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**Cover:** The Burrowing Owl (*Athene cunicularia*) is a widely distributed species in Neotropics, common in human-altered environments, including farms and cities. In this issue, Franco & Marçal-Junior studied its distribution and burrow characteristics in a range of urban habitats in southeastern Brazil, while Cavalli *et al.* (in this issue) compared blood stress indicators in owls from rural and urban areas in Argentina. Photo author: Ronald Gruijters.

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# Revista Brasileira de Ornitologia

**Volume 26 – Issue 1 – March 2018**

## CONTENTS

### BEHAVIOR

### ECOLOGY & CONSERVATION

### SYSTEMATICS, TAXONOMY AND DISTRIBUTION

*Revista Brasileira de Ornitologia 26(1): 1–8.*
*March 2018*

# Influence of urbanization on the distribution and defense strategies of the Burrowing Owl *Athene cunicularia* in the city of Uberlândia, southeastern Brazil

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**ABSTRACT:** Urbanization causes drastic changes in habitat and species behavior. In birds, these changes influenced the extinction of some species. The Burrowing Owl *Athene cunicularia* (Molina, 1782) (Aves: Strigiformes) has achieved some success in its adaptive process in anthropic environments. The main objective of this study was to measure distribution of this species in urban areas. The specific objectives were to quantify and compare the occurrence of this owl and its satellite burrows among urban biotopes; evaluate the importance of satellite burrows as a defense strategy and compare the depth of burrows in different biotopes. Field activities were carried out from August 2015 to November 2016. Sixty areas were sampled in different urban regions. The species was present in 29 of the 60 sites investigated, totaling 112 individuals, 88 adults, 14 young and 10 chicks; 98 burrows were recorded, from which 22 were refuges, seven nests and 67 satellite burrows. Residential and Urban Green Area biotopes had the highest number of individuals and burrows with a significant difference relative to the Commercial/Industrial biotope. A greater number of individuals were found in areas with a high number of burrows showing a positive linear relationship between these variables. The burrows were deepest, on average, in Urban Green Area biotopes. We conclude that the species has a wide distribution in the city with significantly high numbers in the Residential biotope. This same tendency is verified for the distribution of burrows. In areas with a large number of individuals, the same was observed for the number of satellite burrows. Deeper burrows in the Urban Green Areas are perhaps due to the greater transit of people, one of the main features of this biotope and one of the major threats to the Burrowing Owls.

**KEY-WORDS:** biotope, habitat, occurrence, satellite burrows, survival.

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## INTRODUCTION

Urbanization can be defined as a process of anthropic occupation that gradually transforms natural environments and includes the presence of relatively permanent human populations on the site (Marzluff *et al.* 2001). On a global scale, anthropic pressures have influenced the structure and behavior of faunal populations and communities, and also of ecosystems in remnants of natural areas (Bradshaw & Holzapfel 2006, Delibes *et al.* 2011). Human presence can lead to population decline, persistence, or even the expansion of bird distributions (Sih *et al.* 2011). Furthermore, the disturbances caused by anthropic actions seem to be causing changes in the distribution and behavior of birds and might also be leading many species to extinction (Silva & Nakano 2008).

Many birds have adapted to the anthropic environment and their presence is important for pest control, such as predation of rats and insects, besides having an important role in the food chain (Millennium Ecosystem Assessment 2005). In addition, they perform functions like pollination and dispersal of fruits and seeds (Silva & Nakano 2008).

Some of these birds live in urban environments, such as *Athene cunicularia* (Molina, 1782), that is widely distributed throughout the Americas, from Canada to southern Argentina (Poulin *et al.* 2005, 2011). Burrowing Owls have preference for open habitats, foraging and breeding in short, low-density vegetation and mainly grasslands (Rebolo-Ifrán *et al.* 2017). These owls are common in Brazil and known for being urban dwellers, showing behavioral adjustments to anthropic-altered environments (although they are commonly observed in natural areas) (Sick 1997, Motta-Junior & Alho 2000). Some populations are able to exploit human-made habitats with a preference for urban over rural areas (natural grasslands and low-intensive agro-pastoral lands) (Rebolo-Ifrán *et al.* 2017). Main causes of mortality include collisions with vehicles and nest destruction (Silva 2002). The behavioral responses of Burrowing Owls to threats can be easily recognized, such as the use of deep burrows, use of satellite burrows, flying away in the presence of potential predators, making alarm calls, adopting threat postures and some type of attacks (Coulombe 1971, Thomsen 1971, Fisher *et al.* 2004).

Burrowing Owls are present in many parts of the world and are considered one of the main predator species of rodents in urban areas (Martins & Eagler 1990, Sick 1997, Motta-Junior & Alho 2000). However, the behavior of the species is affected by urbanization and it is reported that the increase in vehicular traffic around the nest produces an increase in the couple's waking time (Plumpton & Lutz 1993). Similarly, populations of Burrowing Owls are under heavy pressure from domestic animals, such as dogs and cats (Dechant *et al.* 2003, Rosenberg & Haley 2004, Moulton *et al.* 2006). These threats determine behavioral responses that include subterranean retreat, deeper burrows, the use of satellite burrows, the issuance of alarm calls, and dive-in-flight attacks (Coulombe 1971, Thomsen 1971, Fisher *et al.* 2004). It has also been described the use of mammalian manure, placed near the entrance of the burrow, to avoid potential predators with bad odor (Martin 1973).

Burrows are the essential component of Burrowing Owl habitat: both natural and artificial burrows provide protection, shelter, and nests (Henny & Blus 1981). Burrowing Owls typically use burrows made by fossorial mammals, but also may use man-made structures, such as cement culverts; cement, asphalt, or wood debris piles; or openings beneath cement or asphalt pavement. Burrowing Owls exhibit high site fidelity, reusing burrows year after year (Rich 1984, Feeney 1992). Once young individuals learn to fly, the family group often moves from one burrow to another (Thomsen 1971).

Declines in populations of this species in North America called the attention of environmentalists (Holroyd *et al.* 2001, Skeel *et al.* 2001, Warnock & Skeel 2004, Conway & Pardieck 2006) and, in Florida, the Burrowing Owl had its status updated to threatened in the state red lists (Florida Fish and Wildlife Conservation Commission 2017). The aim of the present study was to determine the distribution and the abundance of the Burrowing Owl in urban areas of the city of Uberlândia, southeastern Brazil, by (1) evaluating the occurrence and abundance of the species among different urban biotopes; (2) determining the occurrence and distribution of burrows (satellites, nests or refuges) per urban biotopes; (3) evaluating different defense mechanisms, such as the importance of satellite burrows, the relationship between the number of individuals and burrows; and the depth of the burrows in different biotopes, which are fundamental aspects for conservation of the studied species in modified environments.

## METHODS

### Study area and data collection

The municipality of Uberlândia has about 669,000 habitants (IBGE 2016), with a total area of 4040 km$^2$ in the state of Minas Gerais (MG), southeastern Brazil, from which 219 km$^2$ are urban. In areas surrounding the city, the native vegetation was reduced to remnants of less than 15% of the original cover, with evident reduction of the local fauna (Brito & Prudente 2005).

We visited areas with a potential occurrence of the species, typically with short grasses and wide spaces of open areas (Coulombe 1971, Plumpton & Lutz 1993, Marks *et al.* 1999). Field activities were carried out from August 2015 to November 2016, with monthly data collections along the day (from 7:00 h to 18:00 h) with small interruptions, not every day of the month, and totaling 2000 h of observation.

Sixty sites (with areas of about 33 m$^2$ each) were sampled in different parts of the city, 20 per urban biotope, and visited monthly. The minimum distance between sites was 200 m, in order to guarantee the independence of the samples and considering the territorial behavior of the studied species (Gaston 2003). These sites were selected according to the potential occurrence of the Burrowing Owls with the help of satellite images obtained from the Google image bank of the city of Uberlândia (Google Earth 5.1 2009) and also by direct field observations. All sites were georeferenced by taken a point in the middle using a Global Positioning System (GPS) and a map of the city was made with these GPS points in the software QGIS 2.18.2 (Fig. 1).

Biotope refers to a certain living space distinct from the others, endowed with environmental conditions suitable for specific organisms (Sukopp & Weiler 1988). The selected sites were classified according to the European Method for Mapping Biotopes: Urban Green Areas, Residential and Commercial/Industrial (Sukopp & Weiler 1988, Weber & Bedê 1998). Urban Green Areas include urban parks, squares, sports centers, theaters, universities, schools and airports, all places in which there is a high flow of people and a medium level of urbanization. The residential biotope is characterized by the presence of houses, condominiums and residential buildings, with less evident levels of pollution and environmental disturbances; in addition, this biotope has a lower flow of humans and vehicles (but with constant presence of domestic animals). The Commercial/Industrial biotope includes open areas with short grasses, near places with intense commerce, such as malls, industries or construction sites, with intense traffic of vehicles and high level of urbanization.

Three visits were conducted to each site, totaling 180

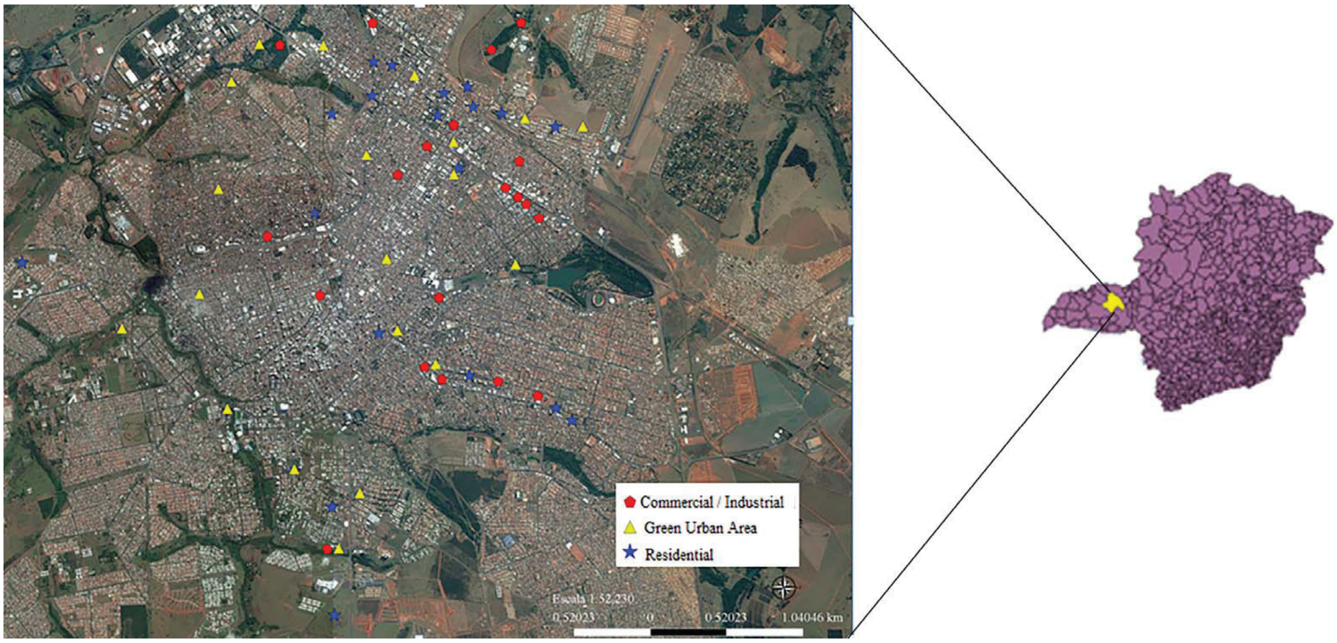

**Figure 1.** A map of the distribution of the sampled points for the Burrowing Owl occurrence, according to the investigated biotopes (Urban Green Area, Residential or Commercial/Industrial) in the urban area of Uberlândia (MG), Brazil.

visits (60 visits in each biotope investigated). The relative abundance was calculated by counting individuals of the target species per site and the same was done for the burrows. Individuals were classified according to gender (only adults) (Zarn 1974) and age group (adults, chicks and juveniles) (Appendix I). Burrows were classified as main or satellite. Main burrows were subdivided by nests (in which chicks or eggs were present) and refuges (in which only adults were present). Satellite burrows were represented by non-inhabited burrows near the main ones, and are used as a defense mechanism against threats, in which individuals rotate between burrows in order to confuse predators (Henny & Blus 1981, Desmond & Savidge 1999). Some burrows were lost due to human action.

To measure the depth of the burrows we used a digital measuring tape (Bosch GLM30) 5 m long. Only burrows that we could reach without causing stress (absence of individuals) or nests without the presence of chicks, were measured.

### Data analysis

Homogeneity tests of variances and normality of the sampled data were performed using a Lilliefors test and by evaluating the data distribution in scatter plots. Sample data transformations (three times in the Variance Analysis, in addition to the Linear Regression) were performed by square rooting values, which were necessary due to the non-normality distribution of the sampling data (Zar 2010). To determine the differences in Burrowing Owl abundance and number of burrows according to urban biotopes we used the ANOVA One-Factor test. Tukey's test was used to determine which factor levels (urban biotope) differed from each other (Zar 2010). Another ANOVA test was used to evaluate the differences in burrow depth by biotope.

To evaluate the correlation between number of individuals and burrows we performed a simple linear regression. Values were square root transformed for normality adjustment (Zar 2010). All statistical analyzes were performed using the Systat 10.2 software, with a significance level of $\alpha = 0.05$ (Zar 2010) and graphs were built using Illustrator 21.1.0.

## RESULTS

### Distribution, occurrence and abundance

The species was found in 29 out of the 60 sampled sites (48%). In total, 98 burrows were registered, with a mean of 3.14 burrows per point, with 29 main burrows (22 refuges and seven nests) and 69 satellite burrows. We recorded 112 individuals (Table 1).

### Distribution and occurrence by biotopes

Residential biotope points showed the highest number of individuals ($n = 55$) followed by Green Urban Area points ($n = 47$) and Commercial/Industrial Area points ($n = 10$). The largest number of individuals found in a single point was recorded in a Residential biotope ($n = 8$). A mean of three individuals per point were recorded in the

**Table 1.** Number of individuals of Burrowing Owl, by age group (adults, juveniles and chicks) and gender (male and female) in the biotopes investigated in the urban area of Uberlândia (MG), Brazil.

| **Biotopes** | **Adults** | | **Chicks** | **Juveniles** | **Total** |
|---|---|---|---|---|---|
| | **Male** | **Female** | | | |
| Residential | 21 | 22 | 9 | 3 | 55 |
| Green Urban Area | 18 | 18 | 4 | 7 | 47 |
| Commercial/Industrial | 3 | 6 | 1 | 0 | 10 |
| TOTAL | 42 | 46 | 14 | 10 | 112 |

Residential biotope, two in Green Urban Area and 0.5 in Commercial/Industrial ($F_{(2,57)} = 4.2$, $P = 0.020$, Fig. 2A), with a significant difference between the Residential and Commercial/Industrial biotopes ($P < 0.016$).

### Distribution and occurrence of burrows by biotopes

We found 51 burrows in the Residential biotope, 39 in Green Urban Area and 8 in Commercial/Industrial ($F_{(2,57)} = 3.19$, $P = 0.048$, Fig. 2B), with a significant difference between Residential and Commercial/Industrial (Tukey's test; $P < 0.040$).

### Relationship between satellite burrows and number of individuals

In general, large numbers of satellite burrows were found in points with large number of individuals, with a positive linear relationship between the two variables ($F_{(1,58)} = 428.89$, $P < 0.001$, $R^2 > 0.88$) (Fig. 3) (Table 2).

### Depths of burrows in the urban biotopes

Thirty-four depths of burrows were measured. The highest mean was observed in the Green Urban Area biotope, reaching a maximum depth of 3.5 m. There was a significant difference between the three biotopes ($F_{(2,17)} = 4.05$, $P < 0.030$, Fig. 4), with the greatest depths in the Green Urban Area ($P = 0.049$).

