,Wk				

APPENDIX II

List of 90 undocumented bird species recorded within the municipality of Bertioga, São Paulo, Brazil. Abbreviations are according to Appendix I. BBS = Boraceia Biological Station, municipality of Salesópolis, São Paulo, Brazil. FO = Fabio Olmos' personal records.

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism	BBS
Crypturellus tataupa	Tataupa Tinamou	A	B	A,D					
Odontophorus capueira	Spot-winged Wood-Quail	A,V	1	A,D,P,W				E	
Sula leucogaster	Brown Booby	V	B	FO					
Eudocimus ruber	Scarlet Ibis	V	B	FO			EN		
Elanoides forficatus	Swallow-tailed Kite	V		D					
Ictinia plumbea	Plumbeous Kite	V		D					
Pseudastur polionotus	Mantled Hawk	V	2	A	NT		VU	E	x
Spizaetus tyrannus	Black Hawk-Eagle	V	?	FO					
Spizaetus melanoleucus	Black-and-white Hawk-Eagle	V	B	A			CR		
Tringa melanoleuca	Greater Yellowlegs	?		W					
Sterna paradisaea	Arctic Tern	?		W					
Patagioenas plumbea	Plumbeous Pigeon	A	123	A,D					
Coccyzus americanus	Yellow-billed Cuckoo	V	B	A					
Megascops atricapilla	Black-capped Screech-Owl	A	B	A,W				E	
Strix hylophila	Rusty-barred Owl	A	1	A	NT			E	
Strix virgata	Mottled Owl	A	B	A					
Glaucidium minutissimum	Least Pygmy-Owl	A	B	A				E	
Nyctiphrynus ocellatus	Ocellated Poorwill	A		D					
Antrostomus rufus	Rufous Nightjar	A		D					
Hydropsalis torquata	Scissor-tailed Nightjar	V		D					
Panyptila cayennensis	Lesser Swallow-tailed Swift	V	B	A			DD		
Glaucis hirsutus	Rufous-breasted Hermit	V		D					
Phaethornis pretrei	Planalto Hermit	V		D					
Phaethornis eurynome	Scale-throated Hermit	V		D				E	x
Stephanoxis lalandi	Plovercrest	V		D				E	x
Hylocharis chrysura	Gilded Hummingbird	V		D					
Polytmus guainumbi	White-tailed Goldenthroat	V		J					

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism	BBS
Heliothryx auritus	Black-eared Fairy	V	B	A			NT		
Nystalus chacuru	White-eared Puffbird	A,V		D					
Pteroglossus bailloni	Saffron Toucanet	V		J			VU		
Melanerpes candidus	White Woodpecker	A,V		D					
Colaptes melanochloros	Green-barred Woodpecker	A	B	A					
Herpetotheres cachinnans	Laughing Falcon	A,V	B	A,D,W					
Amazona farinosa	Mealy Parrot	A,V	B	A			CR		
Thamnophilus doliatus	Barred Antshrike	A,V		D					
Thamnophilus ruficapillus	Rufous-capped Antshrike	V		D					x
Thamnophilus pelzelni	Planalto Slaty Antshrike	A,V		D					
Batara cinerea	Giant Antshrike	A,V		D					x
Mackenziaena leachii	Large-tailed Antshrike	A,V		D				E	x
Mackenziaena severa	Tufted Antshrike	A		D				E	x
Drymophila ferruginea	Ferrugineous Antbird	A,V		D				E	
Drymophila genei	Rufous-tailed Antbird	V		D			NT	E	x
Drymophila ochropyga	Ochre-rumped Antbird	A		D	NT		NT	E	x
Drymophila malura	Dusky-tailed Antbird	A,V		A,D				E	x
Grallaria varia	Variegated Antpitta	A	1234	A,D					
Hylopezus nattereri	Speckled-breasted Antpitta	A,V		D				E	x
Chamaeza campanisona	Short-tailed Antthrush	A		D					x
Chamaeza meruloides	Cryptic Antthrush	A		D				E	x
Sittasomus griseicapillus	Olivaceous Woodcreeper	A,V	B	A,D,W					
Lepidocolaptes squamatus	Scaled Woodcreeper	A,V		D				E	x
Furnarius figulus	Wing-banded Hornero	P,V		D,Wk					
Lochmias nematura	Sharp-tailed Streamcreeper	A,V	B	A,D,P					
Anabazenops fuscus	White-collared Foliage-gleaner	A,V		D				E	x
Heliobletus contaminatus	Sharp-billed Treehunter	V		D,W				E	x
Syndactyla rufosuperciliata	Buff-browed Foliage-gleaner	V		D					
Synallaxis albescens	Pale-breasted Spinetail	V		D			NT		
Cranioleuca pallida	Pallid Spinetail	V		D,W				E	x
Neopelma chrysolophum	Serra Tyrant-manakin	A,V		D				E	x