## DISCUSSION

The results obtained corroborated other studies (Haug *et al.* 1993, Holmes 1998, Chipman *et al.* 2008, Berardelli *et al.* 2010), according to which the Burrowing Owl is a common species in cities and tolerant to anthropic environments. Burrowing Owl appears in different bird lists of the Uberlândia (Silveira *et al.* 1989, Pimenta 1993, Franchin & Marçal-Junior 2004, Franchin *et al.* 2004) and, as demonstrated here, the species was able to explore all urban biotopes sampled in this study. Some studies also suggest that Burrowing Owls are easily behaviorally adjusted to humans, being able to colonize different human-altered habitats (Sih *et al.* 2011, Sol *et al.* 2013, Rebolo-Ifrán *et al.* 2017). On the other hand, some studies indicate that urbanization leads to the population decline of Burrowing Owls (Millsap & Bear 2000, Jones & Bock 2002, Chipman *et al.* 2008). This decline is attributed to the loss of habitat to cultivation and other land use activities, predation by domestic animals and human persecution, amongst other factors (Haug *et al.* 1993, Sheffield 1997). Although results of the present study have not demonstrated a negative impact of the urbanization on Burrowing Owls, we cannot disregard that the conservation of the species could be affected by the increase of human pressure, in the future.

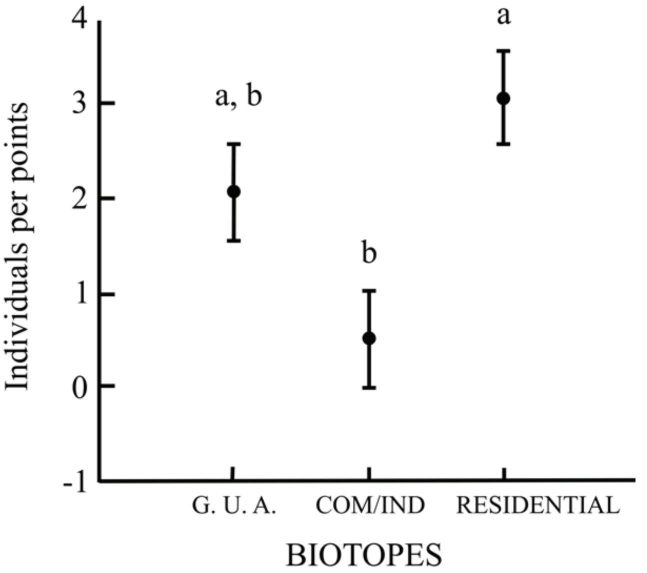

**Figure 2.** (**A**) Mean of individuals of Burrowing Owl per point distributed according to the biotopes (G.U.A = Green Urban Area; COM/IND = Commercial/Industrial) in Uberlândia (MG), Brazil; (**B**) Mean number of burrows per point, showing a relationship between burrows (refuges, satellites and nests) and biotopes (G.U.A = Green Urban Area; COM/IND = Commercial/Industrial) of the Burrowing Owl in Uberlândia (MG), Brazil. Confidence intervals were considered for $P < 0.05$.

The higher frequency of individuals and burrows in residential and green urban biotopes may be associated with a lower likelihood of disturbance in these areas

**Table 2.** Number of individuals and burrows: main (refuges and nests) and satellite burrows of Burrowing Owl according to biotopes investigated in the urban area of Uberlândia, MG, Brazil. Percentage is the number of each burrow type in relation to the total number of burrows observed ($n = 98$ burrows).

| **Biotopes** | **Main** | | **Satellite Burrows** | **Individuals** |
|---|---|---|---|---|
| | **Refuges** | **Nests** | | |
| Residential | 8 | 6 | 37 | 55 |
| Green Urban Area | 9 | 0 | 30 | 47 |
| Commercial/Industrial | 5 | 1 | 2 | 10 |
| TOTAL | 22 (22.4%) | 7 (7.1%) | 69 (70.5%) | 112 |

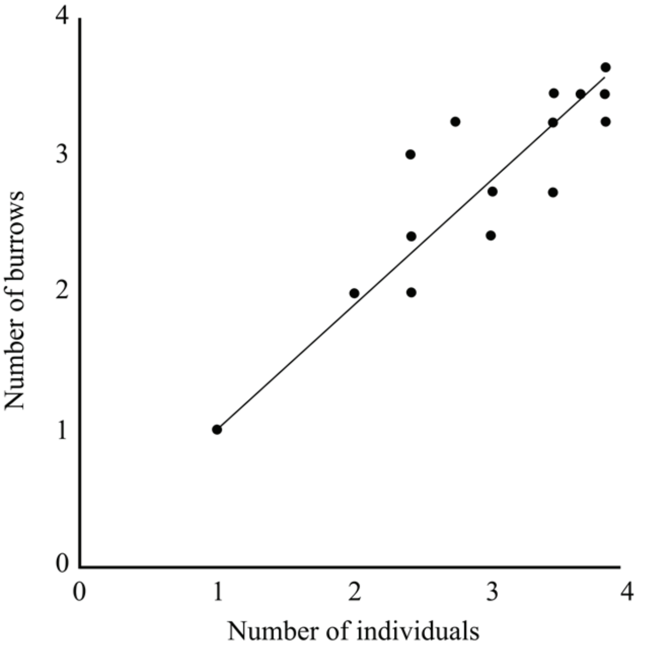

**Figure 3.** Simple linear regression showing the positive relationship between the number of satellite burrows and the number of individuals of Burrowing Owl, in the city of Uberlândia (MG), Brazil.

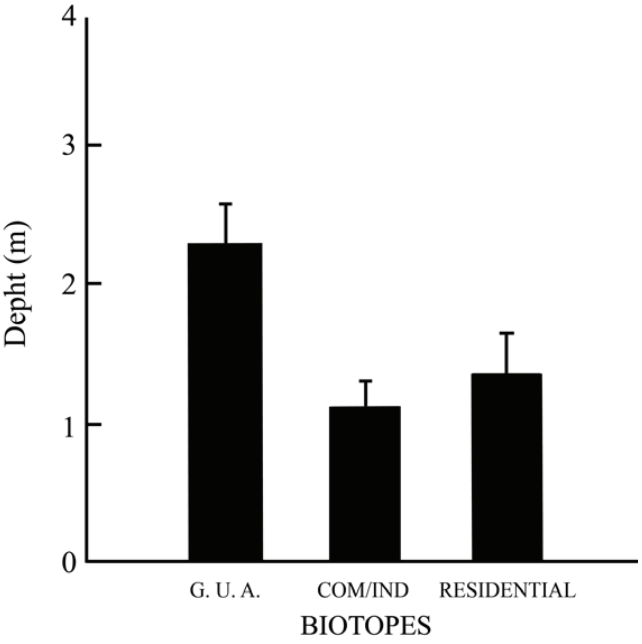

**Figure 4.** Average depths of burrow of the Burrowing Owl according to biotopes (GUA = Green Urban Area; COM/IND = Commercial/Industrial; RESID = Residential), with a significant difference between the Green Urban and Commercial/Industrial Areas of Uberlândia (MG), Brazil.

compared to the Commercial/Industrial biotope, which had heavy traffic of vehicles and people, as well as low availability of land empty. The flow of vehicles and humans is considered to be the main cause of Burrowing Owl mortality (Silva 2002). On the other hand, the presence of empty lands may have favored the greater occurrence of the species, as these unoccupied spaces present favorable conditions for species survival (Forman & Godron 1986, Blair 1996). It is worth mentioning that these areas present greater availability of food resources due to the intense lighting near burrows, which attracts some beetles and other insects (Chipman *et al.* 2008).

The urban environment has few refuges and places for breeding, feeding, resting and protection against adverse climatic conditions such as rain or wind (Poulin *et al.* 2011). The Burrowing Owl does not dig their own burrows, but takes advantage of previously dug burrows, modifying only their depths and widths (Belthoff & Smith 2003). The availability of burrows affects the choice of habitat: the greater the number of burrows, the greater the probability of Burrowing Owls choosing it (Plumpton & Lutz 1993, Desmond & Savidge 1999, Ronan 2002, Poulin *et al.* 2005, Lantz *et al.* 2007). Burrowing Owls seemed to choose more areas corresponding to the Residential biotope, which presented greater numbers of burrows (main ones and satellites) and, consequently, more individuals, probably because that biotope presented the most favorable characteristics for the species survival, such as short grasses and greater food availability. In this study, deeper burrows were recorded in Residential and Green Urban Areas. Burrows are used for nesting, refuge, to storage food and also may serve as a defense mechanism. Accordingly, Burrowing Owls tend to dig deeper, especially in places with higher degrees of threats (Thomsen 1971). We believe that behavior of digging deeper is related to the type of biotope, like in Residential and Green Urban Areas, biotopes with a probable higher risk of predation by domestic animals and other potential predators. May be the greater the number of individuals, the greater will be the need for protection against possible threats, such as predators, that can use urban areas as refuge (Griffin *et al*. 2017). This was seen in areas with a large number of satellite burrows, which, associated with the behavior of species individuals to "rotate" among burrows, are used in order to cause a distracting effect on predators (Henny & Blus 1981, Desmond & Savidge 1999). It is known that avoidance of predation is an important determinant of fitness in many animals (Ruxton *et al.* 2004).

Our results show that Burrowing Owls is a species highly adjusted to the human ecosystem, being able to explore different urban biotopes and that its distribution in the municipality of Uberlândia is due to the likelihood of disturbance, as well as the occurrence of empty lands. These aspects can be useful for conservation of the species here and in other cities.

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## APPENDIX I

Classification of Burrowing Owl, *Athene cunicularia*: Adult female (**A**) and male (**B**); Juveniles (**C**) and chick (**D**), in urban environment. Photo authors: Felipe F. Franco (A & B); Phyllis Greenberg (C & D).

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SHORT-COMMUNICATION

# A review of flocking behavior by Hook-billed Kite, *Chondrohierax uncinatus*, in South America

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**ABSTRACT:** The Hook-billed Kite (*Chondrohierax uncinatus*) is a diurnal raptor species that is widely distributed across the Neotropics, but some aspects of its social and ecological behavior are poorly understood. Here, we review and report records of flocking behavior of this species at various locations in South America, mainly in Brazil. We report eight new observations of such behavior, mainly in northern Brazil. It is possible that flocking behavior in this species is more common in northern South America than in the southern part of the continent, but it is perhaps overlooked or goes unreported by observers in these places.

**KEY-WORDS:** Accipitridae, Brazil, flocks, migration, raptor.

Hook-billed Kite *Chondrohierax uncinatus* is widely distributed in the Neotropics (Ferguson-Lees & Christie 2001). It is a mid-sized polymorphic diurnal raptor distributed from the southernmost USA (southern Texas) and western Mexico south through Central and South America to southern and eastern Brazil, and northern Argentina, as well as on Trinidad and on Grenada (Ferguson-Lees & Christie 2001). Cuban Kite *C. wilsonii*, which is endemic to the mountains of eastern Cuba, is sometimes considered conspecific with Hook-billed Kite but is now frequently regarded as a separate species, whereas *C. u. mirus*, which is endemic to Grenada, is generally considered to be a subspecies of Hook-billed Kite (del Hoyo & Collar 2014). Hook-billed Kite is usually considered solitary and sedentary, but there have been recent reports of flocking behavior and migratory movements, mainly in Central America and northern South America (Bildstein & Zalles 2001, Jones 2003, Porras-Peñaranda & McCarty 2005, Eisermann & Avendaño 2006, Jones & Komar 2006, 2008, 2011), and the species is considered a partial migrant in part of its range in South America (Juhant 2011). In Venezuela, it has been reported to congregate in small to large flocks of 6–12 individuals between June and September (Paulson 1983, Hilty 1999), and in central Brazil, in Tocantins, and northeast Brazil, in Sergipe, migratory movements have been recorded between November and February (Olmos *et al.* 2006, Rego *et al.* 2011). The species is reported to migrate in flocks in the Andes (Fjeldså & Krabbe 1990) and to be a partial migrant in Argentina as well (Contreras *et al.* 1990, di Giacomo 2005).

Flocking is a well-known behavior for some New World hawks, like Red-tailed Hawk *Buteo jamaicensis*, Swainson's Hawk *B. swainsoni* and Snail Kite *Rosthramus sociabilis* (Hilty & Brown 1986, Ferguson-Lees & Christie 2001). In many cases, flocking by raptors is related to their migrations, and this has been suggested in the case of *C. uncinatus* (Hilty 1999). Here we report additional observations of this intriguing behavior, registered mainly in northern Brazil. Our objective is to verify geographic and seasonal patterns of flocking migratory behavior of *C. uncinatus* in South America based on the literature and additional observations reported herein.

In Amazonas state, four birds were seen together at Itacoatiara (03°08'31''S; 58°26'33''W), in 1999 in the dry season (Mario Cohn-Haft, pers. comm.). In Belém, the capital of Pará state, a flock of *c.* 30 birds was observed in Parque do Utinga, near the Museu Paraense Emílio Goeldi (MPEG), in February or March 2002 (Bret Whitney, pers. comm.). In September 2003, four individuals (none of them dark morph) were observed circling together over the Reserva Biológica Sooretama (*c.* 19°03'S; 40°00'W), near the town of Linhares, Espírito Santo state by G.M.K.

On 29 May 2007, at *c.* 09:30 h, S.M.D. photographed a flock of about 35 individuals, flying over the research campus of the Museu Paraense Emílio Goeldi (MPEG), in Belém (01°27'21''S; 48°30'16''W) (Fig. 1). It was not possible to accurately count the number of individuals of each morph, as no binoculars were available, but at least ten were pale gray below, with three broad white bands and two narrower black bands in the tail. Some were darker below, with two white and two black bands on the tail, and there was at least one black-morph individual. The flock was observed soaring for about two minutes before disappearing from sight in a northeasterly direction.

A flock of 6–8 individuals was observed over the city of Ipanema, Minas Gerais (19°48'03''S; 41°42'47''W), in October 2009, flying over a mosaic of urban area, forest and grassland, at the edge of the city (Paulo Thieres, pers. comm.). On 05 May 2011, a flock of c. 25 individuals, also involving multiple morphs, was seen by CEBP in the municipality of Marabá (05°22'11.59''S; 49°11'54.32''W), Pará, at about 10:30 h. The flock was observed very briefly, crossing above the canopy of a small forest fragment. The very bright sky did not permit many differences in morphology among the birds to be appreciated, but at least two different plumage patterns were involved. The flock apparently moved off northeast. A flock of 11 birds was observed near Manaus, Amazonas (03°06'S; 60°01'W), on 18 September 2011 by E.P. (Fig. 1), and a similar (or the same?) flock was seen one week later, 20 km away. Finally, on 28 May 2016, a flock of eight birds was seen by S.M.D. in the municipality of Portel, also in Pará state.

Most records of flocking behavior are from northern South America. Hook-billed Kite is distributed over most of South America, and the available records at the internet site Wikiaves (http://www.wikiaves.com.br/caracoleiro) are as equally concentrated in southeast Brazil as in northernmost parts of the country. Given the larger number of birdwatchers in southern Brazil as opposed to the north of the country, it might be expected that such behavior would be as frequently registered in southern Brazil if it was as common there as in northern South America. Family flocks of up to four individuals of *C. uncinatus* have been observed, but cannot be linked to migration (Bret Whitney, pers. comm.), so it is possible that the small flocks observed in Espírito Santo and Minas Gerais states (the two southernmost ones) pertained to families rather than migrants. If so, that would leave migration in this species apparently restricted to northernmost Brazil. Such differences in the behaviour of a diurnal raptor across the continent would not be unique to Chondrohierax, as in many well-known migratory raptors, only part of the population migrates (Ferguson-Lees & Christie 2001).

Records in Brazil and Venezuela were made mainly between September and February, and in May–June. This matches well with observations of flocks in the USA and Central America, which have mostly been made between September and November, and April and May (Bildstein & Zalles 2001, Jones 2003, Brush 2005, Porras-Peñaranda & McCarty 2005, Eisermann & Avendaño 2006, Jones & Komar 2006, 2008, 2011). Most observations in cis-Andean South America were made along or near major rivers (the Orinoco, Amazonas, Tocantins, São Francisco, Rio Doce – Fig. 2), which may merely reflect the specie preference for humid areas with abundant snails. Based on the comparatively small number of observations, flocking behavior may be only occasional in eastern South America, but it is perhaps also frequently overlooked or unreported by observers unaware of its significance. In conclusion, the few available observations suggest that *C. uncinatus* flocks more frequently in northern South America than in the far southeast of its range, and mainly in the middle of the year or between September and February. Nevertheless, more information on this interesting behavior will be essential to determine if it is linked to migrations and if they really are seasonal movements.

**Figure 1.** Large flocks of Hook-billed Kites (soaring over Belém, Pará state (left) and Manaus, Amazonas state (right), both in Brazil.

**Figure 2.** Localities of Hook-billed Kite (*Chondrohierax uncinatus*) flocks in South America. Numbers indicate bibliographic references: 1 - Paulson (1983); 2 - Hilty & Brown (1999); 3 - Olmos *et al.* (2006); 4 - Rego *et al.* (2011); 5 - this study. Rivers depicted in gray.

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SHORT-COMMUNICATION

# Several cavity-nesting birds fight for a single tree hollow in an Atlantic Forest fragment: consequence of increasing nest-site limitation?

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**ABSTRACT:** Most remnants of Atlantic Forests are found as small and isolated forest fragments. Forest fragmentation and edge effects often lead to structural changes in vegetation that may affect the availability of tree cavities for birds that rely on hollows for reproduction. Here I describe an unusual dispute for a cavity among birds (at least six *Primolius maracana*, two *Pionus maximiliani* (Psittacidae) and two *Pteroglossus aracari* (Ramphastidae)) in the Estação Ecológica dos Caetetus, southeast Brazil. Consequences of Atlantic Forest fragmentation, together with an increase in abundance of cavity users such as Opossums (*Didelphis* spp.) and exotic Honey Bees (*Apis mellifera*) might be decreasing the already small availability of cavities for medium- and large-sized cavity-nesting birds. The conservation of large hardwood trees is probably critical for the persistence of cavity-nesting birds in fragmented Atlantic Forest landscapes. Supply of nest boxes and control of Honey Bees may also be considered.

**KEY-WORDS:** Africanized honey bees, conservation, habitat fragmentation, hole-nesting bird, parrot, *Primolius maracana*.

The role of nest site availability in limiting the abundance of cavity-nesting birds has been confirmed by several studies from temperate regions (Newton 1994 and references therein). This issue remains relatively poorly investigated in the Neotropics (but see Cockle *et al.* 2010, 2017) where a substantial number of families comprise of obligate cavity-nesting bird species (*e.g.*, Psittacidae, Picidae, Dendrocolaptidae, Ramphastidae, Trogonidae, plus some Falconidae, Strigidae, Tyrannidae, Troglodytidae) (Sick 1997). However, snag (dead tree) availability, a common source of cavities used by birds for roosting or reproduction, is considered less abundant in tropical than in temperate forests (Guibbs *et al.*1993, but see Cockle *et al.* 2010) which suggests an increased role of the low availability of cavities for bird reproduction in tropical forests. Indeed, nest-box supplementation increases the reproduction of several cavity-nest species in the Atlantic Forest (Cockle *et al.* 2010), an evidence that nest site availability limits bird reproduction in these forests.

The Brazilian Atlantic Forest is a global hotspot of biodiversity that holds many endemic birds, several of them obligate cavity-nesters that are threatened or near threatened by extinction (Brooks *et al.* 1999). The Atlantic Forest is today shattered into thousands of forest fragments covering only *c.* 11–16% of its pre-Columbian area (Ribeiro *et al.* 2009). Such drastic habitat loss and fragmentation decreased the abundance and distribution of many bird species through direct effects, but indirect effects such as a reduction in critical resources for reproduction, like cavities, may also be important. In the Amazon, forest fragmentation increases the mortality, damage and turnover rates of trees when compared to continuous forest control plots, and large trees are especially prone (Laurance *et al.* 1998, 2000). These effects are apparently the result of increased windthrow and microclimatic changes due to edge effects (Laurance *et al.* 1998, 2000). Edge effects increase sharply in importance once fragments fall below 100–400 ha in size, depending on fragment shape (Laurance *et al.* 1998). Since most of Atlantic Forest remnants are small, irregularly shaped forest fragments (*e.g.*, more than 80% of fragments are ≤50 ha; Ribeiro *et al.* 2009), edge effects are probably playing an important role in the dynamics of Atlantic Forest tree communities. Indeed, large hardwood long-lived tree species are often replaced by small, softwood and short-lived tree species in Atlantic Forest fragments (Tabarelli *et al.* 2008), which are unlikely to offer adequate opportunities for birds that reproduce in cavities (Cockle *et al.* 2010, 2017, Katayama *et al.* 2017). As the availability of cavities decreases, it is expected an increasing number of disputes among birds over the available cavities. Indeed, intense disputes over cavities have been reported in some Atlantic Forest fragments (Pizo 1996).

Here I report an unusual dispute over a tree hole among three cavity-nesting bird species in the Caetetus Ecological Station (22°24'11''S; 49°42'05''W) (hereafter Caetetus), in southeastern Brazil. Caetetus is an old-growth semideciduous forest fragment (2178 ha) surrounded by pasturelands and field crops. On 15 September 1999, at 09:39 h I observed four Blue-winged Macaws (*Primolius maracana* (Vieillot, 1816)) on a large live tree (Fabaceae) approximately 23 m high. One Macaw was perched vertically and projected its body and head several times towards a 10 cm hole that was located at a height of 9 meters. The latter bird was calling and pecking in an aggressive manner, while other two *P. maracana* alternated calls and short flights around the tree crown and over the individual on the trunk. A few minutes later two Black-necked Aracaris (*Pteroglossus aracari* (Linnaeus, 1758)) chased away all *P. maracana* and flew towards the tree hole. One of the *Pteroglossus* alternated pecks in the hollow with visual inspections of the entrance, while the other one remained perched on the tree crown. Whenever a *P. maracana* tried to return, it was promptly chased away by the *Pteroglossus* which flew directly at it. Each *Pteroglossus* frequently switched position with one another, alternating *c.* 30 s of pecks with 3–5 min of vigilance on a nearby branch. After 1 h, during a short rest taken by the *Pteroglossus*, two adult *P. maracana* left the tree hollow and flew away. At that point, both *Pteroglossus* entered the cavity. They remained inside the hollow and at the entrance until noticing me (30 min), then flew away. At 11:40 h two Scaly-headed Parrots (*Pionus maximiliani* (Kuhl, 1820)) perched on the tree and one of them started to inspect the hole. Suddenly, two *P. maracana* chased away both *Pionus* and occupied the cavity. At 11:58 h they noted me and flew to a nearby tree, and the observation ended. I did not see any signs of egg or nestling predation by the *Pteroglossus* during my observations. All birds involved were probably mated pairs in nest competition based on their aggressive behavior towards other birds, since reproductive cycle starts in September, lasting until January (Sick 1997).

At least 26 species of obligatory cavity-nesting birds occur in Caetetus together with other animals (*e.g.*, Black-lion Tamarin [Mikan, 1823], marsupials, bees) (A. V. Christianini pers. obs.). It is likely that there will be overlap in hollow size used by these species, which are not primary excavators of cavities. Several local cavity-nesting birds are medium sized (233–293 g for *P. maximiliani* and *P. maracana*; Collar 1997) requiring cavities in large trees for reproduction (Carvalho & Carvalho 1992, Cockle *et al.* 2010). Despite habitat fragmentation may increase the scarcity of large cavities, two new elements may be reinforcing the constraints to the reproduction of large cavity-nesting birds in Atlantic Forest fragments: an increase in the abundance of common opossums (*Didelphis* spp.) in response to forest fragmentation (Fonseca & Robinson 1990), and Africanized Honey Bees (*Apis mellifera* Linnaeus, 1758) introduced by European settlers. Both often supplant birds when competing for nest-cavities (Guedes & Harper 1995, Tubelis & Tubelis 2000). Studies with nest-box provisioning in Atlantic Forest fragments often report high rates of boxes occupied by opossums and Honey Bees (Tubelis & Tubelis 2000, A.V. Christianini, unpub. data). The synergistic effect of forest fragmentation and the increasing abundance of opossums and Honey Bees might be increasing the competition for large cavities in Atlantic Forest fragments. However, further research is needed to access the extent of this circumstantial evidence (*e.g.*, Cockle *et al.* 2010) and to confirm the adequacy of management options to keep an adequate availability of hollows for bird reproduction, such as an active management of snag availability, supply of nest boxes and control of honey bees.

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ARTICLE

# A review of the ornithological knowledge of the northern Serra do Mar mountains in the state of São Paulo, southeastern Brazil

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**ABSTRACT:** The northern portion of the Serra do Mar mountains in the state of São Paulo, near the border with the state of Rio de Janeiro, including a portion of the Rio Paraíba Valley, ranges between 450 and 1900 m a.s.l. in altitude and is composed of sub-montane and montane Atlantic Forest. It is unique in that the ornithological knowledge of the region can be traced back to the 19th century. Here we present a compilation of historical and recent data, including intensive field work undertaken between 1989 and 2015 in nine natural areas as well as the Bananal Ecological Station (BES), the only protected area in the region. A total of 371 bird species were recorded in the Bananal region and can be separated into two main bird communities, those of the higher Serra de Bananal and those of the lowlands of the Paraíba Valley. These are typical of the avifauna of the mountainous regions of the Serra do Mar and the Paraíba Valley, respectively. Of the above species, 23 lacked any recent records with a single possible extinction, 257 were recorded in the BES, 111 are endemic to the Atlantic Forest and 15 are listed as threatened. Despite its small size compared to other protected areas in the Serra do Mar, the BES and its surrounding areas have well preserved regional characteristics and are highlighted as an important area for bird conservation in the northern portion of the Serra do Mar in São Paulo.

**KEY-WORDS:** Atlantic Forest, Bananal, Bocaina, Paraíba Valley, threatened species.

## INTRODUCTION

The Serra da Bocaina is located along the border between the states of São Paulo and Rio de Janeiro and is part of the Serra do Mar, a complex of mountain ranges that extend from the state of Santa Catarina to Rio de Janeiro. It has a pronounced altitudinal gradient ranging from sea level to over 2000 m a.s.l. (Almeida & Carneiro 1998). This provides a range of environmental conditions that influence the composition of the region's avifauna, which surpasses 400 species and has been considered as one of the richest in the Atlantic Forest (Mallet-Rodrigues *et al.* 2015). As well as harbouring a large number of threatened and restricted range species, the Serra da Bocaina also shelters about 60% of the species endemic to the Atlantic Forest, the highest of any Brazilian IBA - Important Bird Area (Bencke *et al.* 2006).

The Austrian naturalist Johan Natterer explored the southern portion of the Serra da Bocaina, in the state of São Paulo. In 1818 he collected along the Tropeiros Road, a route that once connected the cities of Rio de Janeiro and São Paulo. Peter Lund (October 1833), E. Garbe (August 1909), and H. Lüderwaldt (May 1924) later undertook shorter expeditions (Pinto 1950, Paynter-Jr. & Traylor-Jr. 1991, Willis & Oniki 2003). The first attempts to describe the avifauna of this region were made by A. Schneider, who collected at the locality known as the Sertão das Cobras in August and September 1940 and February 1942 (Pacheco & Bauer 1995). Another attempt was made by an expedition led by the Zoology Department of the Secretary of Agriculture of the state of São Paulo (currently the Museu de Zoologia da Universidade de São Paulo, MZUSP) which in August 1941 collected specimens in the region of the Serra de Bananal and the "alto Rio Paca region/Fazenda Califórnia" (Pinto 1941, 1944, 1945). Additional material was collected in 1952, 1961, 1965 and 1977, and several ornithologists sporadically visited the Serra da Bocaina region, including

Werner Bokermann (November 1964), E. Willis (8 visits between January 1985 and November 1996) and Dante Buzzetti and Jeremy Minns, who made expeditions to Bananal Biological Station in 1995, 1996, 2003, 2004 and 2005, the data being partially published by Minns *et al.* (2010). Specimens collected were deposited in the Natural History Museum of Los Angeles, MZUSP, and the Field Museum of Natural History (Sick & Teixeira 1979, Willis & Oniki 1985, Paynter-Jr. & Traylor-Jr. 1991, Fonseca & Pacheco 2000, Willis & Oniki 2003).

As a result, ornithological knowledge of the Serra da Bocaina has accumulated over two centuries and it is certainly one of the few regions of the entire Atlantic Forest domain to have been continuously studied. This provides a unique opportunity for comparisons to be made over a long time span. Here, we present a compilation of the existing ornithological knowledge of the area, based on historical data as well as the results of intensive recent sampling expeditions to the region. Changes in the bird community and biogeographical relationships have also been investigated by comparison of past and recent records.

## METHODS

### Study areas

*Bananal Ecological Station (BES)*: (Portuguese: Estação Ecológica de Bananal): this conservation unit conserves 884 ha and is located in the municipality of Bananal, in the northern portion of the Serra do Mar/Bocaina, São Paulo state, on the border with Rio de Janeiro (Fig. 1). It has an altitudinal gradient ranging between 1200 and 1900 m a.s.l. with montane forest as the predominant vegetation type (Fig. 2). However, cloud forest, Araucaria Forest, bamboo (*Chusquea* spp. and *Merostachys* sp.), natural grassland and degraded areas in different stages of succession are also present near the station. We sampled the avifauna at five main areas: Pedra Vermelha/Córrego do Barbosa Trail, Ouro-Mirante Trail, Invernada Road, Encosta and Cachoeira Sete Quedas Trail, all close to the headquarters (22°47'53''S; 44°21'35''W, 1200 m a.s.l.) and its access roads (Fig. 1). They all have similar vegetation characteristics and consist mostly of secondary forest in an advanced state of regeneration with relatively well defined vertical stratification and an herbaceous stratum composed of seedlings, terrestrial bromeliads, and small ferns with a thick layer of litterfall. The understory reaches a height of between 5 and 10 m and is characterized by the presence of *Dicksonia* ferns, *Geonoma* palms, various vines and the saplings of many typical species, especially the Juçara Palm *Euterpe edulis*. The largest trees reach up to 20 m tall but a dense and continuous canopy has not yet formed along most of the sampling trails and is present only in certain areas, especially in the valley bottom.

Another nine localities were also sampled: four on the slopes of the Paraíba Valley, at 450 m a.s.l. (B1, B2, B3 and B4), one intermediate area in the Serra de Bananal, at

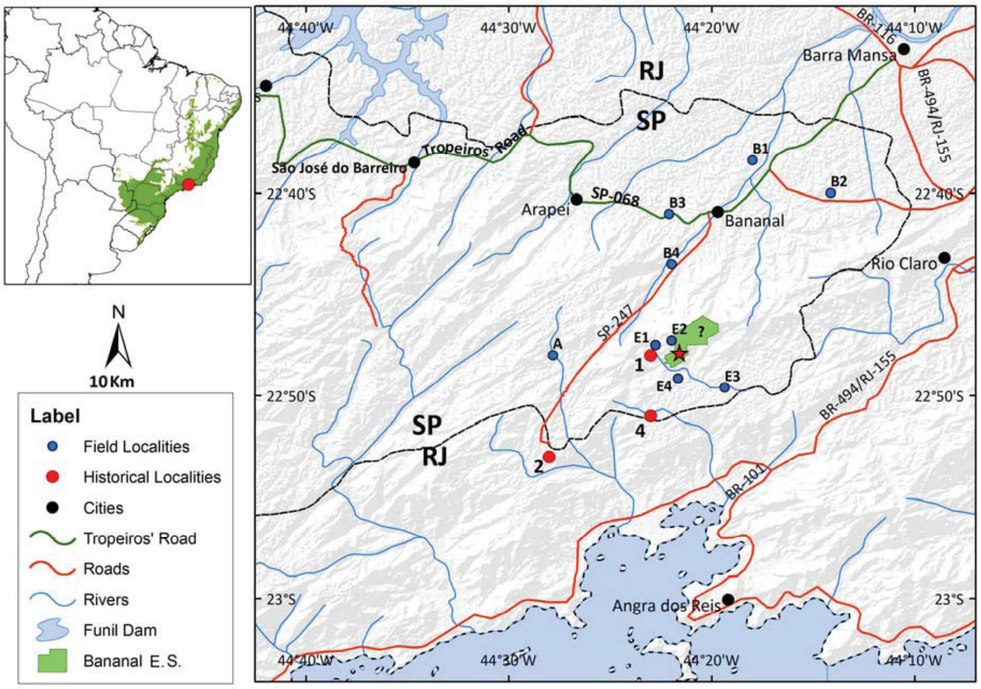

**Figure 1.** Location map of the Bananal Ecological Station-BES. The numbers correspond to the following localities: 1. Sertão das Cobras, 2. Serra de Bananal (Rio Paca/Fazenda Califórnia), 3. vicinity of the BES, and some additional data contained in Paynter-Jr. & Traylor-Jr. (1991) (no exact locality and no indication on the map) and 4. Fazenda da Posse. The star indicates the location of the study areas within the BES.