Taxa	English name	Evidence	Elevation	Source	GL	BR	SP	Endemism	BBS
Ilicura militaris	Pin-tailed Manakin	V		D					
Pachyramphus viridis	Green-backed Becard	A		D					
Pachyramphus castaneus	Chestnut-crowned Becard	V		D,W					
Corythopis delalandi	Southern Antpipit	A		D					
Phylloscartes ventralis	Mottle-cheeked Tyrannulet	V		D					x
Phylloscartes paulista	Sao Paulo Tyrannulet	?		W	NT		VU	E	
Phylloscartes oustaleti	Oustalet's Tyrannulet	A,V	23	A	NT			E	
Poecilotriccus plumbeiceps	Ochre-faced Tody-flycatcher	V		D					x
Hemitriccus orbitatus	Eye-ringed Tody-Tyrant	A	124	A,D,P,W	NT			E	
Hemitriccus nidipendulus	Hangnest Tody-Tyrant	V		D				E	
Tyranniscus burmeisteri	Rough-legged Tyrannulet	V		D					x
Elaenia obscura	Highland Elaenia	V		D					
Phaeomyias murina	Mouse-coloured Tyrannulet	V		D					
Myiarchus tyrannulus	Brown-crested Flycatcher	V		D					
Sirystes sibilator	Sirystes	A		D					
Megarynchus pitangua	Boat-billed Flycatcher	A,P,V	B	A,D,Wk					
Conopias trivirgatus	Three-striped Flycatcher	?		W					
Knipolegus nigerrimus	Velvety Black-Tyrant	V		D					x
Muscipipra vetula	Shear-tailed Grey Tyrant	A,V		D				E	x
Cyclarhis gujanensis	Rufous-browed Peppershrike	A,P,V	234	A,D,W,Wk					
Hylophilus poicilotis	Rufous-crowned Greenlet	A	B	A,D				E	x
Progne tapera	Brown-chested Martin	V	B	A					
Tachycineta leucorrhoa	White-rumped Swallow	A,V	B	A,W					
Myiothlypis leucoblephara	White-browed Warbler	A,V		D					x
Cacicus chrysopterus	Golden-winged Cacique	V		D					x
Gnorimopsar chopi	Chopi Blackbird	P,V		D,Wk			NT		
Saltator similis	Green-winged Saltator	A	2	A,D,W					x
Orchesticus abeillei	Brown Tanager	V		D	NT		NT	E	x
Tangara desmaresti	Brassy-breasted Tanager	V		D				E	x
Tangara cayana	Burnished-buff Tanager	P,V	B	A,D,Wk					
Stephanophorus diadematus	Diademed Tanager	V		D					x
Emberizoides herbicola	Wedge-tailed Grass-Finch	V	B	A					

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SHORT-COMMUNICATION

Rodent predation by *Turdus leucomelas* (Passeriformes: Turdidae)

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ABSTRACT: Pale-breasted Thrush (*Turdus leucomelas*) is described as an omnivorous bird that forage solitarily or in pairs on the soil. This note reports a rodent predation event by *T. leucomelas*. The event was recorded on November 14th 2013, in a riparian Forest fragment of Grande River, in Igarapava Municipality, São Paulo, Brazil. Although the presence of small vertebrates on the diet of *T. leucomelas* is known, this is the first record of a mammal being predated by this bird species. This record is important because it contributes to a better understand of the natural history of Neotropical passerines.

KEY-WORDS: Diet, feeding, Pale-breasted Thrush, predation, rodent.

The Pale-breasted Thrush *Turdus leucomelas* Vieillot, 1818 (Passeriformes, Turdidae) (CBRO 2014) occurs in the South American continent, from the Guianas and Venezuela to Bolivia, Argentina, Paraguay and Brazil. In Brazil, it has a wide distribution, not occurring only in the central and western regions of the Amazonian forest and the eastern portions of Santa Catarina and Rio Grande do Sul states (Sick 1997, Mendes-Neto & Vasconcelos 2005, Sigrist 2013).

This thrush normally inhabits semi-forested areas, but it can be recorded in a variety of habitats, including urban areas (Sick 1997). Female builds a bowl-shaped nest, made up of clay, roots, and dried vegetal matter, on human constructions, ravines and hedgerows, in heights varying from 1 to 2.5m from the ground (Sick 1997). Two to three green-bluish red spotted eggs are incubated by the female for 10 to 12 days, when the nestlings are born (Mendes-Neto & Vasconcelos 2005, Sigrist 2013).

Pale-breasted Thrush is described as an omnivorous bird that forage solitarily or in pairs on the ground (Willis 1979, Sick 1997). From stomach content studies and direct observations in the wild, the diet of *T. leucomelas* was delimited: fruits, seeds, insects, arachnids, earthworms, gastropods, and small vertebrates, such as lizards and snakes (Moojen *et al.* 1941, Schubart *et al.* 1965, Poulin *et al.* 1994, Piratelli & Pereira 2002, Durães & Marini 2005, Lopes *et al.* 2005a,b, Lima *et al.* 2010, Sazima & D'Angelo 2011).

Although the capacity of predating small vertebrates by *T. leucomelas* has already been attested (Lopes *et al.* 2005b, Sazima & D'Angelo 2011), there is no report in scientific literature of this bird species predating upon small mammals. Thus, the aim of this short communication is to report on the first record of *T. leucomelas* predating upon a small rodent.

The event was recorded on 14 November 2013, at 03:30 PM, in a riparian forest fragment along the Grande River, in Igarapava Municipality, São Paulo, southeastern Brazil (19°59'22.53"S / 47°48'38.25"W; elevation: 497 m). The riparian forest fragment is located near a sugar-alcohol plantation and has many small ranches inside it.

Two Pale-breasted Thrushes were observed persecuting two small rodents through the litter. During the persecution, the thrushes tried to capture the rodents using their beaks; this behavior was recorded during 30 seconds, when one of the thrushes and one of the rodents run out of sight. The other thrush jumped into the rodent and captured it, holding the mouse against the ground with its beak. The mouse tried to escape wrestling, but he did not make it. Then, the thrush flew holding the dead mouse on its beak, first landing on the ground (Figure 1a) and then on a branch (Figure 1b).

In a study on the small mammal community at the same area, Corrêa (2014) recorded nine rodent species, with the species of the genus *Oligoryzomys* being the most frequent ones. Looking at the morphological

FIGURE 1. Pale-breasted Thrush (*Turdus leucomelas*) with a small dead rodent in its beak on the ground (A) and on a branch (B).

characteristics of the predated mouse, it is very likely that it belonged to this genus (see Carleton & Musser 1989).

Lopes *et al.* (2005b) suggested that vertebrate predation events by Neotropical passerines were rare, since these events were recorded in only 9% of the known species; among these, in only 18% of the species, small vertebrates other than frogs or lizards were recorded. Mammals were recorded in the diet of only 23 (11%) of the 203 species analysed, distributed in nine families, with Turdidae included (Lopes *et al.* 2005b). From the eight Turdidae species evaluated, only *Turdus migratorius*, native to North America, presented vestiges of mammals in its diet (Lopes *et al.* 2005b). These results suggested that the mammal predation by Neotropical passerines is even rarer.

According to Sazima & D'Angelo (2011), passerine birds hunt vertebrates mostly during the reproductive season, because feeding vertebrates to the nestlings and juveniles provide more proteins, calcium and energy to their development if compared to fruits and invertebrates. The predation event described herein occurred during the breeding season of *T. leucomelas* (October to December, Lobato *et al.* 2011), indicating that it may include vertebrates in the diet of their nestlings or that they ingest such items to complement their nutritional necessities during this critical period.

Vertebrate predation events by passerine birds have been recorded in the last decade; records came from stomach content studies (Chapman & Rosenberg 1991, Lopes *et al.* 2005b, Aguiar & Coltro-Jr 2008) and occasional sightings (Sazima 2007, Lima & Rodrigues 2008, Pizo 2008, Carvalho-Filho 2009, Mafia *et al.* 2011, Sazima & D'Angelo 2011, Brito *et al.* 2014), such as the one presented herein. Therefore, our record is important because it contributes to a better understand of the natural history of Neotropical passerines (Christianini 2005, Mesquita 2009).