**Figure 2.** View of a part of the Serra de Bananal. Photo author: F. Schunck.

1100 m a.s.l. (A) and another four near the BES, between 900 and 1400 m a.s.l. (E1, E2, E3 and E4) (Fig. 1). All had phytophysionomies similar to those found in the BES, besides areas with pristine vegetation, open or at other transitional stages of succession, according to the descriptions below.

*Sertão da Bocaina (A) (22º48'00''S; 44º27'49''W, 1100 m a.s.l.)*: located 8 km SW of the BES, near the Trutário Aqua, it possesses a large artificial lake and a couple of areas of pasture and shrubby secondary vegetation. Regenerating mountain forest covers the surrounding slopes.

*Forest fragment near Fazenda Três Barras (B1) (22º38'21''S; 44º17'59''W, 450 m a.s.l.)*: located in the Paraíba Valley lowlands, it contains thick seasonal semideciduous forest within a pastureland matrix with influence from the Bananal River, which forms its eastern border.

*Forest fragment near Fazenda Boa Vista (B2) (22º39'59''S; 44º14'08''W, 450 m a.s.l.)*: located in the Paraíba Valley lowlands, it contains thick seasonal semideciduous forest within a pastureland matrix, much of which were coffee plantations until some decades ago.

*Fazenda Coqueiros fragment (B3) (22º41'01''S; 44º22'06''W, 450 m a.s.l.)*: located in the Paraíba Valley lowlands, it consists of seasonal semideciduous forest on what was previously a farm.

*Estrada do Sertão (B4) (22º43'31''S; 44º21'58''W, 450 m a.s.l.)*: located in the Paraíba Valley lowlands, it consists predominantly of shrubby thicket vegetation in a pastureland matrix. Observations were made from the road.

*Fazenda Encontro (E1) (22º47'30''S; 44º22'46''W, 1200 m a.s.l.)*: located about 5 km from the northeastern portion of the BES, with which it is contiguous, the vegetation is similar to that found in the BES. It is adjoins Fazenda Albion, which belongs to the same family.

*Trilha do Pico Vermelho (E2) (22º47'17''S; 44º21'58''W, 1400 m a.s.l.)*: located nearly 6 km from the eastern portion of the BES, the vegetation is mostly similar to that found at the BES.

*Fazenda Conceição Rio do Braço (E3) (22º49'36''S; 44º19'21''W, 900 m a.s.l.)*: located about 5 km from the southeastern portion of the BES, the property contains a clearing of 1 km by 300 m surrounded by primary mountain forest or forest in an advanced state of regeneration.

*Brejo Grande da Madeireira (E4) (22º49'09''S; 44º21'39''W, 1000 m a.s.l.):* a marshy area 1.5 km long, running along the southern edge of the BES, consisting of predominantly shrubby vegetation on waterlogged soils with an abundance of sedges.

## Bird sampling

*Bananal Ecological Station (BES)*: field work at the BES was undertaken over seven field trips between 2003 and 2015, with a total of 46 days of sampling (270 h; Table 1). The first, second and fourth field trips were undertaken by the MZUSP team, the third by the Instituto Florestal de São Paulo and the fifth, sixth and sevenths by J.F.P., R.L.G. and other collaborators (Table 1).

Birds were sampled by active searches, mist netting, and collection with shotguns for deposition in the bird collection at MZUSP. Ten mist nets (12 × 2 m, 30 mm mesh) were opened along transects in areas 1, 4 and 5 in the morning (between 5:00 h and 6:00 h) and closed in the evening (between 17:30 h and 18:00 h) for 20

**Table 1.** Data from field trips at Bananal Ecological Station (BES) and in the Bananal region, Brazil.

| Locality | Field trip | Hours field | Researchers | Field period |
|---|---|---|---|---|
| BES | 1 | 90:00 h | L.F. Silveira, M. Sboarim & F. Belmonte | between 01–20 December 2003 |
| BES | 2 | 120 h | F. Schunck | between 13–25 April 2004 |
| BES | 3 | 30 h | A.Z. Antunes | between 13–16 September 2011 |
| BES | 4 | 20 h | L.F. Silveira, L.M. Lima & C.O.A. Gussoni | between 12–19 December 2011 |
| BES | 5 | 4:00 h | J.F. Pacheco, R.L. Gagliardi & L. Florit | 20 February 2012 |
| BES | 6 | 3:00 h | J.F. Pacheco, R.L. Gagliardi & C. Bauer | 07 September 2012 |
| BES | 7 | 5:00 h | J.F. Pacheco & L. Florit | 01 January 2015 |
| A | 8a | 3:00 h | J.F. Pacheco & L. Florit | 31 December 2012 |
| A | 9a | 1:30 h | J.F. Pacheco, R.L. Gagliardi & L. Florit | 30 March 2013 |
| A | 10a | 2:00 h | J.F. Pacheco & F. Traiano | 16 November 2013 |
| A | 11a | 4:00 h | J.F. Pacheco & L. Florit | 02 March 2014 |
| B1 | 1a | 1:30 h | J.F. Pacheco & P.S.M. Fonseca | 24 September 1989 |
| B1 | 2a | 1:00 h | J.F. Pacheco & P.S.M. Fonseca | 16 December 1990 |
| B1 | 3a | 0:30 h | J.F. Pacheco, P.S.M. Fonseca & C. Bauer | 03 January 1993 |
| B1 | 4a | 12:00 h | J.F. Pacheco & R.L. Gagliardi | between 18–22 February 2012 |
| B1 | 6a | 12:00 h | J.F. Pacheco & R.L. Gagliardi | between 12–14 October 2012 |
| B1 | 13a | 15:30 h | J.F. Pacheco & L. Florit | between 02–05 April 2015 |
| B2 | 6a | 2:00 h | J.F. Pacheco & R.L. Gagliardi | 14 October 2012 |
| B2 | 11a | 2:30 h | J.F. Pacheco & L. Florit | 03 March 2014 |
| B2 | 13a | 4:30 h | J.F. Pacheco & L. Florit | 03 and 04 April 2015 |
| B3 | 6a | 6:00 h | J.F. Pacheco & R.L. Gagliardi | 13–14 October 2012 |
| B3 | 13a | 3:30 h | J.F. Pacheco & L. Florit | 03–04 April 2015 |
| B4 | 1a | 0:30 h | J.F. Pacheco & P.S.M. Fonseca | 24 September 1989 |
| B4 | 3a | 0:30 h | J.F. Pacheco, P.S.M. Fonseca & C. Bauer | 03 January 1993 |
| B4 | 4a | 4:00 h | J F. Pacheco, R.L. Gagliardi & L. Florit | 18–19 and 22 February 2012 |
| B4 | 5a | 2:00 h | J.F. Pacheco, R.L. Gagliardi & C. Bauer | 07–09 September 2012 |
| B4 | 7a | 5:00 h | J.F. Pacheco, R.L. Gagliardi & A.H. Oliveira | 02–04 November 2012 |
| B4 | 8a | 2:30 h | J.F. Pacheco & L. Florit | 28–30 December 2012; 01 January 2013 |
| B4 | 9a | 3:00 h | J.F. Pacheco & L. Florit | 28–31 March 2013 |
| B4 | 10a | 3:00 h | J.F. Pacheco & L. Florit | 15–17 November 2013 |
| B4 | 11a | 3:00 h | J.F. Pacheco & L. Florit | 01, 03 and 05 March 2014 |
| B4 | 12a | 4:00 h | J.F. Pacheco & L. Florit | between 31 December 2014–04 January 2015 |
| E1 | 1a | 10:00 h | J.F. Pacheco, B.M. Whitney & P.S.M. Fonseca | 23–24 September 1989 |
| E1 | 2a | 8:00 h | J.F. Pacheco & P.S.M. Fonseca | between 15–16 December 1990 |
| E1 | 3a | 16:00 h | J.F. Pacheco, P.S.M. Fonseca & C. Bauer | between 31 December 1992–02 January 1993 |
| E1 | 4a | 12:00 h | J F. Pacheco, R.L. Gagliardi & L. Florit | between 18–22 February 2012 |
| E1 | 5a | 10:00 h | J.F. Pacheco, R.L. Gagliardi & C. Bauer | between 07–09 September 2012 |
| E1 | 7a | 10:00 h | J.F. Pacheco, R.L. Gagliardi & A.H. Oliveira | 03–04 November 2012 |
| E1 | 8a | 10:00 h | J.F. Pacheco & L. Florit | between 28 December 2012–01 January 2013 |

| Locality | Field trip | Hours field | Researchers | Field period |
|---|---|---|---|---|
| E1 | 9a | 17:30 h | J.F. Pacheco, R.L. Gagliardi, P.S.M Fonseca, L. Trindade & L. Florit | between 28–31 March 2013 |
| E1 | 10a | 20:00 h | J.F. Pacheco, R.L. Gagliardi & L. Florit | between 15–17 November 2013 |
| E1 | 11a | 24:00 h | J.F. Pacheco & L. Florit | between 01–05 March 2014 |
| E1 | 12a | 34:30 h | J.F. Pacheco, R.L. Gagliardi & L. Florit | between 31 December 2014–04 January 2015 |
| E2 | 4a | 10:00 h | J.F. Pacheco, R.L. Gagliardi & L. Florit | 19–21 February 2012 |
| E3 | 4a | 4:00 h | J.F. Pacheco, R.L. Gagliardi & L. Florit | 21 February 2012 |
| E3 | 5a | 7:00 h | J.F. Pacheco & R.L. Gagliardi | 08 September 2012 |
| E3 | 7a | 6:20 h | J.F. Pacheco, R.L. Gagliardi & A.H. Oliveira | 04 November 2012 |
| E3 | 8a | 6:00 h | J.F. Pacheco & L. Florit | 30 December 2012 |
| E3 | 9a | 5:00 h | J.F. Pacheco, R.L. Gagliardi & L. Trindade | 30 March 2013 |
| E4 | 5a | 2:00 h | J.F. Pacheco, R.L. Gagliardi & C. Bauer | 08 September 2012 |
| E4 | 7a | 2:00 h | J.F. Pacheco, R.L. Gagliardi & A.H. Oliveira | 03 November 2012 |
| E4 | 12a | 4:30 h | J.F. Pacheco & L. Florit | 31 December 2013 |
| E4 | 9a | 1:30 h | J.F. Pacheco, R.L. Gagliardi, P.S.M. Fonseca, L. Trindade & L. Florit | 29 March 2013 |
| E4 | 11a | 1:30 h | J.F. Pacheco & L. Florit | 03 March 2014 |

consecutive days, with a total sampling effort of 2360 net h. On field trips 1, 2 and 4 we sampled for 960, 1200 and 200 net h, respectively (Table 1). Species recorded within a 5 km perimeter of the BES during the third field trip are indicated as being from the "Surroundings" in Appendix I.

*Localities A, B and E*: field work in the areas outside the BES was undertaken in twelve field trips between 1989 and 2015, mainly by J.F.P., R.L.G. and other collaborators. This totalled 321.5 h of field work; 233 h at sites A and E and 88 h at site B (Table 1). Records were made by direct searches undertaken at different times of the day, such that a single locality was sometimes revisited multiple times on the same day, since they are close together.

Birds were observed with the aid of 10 × 40 and 8.5 × 40 binoculars. Vocalizations were recorded with Sony TCM 5000-EV and PMD222 Marantz recorders and Sennheiser ME 66 and Mineroff shotgun microphones. Recordings are deposited in the *Arquivo Sonoro da Seção de Aves do MZUSP* and the online database WikiAves (www.wikiaves.com.br). Some species were documented by photographs, which are presently only available in the personal collections of the authors, but may be accessed upon request. The nomenclature and systematics follow Piacentini *et al.* (2015).

*Historical data*: ornithological data from the Bananal region was obtained by extensively searching through museum catalogues, scientific articles, books, CD-ROMs, personal data not published and open access websites with photographic and vocalisation records of Brazilian birds, such as WikiAves (WA) and xeno-canto (XC) (www.xeno-canto.org). The keywords used were Bananal and Serra da Bocaina and the searches were completed in January 2017. Reliable and documented records by the ex-manager of the BES were also considered.

Localities where ornithological studies were undertaken in the past included: (1) Sertão das Cobras; (2) Serra de Bananal (Rio Paca/Fazenda Califórnia); (3) proximity to BES, and some additional data contained in Paynter-Jr. & Traylor-Jr. (1991); (4) Fazenda da Posse (for one specimen collected by J.L. Lima) and (5) Bananal region, published by Minns *et al.* (2010) (Fig. 1). We also considered the data cited for the Bananal region but without exact location in the compilation made by Willis & Oniki (2003) (denoted by an X in Appendix I).

## Data analyses

Since the Bananal region possesses considerable altitudinal variation, ranging from 450 to 1900 m a.s.l., a cluster analysis was carried out to detect possible differences in the bird community composition in this portion of the northern Serra do Mar in São Paulo. PAST v. 2.16 was used to calculate the Euclidian distance between sites based on species presence/ absence data.

To detect possible local extinctions in the Bananal avifauna, the data available in the bibliography was compared with that obtained in field trips since 1989.

## RESULTS AND DISCUSSION

We present records of 371 bird species in the Bananal region, belonging to 24 orders and 67 families. Of these, 348 were recorded in the field, 112 were endemic to the Atlantic Forest (Bencke *et al.* 2006), one is considered threatened in Brazil (MMA 2014), and 16 threatened in the state of São Paulo (São Paulo 2008, 2014). The total corresponds to approximately 48% of the avifauna of the state of São Paulo (793 species; Silveira & Uezo 2011), which is highly noteworthy when compared to other reserves that have been studied in the state (Table 2 & Appendix I).

In spite of the difference in the sampling effort between the higher parts of the Serra do Bananal and the Paraíba Valley (Table 1), the cluster analysis showed two avifauna communities across the altitudinal gradient. The first (204 species) occurs in the Paraíba Valley, at around 450 m a.s.l. (B) and the second (314 species) in the higher regions of the Serra da Bananal, between 900 and 1400 m a.s.l. (A, E and BES) (Figs. 1 & 3, Appendix I). We found various species typical of higher parts of the Serra do Mar in the Serra da Bananal, such as *Chamaeza ruficauda* and *Lipaugus ater*, whilst important elements of the avifauna from lower areas, such as *Veniliornis maculifrons* and *Cantorchilus longirostris*, were still present on the slopes of the Paraíba Valley. Even with this apparently well-defined trend, there were exceptions, such as the occurrence of *Piculus flavigula* at Sertão das Cobras and *Manacus manacus* along the upper Rio Paca (nearly 1000 m a.s.l.) (Pinto 1944). Both are usually associated with lowland areas (Sick 1997). *Manacus manacus* has also been found between 800–1000 m a.s.l. near Macaé de Cima, Nova Friburgo, Rio de Janeiro state, where it was considered uncommon (Pacheco *et al.* 2014). Other recent records also show that *V. maculifrons* is present within the immediate surroundings of the BES, in the higher regions of the Serra de Bananal (Pinto 2012, Guerra 2014). Both *P. flavigula* and *M. manacus*, along with *Coccyzus melacoryphus*, were the only species with historical records that were not recorded during our field work in the higher regions of the Serra de Bananal.