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SHORT-COMMUNICATION

Long-trained Nightjar (*Macropsalis forcipata*) (Aves, Caprimulgidae): first Paraguayan record

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ABSTRACT: The first observations of Long-trained Nightjar *Macropsalis forcipata* in Paraguay are documented, confirming speculation that the species was likely to occur in the country.

KEY-WORDS: Atlantic Forest, Caprimulgiformes, distribution, range expansion, Paraguay.

The Long-trained Nightjar *Macropsalis forcipata* is endemic to the Atlantic Forest of southeastern Brazil (Espirito Santo to Rio Grande do Sul) and Misiones Province in northeastern Argentina (Cleere 1999, Cleere & Nurney 1998). The species was first documented for Argentina in 1973 (Olrog 1973), but on the basis of numerous recent records across Misiones Province it has been suggested that it is in expansion, facilitated by human alteration of native forest and that records in neighbouring Paraguay should be expected (Bodrati & Cockle 2012). In this note we confirm the presence of the species in the Atlantic Forest of southern Paraguay.

On 23 September 2014 a male was seen briefly by HH as it flushed from a roadside at the Zanja de Pirapó, Departamento Itapúa, Paraguay (26°43'32.6"S / 55°34'00.8"W). A single male was then seen again at the same location on 5 October 2014 (HH, PS) when it was possible to document the record photographically (Figure 1) and again on 1 November 2014 (HH, PS). The individual could be confidently distinguished from the only possible confusion species, the highland Andean Lyre-tailed Nightjar *Uropsalis lyra*, by the extensive areas of white on the head and breast and broad white edges to the tail streamers. No other species occurring in the region has such massively elongated tail streamers.

The bird sat on an unpaved roadside within a small patch of disturbed Atlantic Forest, surrounded by cultivation. The area is slightly hilly, and the locality is on a steep descent towards a rarely used bridge over the Arroyo Pirapó. Detailed behavioural notes were not taken, but it was possible to confirm the observation that the bird repeatedly returned to the exact same spot after being flushed, as noted by Bodrati & Cockle (2012). Such behaviour has been associated with the establishment of display arenas to which males are faithful (Olmos & Rodrigues 1990).

To date this is the only observation of this species in Paraguay and because only a single male was seen it is impossible to draw any firm conclusions on the status of the species in the country. However the distance of 79.7 km from the closest Argentine locality (San Martín, Obera, 27°24'S / 55°19'W), and an Argentine record very close to the banks of the Paraná River at Puerto Libertad (25°55'S / 54°37'W) facing the Paraguayan department

FIGURE 1: Adult male Long-trained Nightjar *Macropsalis forcipata*, Zanja de Pirapo, Departamento Itapúa, Paraguay, 5 October 2014. (Photo Paul Smith).

of Alto Paraná, suggest that the species may be more widespread in southern and eastern Paraguay than is currently known. If it is indeed a species in expansion then new Paraguayan records and localities may be expected in due course. Sixteen species of Caprimulgidae are now known to occur in the country (FAUNA Paraguay 2014).