The bird community of the higher regions of the Serra do Bananal is very similar to recently published data for the higher parts (between 1000 and 1600 m a.s.l.) of the Serra da Bocaina (Mallet-Rodrigues *et al.* 2015). However, nine species recorded in the Serra de Bocaina were not found in the Serra do Bananal, namely *Glaucidium brasilianum*, *Triclaria malachitacea*, *Dysithamnus stictothorax*, *Laniisoma elegans*, *Phylloscartes oustaleti*, *Myiothlypis rivularis* and *Sporophila falcirostris*.

We recorded a total of 257 bird species for the study sites in the Bananal Ecological Station (BES) between 2003 and 2015 (two more unpublished records made in 1995 by D. Buzzetti bring the total to 259 species), an important conservation area that until now had not been systematically inventoried. This is a very high level of species richness for a single relatively small nature reserve of only 884 ha (Table 2 & Appendix I). When compared to the region as a whole, 12 species were found to be restricted to this reserve whilst 38 were found in the surrounding areas (E) but still had not been recorded within the boundaries of the reserve. These were, in general, species of open or very specific habitats that do not exist or are rare within the reserve (Fig. 1, Appendix I).

The species accumulation curve for the BES shows that our estimate of species richness is reaching a stable asymptote, with few new additions being made in the final expeditions but this is, in part, due to the fact that sampling was concentrated within the region around the reserve's headquarters. Further sampling in unsurveyed areas, especially with different habitats, would undoubtedly

**Table 2.** Bird species richness in protected areas located in the Serra do Mar, São Paulo state.

| Conservation Unit | Number of species | Area (ha) | Source |
|---|---|---|---|
| Intervales State Park | 354 | 41,700 | Aleixo & Galetti 1997 and Vielliard & Silva 2001 |
| Carlos Botelho State Park | 370 | 37,644 | Antunes *et al.* 2013 |
| Turístico do Alto Ribeira State Park | 319 | 35,772 | Antunes & Eston 2010 |
| Serra do Mar State Park, Curucutu Nucleus | 373 | 36,134 | Schunck *et al.* in prep. |
| Juréia-Itatins Ecological Station | 352 | 79,240 | Develey *et al.* in prep. |
| Boracéia Biological Station (including Casa Grande and part of Padre Dória Nucleus of Serra do Mar State Park) | 323 | 96 | Cavarzere *et al.* 2010 |
| Bananal Ecological Station-BES | 259 | 884 | This study |
| Serra do Mar State Park, Picinguaba Nucleus | 254 | 47,000 | Goerck 1997 |
| Paranapiacaba Biological Reserve | 183 | 336 | Silveira 2009 |

increase the curve (Fig. 4). The avifauna of the BES is typical of the mountain regions of the Serra do Mar/Bocaina, with species that occur above 700 m in altitude, such as *Hydropsalis forcipata*, *Stephanoxis lalandi*, *Hylopezus nattereri*, *Hemitriccus obsoletus* and *Stephanophorus diadematus* as well as those that occur above 1000 m a.s.l., including *Drymophila genei* and *Microspingus lateralis*. The presence of game birds, particularly *Tinamus solitarius* and *Penelope obscura*, and species dependent on forests in a good state of conservation and/or that are threatened, such as *Selenidera maculirostris*, *Carpornis cucullata* and *Onychorhynchus swainsoni*, attests to the low degree of disturbance at the BES.

Examples of unsampled habitats in the reserve are the montane or high altitude grasslands found in the highest portions of the reserve to which there is little or no access. These areas may contain bird species typical of this habitat, such as *Polystictus superciliaris* and *Anthus hellmayri*. Indeed, the former was collected in 1961 by J.L. Lima at Rio Mambucaba (1350 m a.s.l.), Fazenda da Posse (Fig. 1) and there are historical records of the latter for the Bananal region (Willis & Oniki 2003). Both species have recently been photographed in the municipality of São José do Barreiro (Martins 2008, Torrubia 2014), relatively close to the Serra do Bananal, besides the fact that they are frequently recorded around Campos do Jordão and Cunha, always in natural open habitats (Willis & Oniki 2003). *Penelope superciliaris* was also recorded by Mallet-Rodrigues *et al.* (2015) in the higher parts of the Serra da Bocaina.

Attention is drawn to a large and varied group of species that were not found in the BES during this study, including various migrants and/or common species, others that are more reclusive and still others that are difficult to identify in the field. Nevertheless, all have historical or recent records in the Bananal and surrounding municipalities. These are *Glaucidium minutissimum*, *Cypseloides fumigatus*, *Chlorostilbon lucidus*, *Drymophila ferruginea*, *Psilorhamphus guttatus*, *M. manacus*, *Tityra cayana*, *Elaenia parvirostris*, *Cnemotriccus fuscatus*, *Contopus cinereus*, *Pyrrhocoma ruficeps*, *Poospiza thoracica* and *Euphonia violacea*. The only species recorded before 2004 in the BES that were not registered in the field by this study were *Lepidocolaptes squamatus* and *Lipaugus lanioides*. The occurrence of these species requires dedicated investigation, as they are linked to specific habitats with punctuated distribution but they are very likely to be recorded in future studies.

Deforestation in the region surrounding the BES now provides new habitats for species of open environments. For example, *Cyanocorax cristatellus* has invaded the region through the Paraíba Valley, arriving in the Serra do Bananal in the 1990s (Alvarenga 1990, Willis & Oniki 2003). Other examples include *Bubulcus ibis*, *Phacellodomus rufifrons* and *Coryphospingus pileatus*. All have significantly expanded their ranges southwards into São Paulo state (Willis & Oniki 1993, Sick 1997, Cestari & Pacheco 2010).

When data regarding the birds of the Serra do Bananal were compared before and after 1989 there were 23 species for which no recent records had been made in the region. Most of these were migratory species, waterbirds or species that rarely occur on the Brazilian Plateau in São Paulo (Appendix I) and may thus still be recorded in future studies. *Jacamaralcyon tridactyla*, in particular, deserves attention, since this species has not been recorded since the 1940s (Collar *et al.* 1992), which strongly indicates that it has possibly become extinct at both the local and the state level, having not been recently recorded at other historical sites (Silveira 2009a) (Appendix I & Fig. 1).

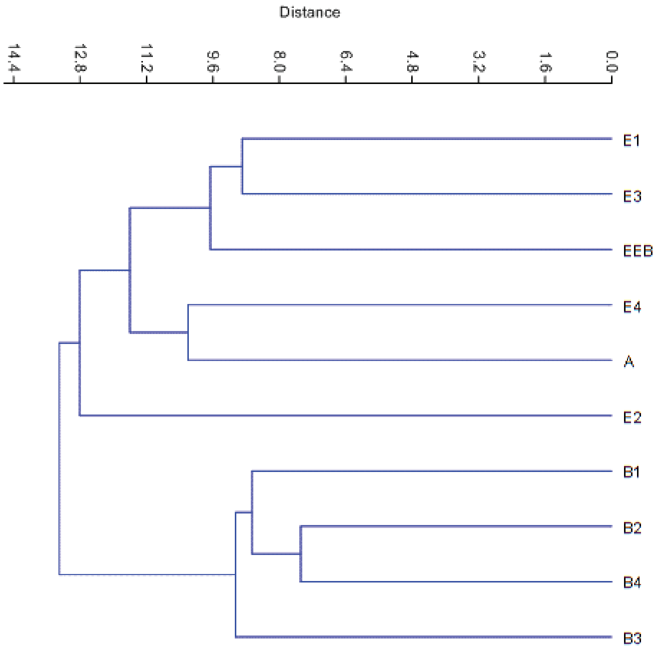

**Figure 3.** Cluster pattern for ten studied points at Bananal region. The localities indicated by the letter B are located in the Paraíba Valley, at lower altitudes. The localities indicated by the letters A and E are located in the Serra de Bananal, at higher altitudes.

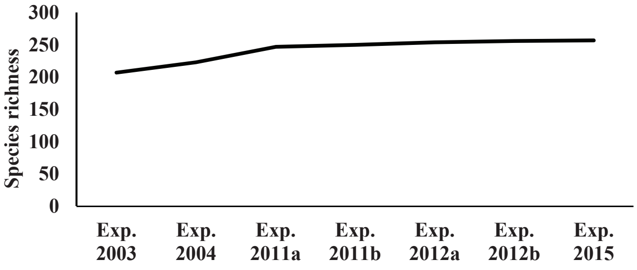

**Figure 4.** Accumulation curve for the species recorded at the Bananal Ecological Station between 2003 and 2015.

## Noteworthy records

*Tinamus solitarius*: considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014), this species was recorded on all field trips to the BES so it can be considered common in the reserve and surrounding areas. In the higher regions of the Serra da Bocaina it was recorded below 800 m a.s.l. (Mallet-Rodrigues *et al*. 2015).

*Sarcoramphus papa*: considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014), this species was photographed flying over the headquarters of the BES by the former manager in 2011. It is regarded as uncommon in the east of the state, with only a few documented records for the Serra do Mar and had not previously been observed in the Bananal region (Willis & Oniki 2003).

*Pseudastur polionotus*: an Atlantic Forest endemic, considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014), it was first photographed in the BES in 2011 by the reserve manager and more recently by other observers (WA1343324). Records of this hawk in the northern parts of the Serra do Mar and Mantiqueira have only begun to occur in the last 10 years (Willis & Oniki 2003). In the Serra da Bocaina it was recorded below 800 m a.s.l. (Mallet-Rodrigues *et al*. 2015).

*Spizaetus tyrannus*: considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014). Recorded on all field trips to the BES, it can be considered common in the reserve and surrounding areas as well as the entire area of the Serra do Mar and Bocaina lying in São Paulo (Mallet-Rodrigues *et al*. 2015).

*Claravis pretiosa*: a widely distributed species in Brazil and the state of São Paulo, where it is more frequently recorded in the summer months (Sick 1997, Willis & Oniki 2003). Previously unknown in the Bananal region, the first and only record was made in February 2012 on the Trilha do Pico Vermelho (E2), in the high parts of the mountain range. Our record is during the expected time of year and may thus indicate seasonal movements, which requires further investigation.

*Primolius maracana*: considered threatened in the state of São Paulo (São Paulo 2008, 2014), it was recorded in the surroundings of BES in 2009 (WA193668) when a group of six individuals was seen during the third field trip (2011). Historical records also exist for this species from the beginning of the 19th century (São José dos Campos; Pelzeln 1871). In Rio de Janeiro state, in the municipalities of Resende, Volta Redonda, Barra do Piraí and Barra Mansa it is considered common (Pacheco *et al*. 1994, Nunes 2003). Thus, it may be expanding its range into the Serra do Mar due to the substitution of humid forest with more open and semi-deciduous vegetation types, which are preferred by this species. In 2009, André De Luca (pers. comm.) recorded this species in Caraguatatuba, which corroborates the hypothesis of geographic expansion due to modifications in vegetation. This scenario has also been confirmed in parts of Rio de Janeiro and Minas Gerais states (Pacheco *et al*. 1994).

*Touit melanonotus*: an Atlantic Forest endemic, considered "Vulnerable" in the list of threatened animals of the state of São Paulo (São Paulo 2008, 2014) and Endangered by the IUCN (2017). It was recorded on the first field trip to the BES (2003), where several individuals flew, vocalising, over the forest surrounding the headquarters. Voice recordings were also obtained at Fazenda Encontro on the 04 March 2014 (of a group in flight) and from an area close to the BES in 2014, whilst a historic record exists for the Bananal region cited by Paynter-Jr. & Traylor-Jr. (1991). It was recorded only at low elevations in the Serra da Bocaina by Mallet-Rodrigues *et al*. (2015).

*Myrmoderus squamosus* and *M. loricatus*: these are species endemic to the Atlantic Forest with parapatric distributions. The shortest distance between documented records of the two taxa is precisely in the Bananal region—approximately 12 km, between the BES and Lídice in the state of Rio de Janeiro (Amaral *et al*. 2013). For the BES, there is a documented record (museum skin) for *M. squamosus* and a recording of an alarm call attributed to *M. loricatus* in Minns *et al*. (2010). The latter should be disregarded, since these calls of the two species are very similar and cannot be used for identification, and the species of the female giving the call was not certain (J. Minns, pers. comm.). In September 1989, an individual of *M. loricatus* was heard singing at Fazenda Encontro (E1), about 5 km from the northeastern portion of the BES, but was never relocated on subsequent surveys. Therefore, based on the available records, we hypothesize that in the Serra da Bocaina *M. squamosus* is present along the moderately low coastal slopes, whilst *M. loricatus* uses the slopes along the edge of the Paraíba Valley, where an exemplar was collected in Cruzeiro (SP) and examined by Hellmayr (1924). What is most intriguing to us, however, is the reason for the lack of recent records of this species in the region. This justifies the need for new studies focusing on the biogeographical importance of the Bananal region.

*Lepidocolaptes falcinellus*: according to Silva & Straube (1996), this woodcreeper occurs from Rio Grande do Sul state northward to the left margin of the Paraíba do Sul River, in northeastern São Paulo, where it is substituted by *L. squamatus*. Inclusion of *L. falcinellus* on the BES list is based on a vocalization heard in 2003 and a visual record from 2011, when an individual was observed in a mixed flock. The presence of *L. squamatus* in the Bananal region and in the BES, however, is certain (MZUSP 27133 and

27134; Silva & Straube 1996, Fonseca & Pacheco 2000, D. Buzzetti, pers. comm.). A documented record of *L. falcinellus* was recently made southwest of the BES in the Cunha region located between 50 and 70 km to the east and northeast of the Paraíba do Sul River (R. Bessa, L. Lima & M.A. Rego, pers. comm.). According to Silva & Straube (1996), this river is the geographical barrier for the north/south separation of these species in the Atlantic Forest. These records of *L. falcinellus* to the northeast and east of the Paraíba do Sul therefore prove that it is not a geographical barrier to these woodcreepers and suggests that they may be sympatric in this region. This was also found to be the case in the Serra da Mantiqueira in Minas Gerais, where interbreeding was detected between the two species (Vasconcelos & D'Angelo-Neto 2009). However, further studies are necessary to better define the distributions of both species as well as the areas in which they may occur in sympatry.

*Leptasthenura setaria*: the occurrence of this Tit-Spinetail is associated with the presence of araucaria pines (*Araucaria angustifolia*) which, in the state of São Paulo, extend throughout the Serra do Mar and Mantiqueira (Sick 1997, Willis & Oniki 2003, Antunes *et al.* 2007). It is common in the Bananal region, and its current presence within the BES and surroundings areas is restricted to araucarias probably planted in the 1960s (Natália Ivanauskas, pers. comm.).

*Onychorhynchus swainsoni*: endemic to the Atlantic Forest, this species is considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014) and globally (IUCN 2017). It was only recorded on the first field trip to the BES, where a single male was mist netted on the Pedra Vermelha Trail, which runs along a forested stream, their preferred habitat. A historical record was made in 1941 during an expedition by the Departamento de Zoologia to the Serra de Bananal (Rio Paca/Fazenda Califórnia) and a photo taken in 2009 (WA95542), documenting the presence of this interesting but still little known species in the region (Pinto 1944, 1945). It was recorded only in the lower portion of the Serra da Bocaina by Mallet-Rodrigues *et al.* (2015).

*Procnias nudicollis*: endemic to the Atlantic Forest, this species is considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014) and globally by the IUCN (2017). It was recorded on five separate trips to the BES (1, 3, 4, 6 and 7), coinciding with the hottest period of the year, when the species vocalises more frequently in the higher regions of the Serra do Mar. The only trips when bellbirds were not recorded were during February and April, which may represent a period of absence from the mountainous regions or a period when they are less vocal and thus less detectable. Sick (1997) confirmed that this species undergoes altitudinal movements, wintering in the coastal lowlands and restingas but this question requires further study.