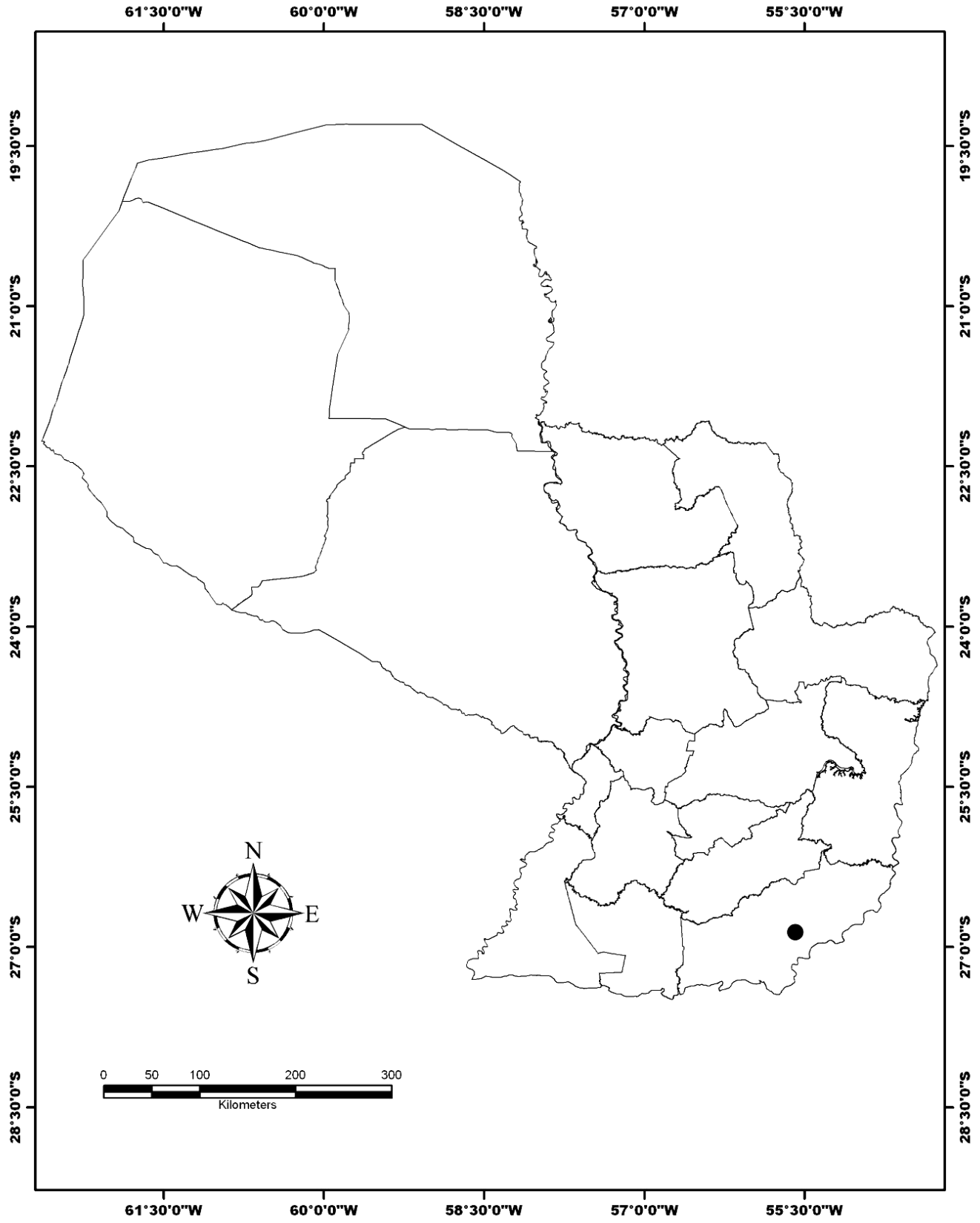

FIGURE 2: Zanja de Pirapo, Departamento Itapúa, Paraguay, the locality where the first country record of the Long-trained Nightjar *Macropsalis forcipata* was obtained.

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SHORT-COMMUNICATION

First records of Masked Tityra *Tityra semifasciata* (Spix, 1825) for the state of Paraná, southern Brazil

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ABSTRACT: We report the first records of the Masked Tityra (*Tityra semifasciata*) for the state of Paraná, in the city of Foz do Iguaçu, between July and September 2014. These records extend the known distribution range of the species and establish a new southern limit for its geographic distribution within Brazil. Although the species occur in nearby regions, it had never been recorded before in southern Brazil, possibly due to confusion with the congeneric Black-tailed Tityra (*Tityra cayana*).

KEY-WORDS: Distribution, Foz do Iguaçu, range extension, Tityridae.

The Masked Tityra (*Tityra semifasciata*) is one of the three species of the genus occurring in Brazil; it has 20-24 cm and weighs between 77 and 88 g (Mobley & de Juana 2014), inhabiting humid to semi-arid forest canopy and crown of taller trees along forest edges, woodland, palm stands, second growth, relatively open areas from forest clearings to savanna with scattered trees, and plantations (Mobley & de Juana 2014).

The species is distributed in Mexico, Belize, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, French Guiana, Colombia, Ecuador, Peru, Bolivia, Brazil (primarily S of Amazon in C & S Amazonas E to Pará, Amapá and N Maranhão, S to Acre, Rondônia, S Mato Grosso and N Goiás) (Mobley & de Juana 2014). In Brazil, the southernmost records obtained so far come from Mato Grosso do Sul State, between 2006 and 2010 (Godoi *et al.* 2011).

In Paraguay, the Masked Tityra was recorded for the first time in 1995, at the Forest Nature Reserve Mbaracayú (Lowen *et al.* 1997), while in the Argentina the first record took place in 2008, at Iguazu National Park, Misiones (Bodrati *et al.* 2008). In 2010 five additional records of *T. semifasciata* were obtained in Misiones, showing the recent expansion of home range in Argentina (Pagano & Bodrati 2011).

The first record for the state of Paraná in Brazil occurred during banding and monitoring birds activities conducted by the authors at the Permanent Preservation Area (APP) in "Parque das Aves", Foz do Iguaçu, (25°37'9.12"S / 54°29'18.09"W). The total area of the property is 16 ha, with eight hectares devoted to the area of the zoo, and the rest covered by semideciduous secondary forest at different successional stages. The property is located only 400 m from the Iguaçu National Park in Brazil and 300 m from the Iguazu National Park in Argentina).

On 25 July 2014, a female Masked Tityra was recorded and photographed (Figure 1), with a mixed-species flock together with Black-crowned Tityra (*Tityra inquisitor*), Three-striped Flycatcher (*Conopias trivirgatus*), Tropical Parula (*Setophaga pitiayumi*), Blue Dacnis (*Dacnis cayana*), Guira Tanager (*Hemithraupis guira*), and Violaceous Euphonia (*Euphonia violacea*). The mixed-species flock was in the canopy about 20m high. The Three-striped Flycatcher (*C. trivirgatus*) and Black-crowned Tityra (*T. inquisitor*) were vocalizing intensely, and probably acted as sentries of the flock. The observation lasted about seven minutes (16:55 to 17:02), allowing detailed observation and obtaining various photographs that enabled confirmation of the species identification. The mixed-species flock was moving towards the Iguaçu River and Iguazu National Park, Misiones, Argentina.

Between 23 and 29 September of 2014 a male and a female Masked Tityra were recorded and photographed (Figure 2) resting on a guatambu tree (*Balfourodendron riedelianum*) in front of the restaurant at "Parque das

Aves". During these days the pair remained in this tree, being seen for long periods and attacking other bird species that landed nearby, such as Red-breasted Toucan (*Ramphastos dicolorus*), Plush-crested Jay (*Cyanocorax chrysops*), Bat Falcon (*Falco rufigularis*) and Red-rumped Cacique (*Cacicus haemorrhous*).

FIGURE 1. A female of Masked Tityra photografed at "Parque das Aves", Foz do Iguaçu, state of Paraná on 25 July 2014.

FIGURE 2. A male (left), and female (right) Masked Tityra photographed between 23 and 29 September 2014, at "Parque das Aves", Foz do Iguaçu, state of Paraná.

In the interval between these records (15 August 2014), the authors and Leandro Castillo, recorded a female Masked Tityra at Puerto Iguazu, Misiones, Argentina (25°36'22.3"S / 54°32'53.9"W), only ca. 6 km from the first Paraná record.

In Brazil, the nearest place from where the species was recorded is Campanário Farm (22°51'22.74"S / 54°59'10.02"W), at Amambaí, Mato Grosso do Sul (Mauricio Neves Godoi *pers. comm.*), ca. 314 km from our Paraná record. In Paraguay, the nearest record is 128 km, while in Argentina, only 6,4 km (Table 1).

It is not easy to explain the increased number of records obtained recently for the Masked Tityra in southern South America (southern Brazil, Paraguay, and Argentina), but one possibility is that prior to these records it had been confused with the similar looking and more abundant Black-tailed Tityra, as suggested by Bodrati *et al.* (2008).

We recommend therefore that observers in southern Brazil be attentive to the diagnostic features of the Masked Tityra, since future records of this species could potentially be obtained at additional localities covered with seasonal semideciduous forests in Paraná as well as Santa Catarina and Rio Grande do Sul. With the accumulation of additional records, the causes of the reported range extension of the Masked Tityra in southern South America could perhaps be elucidated.