*Pyroderus scutatus*: endemic to the Atlantic Forest, this species is considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014). It was recorded on all field trips to the BES so can be considered common in the reserve, where it is historically well known (Willis & Oniki 2003). Various other records exist from around the BES (including photographs and sound recordings). Despite the fact that this species is undergoing a population decline across the interior of the state, because of habitat loss (Develey & De Luca 2009), it is very common in the Serra do Mar, where it frequently occurs in rural areas and even city parks, such as in São Paulo (São Paulo 2010).

*Lipaugus lanioides*: endemic to the Atlantic Forest, this species is considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014). It is rare in the northern portion of the Serra do Mar in São Paulo state, occasionally occurring in the lowlands around Ubatuba (Willis & Oniki 2003, Simpson *et al.* 2012). In the Serra da Bocaina it was recorded between 0 and 500 m a.s.l. (Mallet-Rodrigues *et al.* 2015), whilst only a single record exists for the BES and the entire Serra de Bananal region, being voice recording made by D. Buzzetti in March 1995. This is also the highest record ever made in the Serra do Mar in São Paulo state, where it is only known to occur up to 900 m a.s.l., according to Willis & Oniki (2003).

*Piprites pileata*: endemic to the Atlantic Forest, this species is considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014) and globally by the IUCN (2017). It was recorded on the third field trip to the BES. Another seven records were obtained (including photographs and sound recordings) for the surrounding areas. It is typical of the Serra da Mantiqueira but also occurs in this portion of the Serra do Mar with both historical and recent records in the Bananal region (Willis & Oniki 2003). It was not recorded in the higher parts of the Serra da Bocaina by Mallet-Rodrigues *et al.* (2015).

*Elaenia chilensis*: a southern migratory species (Sick 1983, Marini & Cavalcanti 1990, Willis & Oniki 2003) that usually passes through the states of São Paulo, Rio de Janeiro and Minas Gerais between February and April (Pacheco & Gonzaga 1994, Willis & Oniki 2003, Montanhini 2010). Its presence in the BES was detected during April 2004, along with individuals of *Elaenia mesoleuca* (MZUSP 78357, 78358 and 78360). This provides the first record of this species in the northern portion of Serra do Mar/Bocaina and the only one above 1000 m a.s.l. in the state, providing new information about its migratory route in Serra do Mar. It was not recorded in the higher parts of the Serra da Bocaina by

Mallet-Rodrigues *et al.* (2015).

*Sporophila angolensis*: considered "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014), this species was recorded on the fourth field trip to the BES, when a male was captured by mist net in a partially open area with low vegetation near the reserve headquarters. Another four records were subsequently made around the BES and lower lying areas. These records are important as they show that, even though this is one of the most sought after species in the illegal songbird trade, because of its loud and complex song, it has a stable population in the Bananal region, as is proven by both historical and recent records. This species was only recorded in the lower portions of the Serra da Bocaina by Mallet-Rodrigues *et al.* (2015).

*Cyanoloxia brissonii*: listed as "Vulnerable" in the list of threatened animals in the state of São Paulo (São Paulo 2008, 2014), this species was recorded on the third field trip to the BES, when an adult male was observed and recorded in a partially open area along the forest edge. Another five records exist for the areas surrounding the BES and the lower lying regions. Willis & Oniki (2003) also recorded the presence of this species in the Bananal region, which shows that although it is also sought after for the illegal songbird trade, it is still present in this region of the Serra do Mar. It was also only recorded in the lower portions of the Serra da Bocaina by Mallet-Rodrigues *et al.* (2015).

Data collected in the field and from bibliographic sources show that the bird diversity of the Bananal region is very high and divided into two main communities: one from the higher regions of the Serra de Bananal and the other from the lowlands of the Paraíba do Sul River Valley. However, only 259 out of the 371 recorded species presently receive any kind of legal protection, by means of the BES, which is the only reserve in the region. Thus, the creation of new protected areas is essential in both the highlands of the Serra de Bananal as well as of the forest fragments in the Paraíba do Sul River Valley, where most the original forest cover has already been lost. The present study recorded 26 new species for the Bananal region and the absence of 23 previously recorded species, including *J. tridactyla*, possibly extinct in the state of São Paulo, given the lack of recent records from the current study site and elsewhere in the state. Nevertheless, many of these and other species will likely be recorded in future field work. The region is also biogeographically important for certain species whose distribution limits coincide precisely with the Bananal, such as *M. squamosus*/*M. loricatus* and *L. falcinellus*/*L. squamatus*. However, their occurrence, contact and possible overlap require further investigation. Further studies in the region are therefore important to improve the current knowledge and determine with more precision the occurrence of various species, especially in relation to altitude, an issue typical of birds of the Serra do Mar.

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# APPENDIX I

Species of birds in the Bananal region. END - Species (taxa) endemic to the Atlantic Forest (according to Bencke *et al.* 2006); * Threatened species at the national level (according to MMA 2014); # Threatened species at the state level (according to São Paulo 2008, 2014) and + Introduced species; **Evidence:** V (visual record); A (auditory record); R (sound recording); P (photograph); P* (photograph deposited in WikiAves): C (collected specimen) and L (record by local people). **Habitat:** MF (Montane Forest), NF (Natural Grassland), AA (Open Anthropic Areas), FL (Flooded Areas). Species recorded within a 5 km perimeter of the BES are highlighted in the table with the letter S (surroundings) and groups of birds indicated by the letter G (Groups). The numbers indicated in column number 3 of BES field trips refer to the number of individuals recorded in the field and X corresponds to photographic records made by the manager of the reserve. The column "Historical and Current Data" refers to the compilation by Willis & Oniki (2003) for the entire Bananal region without exact location (denoted by X). Highlighted are the data from Sertão das Cobras (1) and Serra de Bananal (Rio Paca/Fazenda Califórnia) (2), the vicinity of the BES, and some additional data contained in Paynter-Jr. & Traylor-Jr. (1991) (3) (no exact locality), Fazenda da Posse (4) (for one specimen collected by J.L. Lima), (5) for records for the Bananal region published by Minns *et al.* (2010) and (6) for the relevant and documented records obtained by D. Buzzetti in March 1995 in the BES and not published by Minns *et al.* (2010). This column also contains modern records contained in online digital databases (WikiAves and xeno-canto) for the Bananal municipality (R+: recordings and P+: photographs). Species cited in the "Historical and Current Data" column do not have information in the columns Evidence and Habitat as this information was not available in the original sources. For numbers separated by a "-", all intermediate values are valid. Data from field trips are found in Table 1.