TABLE 1. The shortest distances between records of Masked Tityra in Argentina, Paraguay and Brazil, and the first record for the state of Paraná.

Date	Country	City/ State	Geographic Coordinates	Distance (Km)	Reference
15 August 2014	Argentina	Puerto Iguazu, Misiones (Selva Iryapu)	25°36'22.30"S 54°32'53.90"W	6,1	F.Girardi; E. Carrano & L. Castillo (*pers. obs.*)
29 August 2010	Argentina	Puerto Iguazu, Misiones (Ruta Nacional 12, Km 5)	25°37'19.82"S 54°33'7.64"W	6,4	Pagano & Bodrati (2011)
11 October - 4 December 2001; 20 February 2002; 21 April 2002	Paraguay	Dpto. Canindeyú (Resort and Private Reserve Itabó Rivas)	24°28'S 54°36'W	128	Castillo & Clay (2004)
12 August 2011	Brazil	Amambaí, Mato Grosso do Sul (Campanário Farm)	23°6'33.80"S 55°13'31.52"W	314	Mauricio Neves Godoi (*pers. comm.*)
07 August 2007	Brazil	Rio Brilhante, Mato Grosso do Sul (LDC Rio Brilhante Mill)	21°42'04.15"S 54°31'13.94"W	434	Godoi *et al.* (2011)

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SHORT-COMMUNICATION

Crested Quetzal (*Pharomachrus antisianus*) preying on a Glassfrog (Anura, Centrolenidae) in Sierra de Perijá, northwestern Venezuela

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ABSTRACT: We report the predation of a glassfrog (*Hyalinobatrachium pallidum*) by a Crested Quetzal (*Pharomachrus antisianus*). The record was made in a locality in the Sierra de Perijá, near to the northern part of the border between Colombia and Venezuela, and consisted in observinga male *P. antisianus* vocalizing with a glassfrog in its bill. The vocalizations were answered by a female, which approached the male, took the frog with its bill and carried it into a cavity built on a landslide. Subsequent to this, the male remained near to the cavity until the female left it and together they abandoned this place. Based on the behavior observed in the couple of quetzals, and what has previously been described that this group of birds gives their young a diet rich in animal protein comprised of arthropods and small vertebrates, we believe that the couple was raising a brood at the time when the observation was carried out.

KEY-WORDS: Anurophagy, diet, *Hyalinobatrachium*, Trogonidae, Trogoniformes.

The consumption of animal protein is a behavior exhibited by most of the species of the family Trogonidae. Within this family there is a wide range of alimentary habits, ranging from species that are almost exclusively frugivorous to others whose diet consists equally of fruits and insects, and species that are exclusively insectivorous or carnivorous (Smith 2004). Members of the genus *Pharomachrus*, commonly recognized as Quetzals, are the most frugivorous species in the family, described as birds that only eat fruits and sometimes include animal protein as part of their feeding, which is represented by arthropods and/or small vertebrates (Johnsgard 2000, Collar 2001).

Studies focused on describing the diet of Quetzals are scarce. One of the most comprehensive is based on the review of the stomach contents of the following four species: Crested Quetzal (*Pharomachrus antisianus*), Golden-headed Quetzal (*P. auriceps*), Resplendent Quetzal (*P. mocinno*), and Pavonine Quetzal (*P.pavoninus*). This study concludes that these birds are primarily frugivorous and only *P. auriceps* and *P. pavoninus* included arthropods in their diets (Remsem *et al.* 1993). Others that focused on *P. mocinno* indicated that the adults of this species are almost exclusively frugivorous and the animal portion of their diet is given to nestlings (Wheelwright 1983), a behavior also reported for *P. pavoninus* (Lebbin 2007) and *P. auriceps* (Lohnes & Greeney 2008).

The Quetzals (*Pharomachrus* spp.) are characterized by having a glistening plumage with the upperparts, head, neck and chest green or golden green and lower breast, belly and undertail coverts red (Johnsgard 2000). This genus is composed by five species (*P. antisianus*, *P. auriceps*, *P. fulgidus*, *P. mocinno* and *P. pavoninus*), distributed from southern Mexico to Bolivia, where they primarily inhabit cloud and rain forests (Stotz *et al.* 1996, Collar 2001).