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| Tinamiformes | | | | | | | | | | | | | | | | | | | |
| Tinamidae (4) | | | | | | | | | | | | | | | | | | | |
| *Tinamus solitarius*$^{\text{end \#}}$ | R,P,C | MF | X | X | 10 | X | X | X | | P+,R+ | | | | | | 7,10,11 | | 5,7-9 | 5,7 |
| *Crypturellus obsoletus* | R,P | MF | X | X | 8 | X | X | X | | 1,2,P+,R+ | 8,10 | | | 6 | | 1-5,7-12 | 4 | 4,5,7-9 | 5,7-9,11 |
| *Crypturellus parvirostris* | A | MF | X | X | | | | | | X | | 13 | 13 | | | | | | |
| *Crypturellus tataupa* | A | MF | X | | | | | | | X | | 2,6,13 | 13 | | | | | | |
| Anseriformes | | | | | | | | | | | | | | | | | | | |
| Anatidae (3) | | | | | | | | | | | | | | | | | | | |
| *Dendrocygna bicolor* | | | | | | | | | | X | | | | | | | | | |
| *Dendrocygna viduata* | | | | | | | | | | X | | | | | | | | | |
| *Amazonetta brasiliensis* | P | AA,FL | | | | | | | | X,P+ | 8 | 2 | | | 7 | | | | |
| Galliformes | | | | | | | | | | | | | | | | | | | |
| Cracidae (1) | | | | | | | | | | | | | | | | | | | |
| *Penelope obscura* | R,C | MF | X | X | 12 | X | X | | | X,5,P+ | 10 | 6,13 | | 6 | | 4,5,7,8,10-12 | 4 | 5,7-9 | 5,9 |
| Odontophoridae (1) | | | | | | | | | | | | | | | | | | | |
| *Odontophorus capueira*$^{\text{end}}$ | R,P,C | MF | X | X | 6 | | | X | X | P+,R+ | | | | | | 1,4,5,7-10,12 | | 4,5 | 5,7,9 |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| Podicipediformes | | | | | | | | | | | | | | | | | | | |
| Podicipedidae (2) | | | | | | | | | | | | | | | | | | | |
| *Tachybaptus dominicus* | V | AA,FL | | | | | | | | X,P+,R+ | 8,9 | | | | | | | | |
| *Podilymbus podiceps* | P | AA,FL | | | | | | | | X,P+,R+ | 8,9,10 | | | | | | | | |
| Suliformes | | | | | | | | | | | | | | | | | | | |
| Phalacrocoracidae (1) | | | | | | | | | | | | | | | | | | | |
| *Nannopterum brasilianus* | P | | | | | | | | | P+ | 8,9,10 | 6 | | | | | | | |
| Anhingidae (1) | | | | | | | | | | | | | | | | | | | |
| *Anhinga anhinga* | | | | | | | | | | X,P+ | | | | | | | | | |
| Pelecaniformes | | | | | | | | | | | | | | | | | | | |
| Ardeidae (6) | | | | | | | | | | | | | | | | | | | |
| *Nycticorax nycticorax* | P | AA,FL | | | | | | | | P+ | 9,10 | | | | | | | | |
| *Butorides striata* | V | AA,FL | | | | | | | | P+ | 8 | | | | | | | | |
| *Bubulcus ibis* | V | AA | | | S | | | | | P+ | | 6,13 | | 6 | 4,5 | | | | |
| *Ardea alba* | P | AA,FL | | | | | | | | P+ | 8,9,10 | 13 | | | 7 | | | 8 | |
| *Syrigma sibilatrix* | P | AA | | | 2 | | | | | P+ | | 6,13 | | | 4,7,12 | 12 | | 4,7,8 | 9 |
| *Pilherodius pileatus* | | | | | | | | | | X,P+ | | 13 | | | | | | | |
| Cathartiformes | | | | | | | | | | | | | | | | | | | |
| Cathartidae (4) | | | | | | | | | | | | | | | | | | | |
| *Cathartes aura* | V | AA | X | | 1 | X | | | | X,P+ | 11 | 6,13 | 6,13 | 13 | 5,8,9,12 | 4,5,8-12 | | | 9 |
| *Cathartes burrovianus* | V | AA | | | | | | | | P+ | | 13 | 13 | | 4,8,11,12 | | | | |
| *Coragyps atratus* | V | AA | X | X | 6 | X | | X | | X,P+ | 8,9,11 | 1-3,6,13 | 13 | 6,1 | 4,5,9-12 | 1,3-5,7-12 | | 5,7,9 | |
| *Sarcoramphus papa*# | P | AA | | | X | | | | | | | | | | | | | | |
| Accipitriformes | | | | | | | | | | | | | | | | | | | |
| Accipitridae (18) | | | | | | | | | | | | | | | | | | | |
| *Leptodon cayanensis* | V | MF,AA | X | | | | | | | X | | | | | | | | 8 | |
| *Chondrohierax uncinatus* | | | | | | | | | | | | | | | | 3 | | | |
| *Elanoides forficatus* | L | MF,AA | | | | | | | | | | | | | | | | | |
| *Elanus leucurus* | | | | | | | | | | X | | | | | | | | | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| *Harpagus diodon* | P,C | MF | X | | | | | | | P+ | | | | | | 1,9,10,12 | | | |
| *Accipiter superciliosus* | V | MF | X | | | | | | | | | | | | | 9 | | 9 | 9 |
| *Accipiter striatus* | V | MF | | | | | | | | 1,2,P+ | | | | | | 1,4,5 | | 5 | |
| *Ictinia plumbea* | | | | | | | | | | X | | | | | | 7 | | | |
| *Geranospiza caerulescens* | V | MF | | | | | | | | 3 | | | | | | 1 | | 5,8 | |
| *Heterospizias meridionalis* | P | AA | | | | | | | | X,P+ | | 6 | | | 7 | 1-3,8,10-12 | | 5,7,8 | 8,11 |
| *Rupornis magnirostris* | P | MF,AA | X | X | 3 | X | X | | | X,P+ | 10 | 6,13 | 13 | | 4,7,8,10 | 1-5,7,8,10-12 | 4 | 5,7,8 | 5,7,8,11 |
| *Parabuteo leucorrhous* | V | MF | | | | | | | | | | | | | | 9 | | | |
| *Geranoaetus albicaudatus* | V,A | AA | X | | | | | | | X,P+ | | | | 6 | | | | | |
| *Pseudastur polionotus*$^{end\ \#}$ | P | AA | | | X | | | | | 5,P+ | | | | | | 9 | | | |
| *Buteo brachyurus* | V | AA | X | | | | | | | X | | | | 6 | | | | | |
| *Buteo albonotatus* | V | AA | | | | | | | | P+ | | 6 | | | | | | | |
| *Spizaetus tyrannus*$^{\#}$ | V | MF | X | X | 1 | X | | | | X,P+ | | | | | | 1-4,8 | 4 | 7,8,9 | |
| *Spizaetus melanoleucus*$^{\#}$ | V | MF | | | | | X | | | P+ | | | | | | | | | |
| Gruiformes | | | | | | | | | | | | | | | | | | | |
| Rallidae (6) | | | | | | | | | | | | | | | | | | | |
| *Aramides saracura*$^{end}$ | P | FL | X | X | 5 | X | X | | X | X,P+ | 8 | 13 | | 6 | | 1,3-5,7-12 | | 4,8,9 | 7,8,9 |
| *Laterallus melanophaius* | V | FL | | | | | | | | R+ | | | | | | | | | 5,11 |
| *Laterallus leucopyrrhus* | V | FL | | | | | | | | R+ | | | | | | | | | 5 |
| *Mustelirallus albicollis* | L | FL | | | | | | | | X | | 13 | | | | | | | |
| *Pardirallus nigricans* | V | FL | | | | | | | | X,P+ | | 1 | | | | 10 | | 4 | |
| *Gallinula galeata* | P | FL | | | | | | | | X,P+,R+ | 8,9,10 | 2 | | | | | | | |
| Charadriiformes | | | | | | | | | | | | | | | | | | | |
| Charadriidae (1) | | | | | | | | | | | | | | | | | | | |
| *Vanellus chilensis* | V,A | AA,FL | X | X | 2 | X | X | X | X | X,P+ | 8,9,10 | 6,13 | 6,13 | 6 | 4,7,9,10 | 5,9-12 | | 4,5,7-9 | 9,11 |
| Recurvirostridae (1) | | | | | | | | | | | | | | | | | | | |
| *Himantopus melanurus* | | | | | | | | | | X | | | | | | | | | |
| Jacanidae (1) | | | | | | | | | | | | | | | | | | | |
| *Jacana jacana* | | | | | | | | | | X | | | | | | | | | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| Columbiformes | | | | | | | | | | | | | | | | | | | |
| Columbidae (9) | | | | | | | | | | | | | | | | | | | |
| *Columbina talpacoti* | P | AA | X | X | | | | | | 2,P+ | 8 | 2,3,6,13 | 6,11,13 | 6 | 1,3-5,7-9,11,12 | | | 5,7,8 | |
| *Claravis pretiosa* | | | | | | | | | | | | | | | | | 4 | | |
| *Columba livia* | V | AA | | | | | | | | X,P+ | 8 | 6,13 | | | 4,5,7-12 | | | | |
| *Patagioenas picazuro* | V | MF,AA | X | X | 2 | | | | | X,P+ | 9,10 | 6,13 | 6,13 | 6,1 | 4,7-10,12 | 12 | | 5,7-9 | |
| *Patagioenas cayennensis* | V,A | MF | X | | | | | | | X | | 6 | | 6 | | | | | 9 |
| *Patagioenas plumbea* | R | MF | X | | 3 | X | X | X | X | 2,P+,R+ | 8,10 | | | | | 1-3,5,7,8,10-12 | | 5,7,8 | 5,7,8 |
| *Leptotila verreauxi* | A | MF | X | X | | | | | | X,R+ | 8,11 | 2,6,13 | 13 | 6 | 8 | 7,10,12 | | 7,8 | 8 |
| *Leptotila rufaxilla* | R,P | MF | X | X | 2 | | | | | X,P+ | | | | | | | | | |
| *Geotrygon montana* | P,C | MF | X | X | 1 | | | | | 1 | | | | | | 4,5,8-10,12 | 4 | 8 | |
| Cuculiformes | | | | | | | | | | | | | | | | | | | |
| Cuculidae (5) | | | | | | | | | | | | | | | | | | | |
| *Piaya cayana* | V,A | MF | X | X | 1 | X | X | X | | 1,P+ | | 2,6,13 | 11,1 | 6 | 7 | 1-5,7-12 | 4 | 8,9 | 9 |
| *Coccyzus melacoryphus* | | | | | | | | | | P+ | | | | | | | | | |
| *Crotophaga ani* | V,A | AA | X | X | S | | | | | 1,P+ | | 2,3,6,13 | 6,13 | 6,1 | 1,4,7-9,11,12 | | | 8 | |
| *Guira guira* | V,A | AA | X | X | | | | | | X,P+ | 8 | 2,6,11 | 6,11 | 6 | 4,7 | | | | |
| *Tapera naevia* | A | MF | X | | | | | | | X | | 1,6 | 6 | | 12 | 1 | | | |
| Strigiformes | | | | | | | | | | | | | | | | | | | |
| Tytonidae (1) | | | | | | | | | | | | | | | | | | | |
| *Tyto furcata* | V | AA | X | | | | | | | | | | | | | | | | |
| Strigidae (6) | | | | | | | | | | | | | | | | | | | |
| *Megascops choliba* | R,C | MF | X | X | 2 | X | | | | | | | | | | 3,4,8,11,12 | | 4 | |
| *Pulsatrix koeniswaldiana*$^{\text{end}}$ | A | MF | X | | 1 | | | | | 6,R+ | | | | | | 1,7,12 | | 4,5 | |
| *Strix hylophila*$^{\text{end}}$ | R,C | MF | X | X | 1 | X | | | | P+,R+ | | | | | | 8,11,12 | | 4 | 5 |
| *Glaucidium minutissimum*$^{\text{end}}$ | A | MF | | | | | | | | 5 | | | | | | | | 5 | |
| *Athene cunicularia* | V | AA | X | | | | | | | X | | | | | 1 | | | | |
| *Asio stygius* | A | MF | | | | | | | | | | | | | | 10 | | | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| Nyctibiiformes | | | | | | | | | | | | | | | | | | | |
| Nyctibiidae (1) | | | | | | | | | | | | | | | | | | | |
| *Nyctibius griseus* | C | MF | X | | | X | | | | P+,R+ | | 6 | | | | 3,7,12 | 4 | | |
| Caprimulgiformes | | | | | | | | | | | | | | | | | | | |
| Caprimulgidae (5) | | | | | | | | | | | | | | | | | | | |
| *Lurocalis semitorquatus* | C | MF | X | | 1 | X | | | | X,R+ | | 6 | | | | 3,4,7,8,10,12 | 4 | 4,7 | |
| *Nyctidromus albicollis* | V,A | AA,NF | X | | 1 | | | | | X | | 6 | | 6 | | 9,11,12 | 4 | 8 | |
| *Hydropsalis longirostris* | V | AA,NF | | | | | | | | | | | | | | 1 | | | |
| *Hydropsalis torquata* | V | AA,NF | X | | | | | | | | | | | | | | | 5 | 9 |
| *Hydropsalis forcipata*$^{end}$ | V | AA,NF | X | | | | | | | | | | | | | 4,11 | | | |
| Apodiformes | | | | | | | | | | | | | | | | | | | |
| Apodidae (5) | | | | | | | | | | | | | | | | | | | |
| *Cypseloides fumigatus* | V | MF,AA | | | | | | | | X | 9 | | | | | 1,2,8,12 | | | |
| *Streptoprocne zonaris* | V,A | MF,AA | X | | G | X | | X | X | X,P+ | | 6,13 | 6 | 6 | 4,7,11 | 1-5,9-12 | | 4,5,8 | |
| *Streptoprocne biscutata* | V | MF,AA | | | | | | | | | | | | | | 1 | | | |
| *Chaetura cinereiventris* | V,A | MF,AA | X | | G | X | | X | | | | | | | | 2,3,7,8,10,11 | | 4,5,8 | |
| *Chaetura meridionalis* | C | MF,AA | X | | S | X | | X | | X | 9,10 | 3,6,13 | 6,13 | 6,1 | 4,7-10 | | | 4 | 8 |
| Trochilidae (16) | | | | | | | | | | | | | | | | | | | |
| *Ramphodon naevius*$^{end}$ | V | MF | | | | | | | | | | | | | | | | 9 | |
| *Phaethornis pretrei* | V | AA | | | | | | | | X,P+ | | 1,3,6,13 | 6,11 | 6,1 | 3,4,7-10,12 | | | | |
| *Phaethornis eurynome*$^{end}$ | P,C | MF | X | X | 4 | X | X | | | 2,5,P+,R+ | 11 | | | | | 1-5,7-12 | 4 | 5,7-9 | |
| *Eupetomena macroura* | V | AA | | | | | | | | X,P+ | | 6,13 | 11,1 | 6,1 | 7,10 | | | | |
| *Aphantochroa cirrochloris*$^{end}$ | V | | | | | | | | | | | | | 6 | | | | | |
| *Florisuga fusca*$^{end}$ | V | MF,AA | X | | | X | X | | X | P+ | 8 | 6,13 | | 6,1 | | 3,8,9,11,12 | 4 | 4,7-9 | 8,9,11 |
| *Colibri serrirostris* | V | MF,AA | X | | | | | | | X,P+ | | 3,6,13 | 6,13 | 6 | 4,5,7,8,10-12 | | | | |
| *Anthracothorax nigricollis* | V | MF,AA | X | | | | | | | | | 6,13 | | | | | | | |
| *Stephanoxis lalandi* $^{end}$ | R,P,C | MF | X | X | 3 | X | X | | | 1,2,5,P+,R+ | 9 | | | | | 1-5,7-12 | 4 | 8 | 8 |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| *Chlorostilbon lucidus* | V | AA | | | | | | | | X | | 1,6,13 | 6,11,13 | 6 | 4,12 | 1-3,11 | | | 8,11 |
| *Thalurania glaucopis*$^{\text{end}}$ | P,C | MF | X | X | 6 | X | X | | X | 2,P+ | | 13 | 13 | 6,1 | | 1,4,5,7-12 | 4 | 5,7-9 | 9 |
| *Leucochloria albicollis*$^{\text{end}}$ | C | MF | X | | 4 | X | X | | | 2,P+ | 8,10 | | | | | 1-5,7-12 | 4 | 4,7,9 | 5,7-9,11 |
| *Amazilia versicolor* | V | MF,AA | | | 1 | | | | | 2 | | 13 | | | | | 4 | | |
| *Amazilia lactea* | V | AA | | | | | | | | X,P+ | | 1,13 | 11,1 | 6,1 | | | | | |
| *Heliodoxa rubricauda*$^{\text{end}}$ | R,P,C | MF | X | X | 6 | X | X | X | | 2,5,P+ | | | | | | 1-5,7-12 | 4 | 4,5,7,9 | 9,11 |
| *Calliphlox amethystina* | V | MF,AA | | | 1 | | | | | 2,P+ | | | | 6 | 7 | 1,3,11,12 | | | 7 |
| Trogoniformes | | | | | | | | | | | | | | | | | | | |
| Trogonidae (3) | | | | | | | | | | | | | | | | | | | |
| *Trogon viridis* | | | | | | | | | | X,5 | | | | | | | | | |
| *Trogon surrucura*$^{\text{end}}$ | R,P,C | MF | X | X | 10 | X | | X | | 1,5,6,P+,R+ | 10 | 6 | | 6 | | 1-3,5,7-12 | 4 | 5,7-9 | 8 |
| *Trogon rufus* | R,C | MF | X | X | 4 | X | X | | | 1,2,5,6,P+ | | | | | | 1,5,8,12 | | 5,7,8 | 8 |
| Coraciiformes | | | | | | | | | | | | | | | | | | | |
| Alcedinidae (3) | | | | | | | | | | | | | | | | | | | |
| *Megaceryle torquata* | V | AA,FL | | | | | | | | X,P+ | 8 | 13 | | | 7,9,12 | 8,10 | | | |
| *Chloroceryle amazona* | V | AA,FL | | | | | | | | | | | | | 7 | | | 7 | |
| *Chloroceryle americana* | P | AA,FL | | | | | | | | P+ | | 13 | | | | 3 | | | |
| Momotidae (1) | | | | | | | | | | | | | | | | | | | |
| *Baryphtengus ruficapillus*$^{\text{end}}$ | R | MF | | | 2 | X | | | | | | | | | | | | 5 | |
| Galbuliformes | | | | | | | | | | | | | | | | | | | |
| Galbulidae (1) | | | | | | | | | | | | | | | | | | | |
| *Jacamaralcyon tridactyla*$^{\text{end \#}}$ | | | | | | | | | | X | | | | | | | | | |
| Bucconidae (2) | | | | | | | | | | | | | | | | | | | |
| *Nystalus chacuru* | A | MF,AA | | | S | | | | | X,P+ | | 6 | 11 | | 4,9,12 | | | | |
| *Malacoptila striata*$^{\text{end}}$ | V | MF | | X | | | | | | | | | | | | | | | |
| Piciformes | | | | | | | | | | | | | | | | | | | |
| Ramphastidae (4) | | | | | | | | | | | | | | | | | | | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| *Ramphastos toco* | V | AA | | | | | | | | X,P+ | | 13 | | | 5,7 | | | | |
| *Ramphastos dicolorus*$^{end}$ | V,A | MF | X | X | 3 | X | X | X | X | 1,P+ | | | | | | 1-5,7-12 | 4 | 7,8,9 | 5 |
| *Selenidera maculirostris*$^{end}$ | R | MF | | | 1 | | | | | | | | | | | | | | |
| *Pteroglossus bailloni*$^{end\ \#}$ | V | MF | | | | | | | | X | | | | | | 1 | | | |