Despite the wide distribution in the Neotropical region and the fact that these are very attractive birds, the natural history of Quetzals is poorly known, with *Pharomachrus mocinno* being the better-know species of the group. The remaining species have had less attention and most of their biological aspects are unknown throughout their ranges. This situation also holds in Venezuela, where *Pharomachrus* species are distributed in the Cordillera de Mérida and Sierra de Perijá (*P. antisianus* and *P. auriceps*), the Cordillera de la Costa (*P. fulgidus*) and south of the Orinoco River (*P. pavoninus*) (Hilty 2003).

Knowing the natural history of a species is important for their conservation, with diet being one of the main factors, especially when one wants to establish conservation

plans (Young 1997). *Pharomachrus antisianus* is one of the lesser-known species of Quetzal and it is only known that they feed on fruits, berries, insects, lizard and frogs (de Schauensee & Phelps 1978), without specific details on the composition of these items. Therefore, our objective is to contribute with knowledge of their alimentary habits describing the predation of a Glassfrog by this species.

The predation event was registered on 18 February 2014 at 15:30 h, in a mature cloud forest located in the upper basin of the Lajas River (Serranía de Lajas), in the Venezuelan side of the Sierra de Perijá (10°20'N / 72°34'W, 1700 m elevation). This event consisted of the observation of an adult male of *Pharomachrus antisianus* perched in a tree at level of the understory with a Glassfrog in its bill (Figure 1). The bird was easily located in the vegetation by its noisy and persistent vocalization, which was maintained until a female came to perch in the tree. During the encounter of the couple, the male gave a Glassfrog to the female and it flew with the prey to a cavity built on top of a landslide, followed by the male who landed near the edge of the cavity until the female came out of it. Due to brevity of the event and the rapid movement of birds within the forest, only a photograph of the male when he was perched could be taken. Later observations were conducted over three consecutive days, where the male was observed vocalizing with the female and giving others foods, but unfortunately, it was not possible to identify if these were fruits or animal items.

FIGURE 1. Crested Quetzal (*Pharomachrus antisianus*) perched in a tree at level of the understory whit a Glassfrog (*Hyalinobatrachium pallidum*) in its bill, before to delivering prey to the female (photograph by M. Quiroga-Carmona, taken at February 18 of 2014).

The inclusion of animal items in the diet of frugivorous birds has been described previously in several groups such as barbets, motmots, quetzals, toucans and trogons (Remsem *et al.* 1993). This behavior is attributed to the higher demand for proteins that is required during the reproductive season, since these are necessary for the formation of egg shells and development of the embryos, and a diet composed only on fruits is not nutritionally sufficient during this period (Martin 1987, Winkler 2001). In addition, in altricial nestling birds, protein diets allow rapid growth and for that reason nestlings also are fed with a diet that includes animal items (Morton 1973). This information, together with the fact that the couple of *Pharomachrus antisianus* exhibited a similar behavior to that described several species of Quetzals (*Pharomachrus auriceps*, *P. mocinno* and *P. pavoninus*) during its breeding period, that these species include animal items in the diet of their nestlings (Wheelwright 1983, Lebbin 2007,

Lohnes & Greeney 2008), and that the observation was performed during the reproductive season of *P. antisianus* (Hilty 2003), make us think that this couple had been raising a brood.

The predation of frogs by quetzals has been previously described for *Pharomachrus antisianus* (de Schauensee & Phelps 1978), *P. mocinno* (Stiles & Skutch 1989) and *P. pavoninus* (Lebbin 2007). For the latter species, it has been described that the predated frogs are of the genera *Hyla* and *Phyllomedusa*. We identified the predated frog initially for its morphological characteristics and also based on species of the family Centrolenidae (*Hyalinobatrachium pallidum* and *Centrolene daidaleum*) whose distribution include the sector of the Sierra de Perijá where we performed the observation (Locality 4 described in Fig. 1 of Rojas-Runjaic *et al.* [2012]). In addition, the coloration and the pattern of distribution of the melanophores in the legs suggest that this frog is an individual of *Hyalinobatrachium pallidum* (Castroviejo & Rojas-Runjaic *pers. comm.*).

The scarce information available about the natural history of the Quetzals is a regrettable fact, because it makes difficult to understand their biological relationships, and at the same time, its importance within the ecosystems they inhabit. Additional studies aimed at determining the significance of animal items in their diets and how the quality of habitat may influence in nestling breeding are needed.

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