| Picidae (11) | | | | | | | | | | | | | | | | | | | |
| *Picumnus cirratus* | V,A | MF | | | 1 | | | | | 1,2,P+ | | 6,13 | 6,13 | 6 | 3,4,7 | 8,10-12 | | 5,7,9 | 5,8 |
| *Melanerpes candidus* | V | AA | | | S | | | | | X,P+ | | 6 | 13 | 6 | | | | | |
| *Veniliornis maculifrons*$^{end}$ | V | | | | | | | | | X,P+ | | 6,13 | 13 | 6 | | | | | |
| *Veniliornis spilogaster*$^{end}$ | R | MF | X | | 3 | | X | | | 1,2,5,P+ | | | | | | 1-3,5,8,9,11,12 | | 7,9 | 8 |
| *Piculus flavigula* | | | | | | | | | | 1 | | | | | | | | | |
| *Piculus aurulentus*$^{end}$ | P,C | MF | X | X | 1 | X | | | | 2,6,P+ | | | | | | 1-3,5,7-9,11,12 | 4 | 4,5 | |
| *Colaptes melanochloros* | V,A | MF | X | | | | | | | X,P+ | 8 | 6 | 6 | 6 | 7,8,10 | 1,3,10 | | | |
| *Colaptes campestris* | V,A | AA,NF | X | X | S | | | | | X,P+ | 9,10 | 2,6,13 | 6,13 | 6 | 1,4,5,7,11,12 | 1-3,7,8,10 | | 4,5,7-9 | 5,8,9 |
| *Celeus flavescens* | A | MF | X | | | | | | | | | | | | | | | | |
| *Dryocopus lineatus* | A | MF | X | | 1 | | | | | 2,P+ | | 13 | | 6 | 7 | | | 4,5,8,9 | 11 |
| *Campephilus robustus*$^{end}$ | A | MF | X | | | | | | | 2,5,6,P+,R+ | | 13 | | | | 5,7,8,11,12 | | 7 | |
| Cariamiformes | | | | | | | | | | | | | | | | | | | |
| Cariamidae (1) | | | | | | | | | | | | | | | | | | | |
| *Cariama cristata* | P | AA | | | X | | | | | X | | | | 6 | | | | | |
| Falconiformes | | | | | | | | | | | | | | | | | | | |
| Falconidae (8) | | | | | | | | | | | | | | | | | | | |
| *Caracara plancus* | P | AA | X | X | 1 | X | | X | X | X,P+ | 9 | 1,6,13 | 6,13 | 6 | 5,11 | 1,2,4,5,7,8,10-12 | | 4,5,8,9 | 9,11 |
| *Milvago chimachima* | P | AA | X | X | 2 | X | | | | X,P+ | 8,10,11 | 2,6,13 | 6,13 | 6 | 4,5,7,10-12 | 1,3,4,7-12 | | 5,7-9 | 5,8 |
| *Herpetotheres cachinnans* | A | MF,AA | X | | | | | | | X,P+ | | 6 | | | 5 | | | | |
| *Micrastur ruficollis* | R,P,C | MF | X | | 4 | X | | | | X,6,P+ | 9,10 | | | | | 1,3,4,8,11,12 | 4 | 4,5,8 | 5,7,9 |
| *Micrastur semitorquatus* | P | MF | | | X | | | | | P+,R+ | | | | | | 7 | | 8 | |
| *Falco sparverius* | V | AA | | | | | | | | X,P+ | | 6,13 | | | 7,9 | | | | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| *Falco rufigularis* | V | AA | | | | | | | | | | | | | | 4 | | | |
| *Falco femoralis* | V | AA | X | | | | | | | X,P+ | | 6 | | | | 3 | | | |
| Psittaciformes | | | | | | | | | | | | | | | | | | | |
| Psittacidae (9) | | | | | | | | | | | | | | | | | | | |
| *Primolius maracana*$^{\#}$ | V | AA | | | S | | | | | X,P+ | | 13 | 6,13 | 6 | 7 | | | | |
| *Psittacara leucophthalmus* | V,A | AA | X | X | 14 | | | | X | X,P+ | 8 | 2,6,13 | 6,11,13 | 6 | 1,3-5,7-12 | 12 | | | |
| *Pyrrhura frontalis*$^{end}$ | P,C | MF | X | X | 6 | X | X | X | | 2,P+ | 8,10,11 | | | | | 1-5,7-12 | 4 | 4,7-9 | 7,8,9 |
| *Forpus xanthopterygius* | A | MF | X | | 4 | | | | | X,P+ | | 1,6,13 | 11,1 | 6,1 | 4,5,7-12 | | | | |
| *Brotogeris tirica*$^{end}$ | R | MF | X | X | 4 | X | | X | | 2,5 | | 13 | | | | 1-5,7-12 | 4 | 5,7-9 | 8 |
| *Touit melanonotus*$^{end\,*\,\#}$ | V,A | MF | X | | | | | | | 3,R+ | | | | | | 1,11 | | | |
| *Pionopsitta pileata*$^{end}$ | R,V,A | MF | X | | 4 | | | | | 1,R+ | | | | | | 1-5,7-12 | 4 | 4,5,9 | 8 |
| *Pionus maximiliani* | R,P | MF | X | X | 6 | X | X | | X | X,P+ | | 1,6,13 | 13 | 6 | 4,7,8 | 1-5,7-12 | 4 | 4,8,9 | 8,9 |
| *Amazona vinacea*$^{end}$ | A | | | | | | | | | | | | | | | 5 | | 7 | |
| Passeriformes | | | | | | | | | | | | | | | | | | | |
| Thamnophilidae (19) | | | | | | | | | | | | | | | | | | | |
| *Terenura maculata*$^{end}$ | A | MF | | X | | | | | | | | | | | | | | 4,5,7,8,9 | |
| *Rhopias gularis*$^{end}$ | R,C | MF | X | X | 6 | X | X | X | | 1 | 9 | | | | | 4,5,7-12 | 4 | 5,7-9 | 8,9 |
| *Dysithamnus mentalis* | R,P,C | MF | X | X | 4 | X | X | | | 2 | | 6,13 | | 6 | | 2,4,7,12 | | 4,5,7-9 | |
| *Dysithamnus xanthopterus*$^{end}$ | R,P,C | MF | X | X | 4 | | X | X | | 1,2,5,6,P+R+ | | | | | | 1,2,4,5,8-12 | 4 | 7,8,9 | |
| *Herpsilochmus rufimarginatus* | A | | | | | | | | | | | | | 6 | | | | | |
| *Thamnophilus ruficapillus* | P | MF | | | S | | | | X | X,P+ | | 13 | | | 3 | | | 4 | 5,7,9,11 |
| *Thamnophilus caerulescens* | R,P,C | MF | X | X | 4 | X | X | | X | 1,2,P+ | 9,10 | 6,13 | 11 | 6 | | 1-5,7-12 | 4,11 | 4,5,7-9 | 5,7-9 |
| *Hypoedaleus guttatus*$^{end}$ | A | | | | | | | | | | | | | | | | | 5,7 | |
| *Batara cinerea* | A,R | MF | X | | 4 | | X | | | 1,6 | | | | | | 1-5,8-12 | | | |
| *Mackenziaena leachii*$^{end}$ | R | MF | X | | 5 | | | | | 1,2,6,P+ | | | | | | 1-5,7,8,10-12 | 4 | 4,5,8 | 5,7-9,11 |
| *Mackenziaena severa*$^{end}$ | A | MF | X | | | | X | | | X | | | 11 | | | 3 | | 9 | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| *Myrmoderus cf. loricatus*$^{end}$ | R | MF | | | | | | | | 5 | | | | | | 1 | | | |
| *Myrmoderus squamosus*$^{end}$ | C | MF | X | | | | | | | | | | | | | | | | |
| *Pyriglena leucoptera*$^{end}$ | P,C | MF | X | X | 6 | X | X | X | | 1 | 10 | | | 6 | | 1,3-5,7-12 | 4 | 4,5,7-9 | 5,7-9,11 |
| *Drymophila ferruginea*$^{end}$ | V,A | MF | | | | | | | | X,P+ | | 2,6,13 | | | | | | | |
| *Drymophila rubricollis*$^{end}$ | C | MF | | | 2 | X | X | | X | X,5,6,P+,R+ | | | | | | 5,7,8,10-12 | 4 | 4,5,7-9 | 8 |
| *Drymophila genei*$^{end}$ | R,P | MF | | | 2 | | X | X | | 1,2,5,6,P+,R+ | | | | | | 1-5,7-12 | 4 | | |
| *Drymophila ochropyga*$^{end}$ | A | MF | | X | | | | | | X,R+ | | | | | | 10,12 | | 5 | |
| *Drymophila malura*$^{end}$ | A | MF | | | 1 | | | | | X,P+,R+ | | | | | | 10 | | 5 | |
| Conopophagidae (1) | | | | | | | | | | | | | | | | | | | |
| *Conopophaga lineata*$^{end}$ | R,P,C | MF | X | X | 8 | X | X | X | | 1,2,5,6,P+ | 9 | | | 6 | 8,1 | 1-5,7-12 | 4 | 4,5,7,9 | 5,8,9,11 |
| Grallariidae (2) | | | | | | | | | | | | | | | | | | | |
| *Grallaria varia* | R,C | MF | X | | 4 | X | | X | | 1,6,R+ | | | | | | 1,3-5,7,8,10,12 | | | |
| *Hylopezus nattereri*$^{end}$ | R,C | MF | X | | 3 | | | X | | 1,6 | | | | | | 1-5,7-12 | 4 | 8 | 5,7,8 |
| Rhinocryptidae (4) | | | | | | | | | | | | | | | | | | | |
| *Merulaxis ater*$^{end}$ | R | MF | | X | 2 | | | X | | 1,2,R+ | | | | | | 1,4,7,8,10,12 | 4 | 7 | 8 |
| *Eleoscytalopus indigoticus*$^{end}$ | R | MF | | X | | | | | | 1 | | | | | | | | 5,7 | |
| *Scytalopus speluncae*$^{end}$ | R | MF | X | | 1 | | | | | X,5,6,P+ | | | | | | 1-3,5,12 | | 5 | |
| *Psilorhamphus guttatus*$^{end}$ | A | MF | | | | | X | | | X,R+ | | | | | | 12 | | | |
| Formicariidae (2) | | | | | | | | | | | | | | | | | | | |
| *Chamaeza meruloides*$^{end}$ | R | MF | | | 3 | | | | | | | | | | | 1 | | | |
| *Chamaeza ruficauda*$^{end}$ | R,C | MF | X | X | 5 | X | X | X | | 1,6,P+ | | | | | | 1-5,7-12 | 4 | 4,5,7-9 | 7,8 |
| Scleruridae (1) | | | | | | | | | | | | | | | | | | | |
| *Sclerurus scansor*$^{end}$ | R,C | MF | X | X | 3 | X | | | | 1,2,P+,R+ | | | | 6 | | 1,3,9-12 | 4 | 4,5,7-9 | |
| Dendrocolaptidae (9) | | | | | | | | | | | | | | | | | | | |
| *Dendrocincla turdina*$^{end}$ | A | MF | X | | | X | | | | | | | | | | | | | |
| *Sittasomus griseicapillus* | R,P,C | MF | X | X | 10 | X | X | X | X | 1,2,P+,R+ | 10 | 1 | | 6 | | 1-5,7-12 | 4 | 4,5,7-9 | 5,8,11 |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Banana region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| *Xiphorhynchus fuscus*$^{\text{end}}$ | R,P,C | MF | X | X | 2 | X | X | X | | 1,2,P+ | | 6 | | 6 | | 2,4,5,7-12 | 4 | 4,5,7-9 | 8 |
| *Campylorhamphus falcularius*$^{\text{end}}$ | P,C | MF | X | X | | | | | | 1,2,P+,R+ | | 6,13 | | 6 | | 12 | | 8 | |
| *Lepidocolaptes angustirostris* | P | AA | | | X | | | | | X,P+ | | 6,13 | | | | | | | |
| *Lepidocolaptes squamatus*$^{\text{end}}$ | V | MF | | | | | | | | 2,6,P+,R+ | | 2,6,13 | | | | 1,2,4,7,8,10-12 | 4 | 4,5,7 | |
| *Lepidocolaptes falcinellus*$^{\text{end}}$ | V,A | MF | X | | 2 | | | | | | | | | | | | | | |
| *Dendrocolaptes platyrostris* | R | MF | X | | 1 | X | X | | | 1,2,P+,R+ | | | | 6 | | 1,3-5,7,9-12 | 4 | 4,7,8 | |
| *Xiphocolaptes albicollis* | R,C | MF | X | X | 4 | X | X | X | | 1,2,6 | | | | | | 1,3-5,8-12 | 4 | 4,5,8 | 7,9 |
| Xenopidae (2) | | | | | | | | | | | | | | | | | | | |
| *Xenops minutus* | A | MF | | X | | | | | | | | | | | | | | | |
| *Xenops rutilans* | V | MF | X | | 1 | | X | X | | 1,P+ | | 6,13 | | | 4 | 2,7-12 | 4 | 7,8,9 | |
| Furnariidae (22) | | | | | | | | | | | | | | | | | | | |
| *Furnarius figulus* | V | AA | | | | | | | | X,P+ | 8,9 | 6,13 | | 6,1 | 7,12 | | | | |
| *Furnarius rufus* | V,A | AA | X | X | S | X | X | | | X,P+ | 8,9,11 | 2,3,6,13 | 6,11,13 | 6 | 1,3,4,7-9,11,12 | | | | 5 |
| *Lochmias nematura* | P | MF | X | | 2 | | | X | X | 1,P+ | 9,11 | 4 | | | 7,8,10 | 1-3,5,7-12 | 4 | 4,5,8,9 | 8,11 |
| *Automolus leucophthalmus*$^{\text{end}}$ | A | MF | X | | | | | | | X | | 6 | | | | | | | |
| *Anabazenops fuscus*$^{\text{end}}$ | C | MF | X | | 3 | X | | | | X | | 6 | | 6 | | 3,7,9 | | | |
| *Anabacerthia amaurotis*$^{\text{end}}$ | C | MF | X | | | | X | | | 1,2,5,P+,R+ | | | | | | 7,12 | 4 | 9 | |
| *Anabacerthia lichtensteini*$^{\text{end}}$ | V | MF | | | | | X | | | | | | | | | 2,5 | | 9 | |
| *Philydor atricapillus*$^{\text{end}}$ | V | MF | | X | | | | | | | | | | | | | | | |
| *Philydor rufum* | P,C | MF | X | X | 8 | X | X | X | X | 1,P+ | | 6,13 | | 6 | | 1-5,7-12 | 4 | 5,7-9 | 7,8,11 |
| *Heliobletus contaminatus*$^{\text{end}}$ | P,C | MF | X | | 12 | X | | X | | 1,2,5,P+,R+ | | | | | | 2,4,5,7,9-12 | 4 | 7,9 | 8 |
| *Syndactyla rufosuperciliata* | R,P,C | MF | X | X | 10 | X | X | X | X | 1,2,P+,R+ | | | | | | 1-5,7-12 | 4 | 4,5,7-9 | 5,7,8,11 |
| *Cichlocolaptes leucophrus*$^{\text{end}}$ | R,C | MF | X | X | 3 | | X | | | 1,2,5,6,P+,R+ | | | | | | 1-5,7-12 | 4 | 4,7,9 | |
| *Leptasthenura setaria*$^{\text{end}}$ | R,C | MF | X | | 2 | X | X | | | X,P+,R+ | | | | | | 4,5,7-12 | | | 9 |
| *Phacellodomus rufifrons* | V | AA | | | S | | | | | P+ | | 6,13 | 6,11,13 | 6,1 | 4,5,7-12 | 12 | | | |
| *Phacellodomus erythrophthalmus*$^{\text{end}}$ | V,A | MF | | | S | | | | | X,P+,R+ | | 1,2,6,13 | 11,1 | 6 | 5,7,12 | 1,9,12 | | 4 | 5,8 |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| *Anumbius annumbi* | V | AA | | | S | | | | | X,P+,R+ | | 6,13 | 11 | | 3-5,7-10,12 | | | | |
| *Certhiaxis cinnamomeus* | V,A | FL | | | | | | | | X,P+ | 8 | 2,3,6,13 | 11,1 | 6 | 4,7,8 | | | | |
| *Synallaxis ruficapilla*$^{end}$ | R,P,C | MF | X | X | 6 | | X | X | X | 1,2,P+ | | 13 | 13 | 6 | | 1-5,7-12 | 4 | 4,5,7-9 | |
| *Synallaxis cinerascens* | A,C | MF | | | 2 | X | X | | | X | | | | | | 10 | | 7 | |
| *Synallaxis albescens* | | | | | | | | | | | | 6 | 13 | | 4,7,9 | | | | |
| *Synallaxis spixi* | P | MF | X | X | 2 | X | X | | | 1,2,P+,R+ | 8,9,10 | 1,3,6,13 | | 6 | 1,3-5,7-10,12 | 1-5,7-12 | 4 | 4,5,7,8 | 5,7-9,11 |
| *Cranioleuca pallida*$^{end}$ | R | MF | X | | 4 | X | X | X | | 1,2,5,P+,R+ | 10,11 | 6,13 | 13 | | | 1-5,7-12 | 4 | 4,5,7-9 | 7,8,9 |
| Pipridae (4) | | | | | | | | | | | | | | | | | | | |
| *Neopelma chrysolophum*$^{end}$ | R,P,C | MF | X | X | 3 | X | | | | X,6,P+,R+ | 8 | | | | | 1,7,10,12 | | 7,8,9 | 5,7 |
| *Manacus manacus* | A | | | | | | | | | 2 | | 1 | | | | | | | |
| *Ilicura militaris*$^{end}$ | R,P,C | MF | X | X | 3 | X | X | | | 1,P+ | | | | | | 3-5,7,9-12 | 4 | 4,5,8,9 | 9 |
| *Chiroxiphia caudata*$^{end}$ | R,P,C | MF | X | X | 18 | X | X | X | X | 1,2,P+ | 8,9,10,11 | 2,13 | 11,1 | 6 | | 1-5,7-12 | 4 | 4,5,7-9 | 5,8,9,11 |
| Oxyruncidae (1) | | | | | | | | | | | | | | | | | | | |
| *Oxyruncus cristatus* | R,C | MF | X | | 2 | X | X | | | 2,P+ | | | | | | 1,8,11,12 | 4 | | |
| Onychorhynchidae (2) | | | | | | | | | | | | | | | | | | | |
| *Onychorhynchus swainsoni*$^{end\ \#}$ | P,C | MF | | X | | | | | | 2,P+ | | | | | | | | | |
| *Myiobius atricaudus* | P,C | MF | X | X | 1 | X | | | | 2,P+ | | | | | | 8,10-12 | | 9 | |
| Tityridae (6) | | | | | | | | | | | | | | | | | | | |
| *Schiffornis virescens*$^{end}$ | R,P,C | MF | X | X | 8 | | X | | | 1,P+ | | | | | | 1,2,4,5,7,9-12 | 4 | 4,5,7-9 | 7,11 |
| *Tityra cayana* | V | MF | | | | | | | | | | | | | | | | 7 | |
| *Pachyramphus viridis* | R,C | MF | X | | 6 | X | | | | 2,P+ | | | | | 4 | 1-5,7,8,10,12 | | 8 | |
| *Pachyramphus castaneus* | A | MF | X | | 3 | X | X | X | | X,5,P+ | | 6 | | | | 1-5,7-12 | 4 | 5,7-9 | |
| *Pachyramphus polychopterus* | R,C | MF | X | | | X | X | | | X,P+,R+ | | 1,6,13 | 13 | 6 | 4 | 1-4,7-12 | 4 | 4,7-9 | 4,8 |
| *Pachyramphus validus* | R,C | MF | X | | 1 | X | X | | X | X,P+ | | 6 | | | | 3,4,7-12 | 4 | 9 | 4,8 |
| Cotingidae (6) | | | | | | | | | | | | | | | | | | | |
| *Carpornis cucullata*$^{end}$ | R,P,C | MF | X | X | 16 | X | X | X | X | 1,2,5,6,P+,R+ | | | | | | 1-5,7-9,11,12 | 4 | 4,5,7-9 | 5,7,8 |
| *Phibalura flavirostris* | P | MF | | | | | | X | | 1,P+ | | | | | | 4,5,8,11,12 | | 4 | 8 |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| *Pyroderus scutatus*$^{end\ \#}$ | P | MF | X | X | 10 | X | | | | X,P+,R+ | 8,10 | | | | | 4,5,7-12 | 4 | 5,7-9 | 8 |
| *Lipaugus ater*$^{end}$ | R,P | MF | X | X | 8 | X | X | X | | 1,2,6,P+ | | | | | | 1-5,7-12 | 4 | | 8 |
| *Lipaugus lanioides*$^{end\ \#}$ | | | | | | | | | | 6 | | | | | | | | | |
| *Procnias nudicollis*$^{end\ \#}$ | R,P,C | MF | X | | 14 | X | | X | X | X,P+,R+ | 8,10 | | | | | 1-5,7,8,10,12 | | 4,5,7,8 | 5,7,8 |
| Pipritidae (2) | | | | | | | | | | | | | | | | | | | |
| *Piprites chloris* | R | MF | | X | | | | | | | | | | | | | | | |
| *Piprites pileata*$^{end\ \#}$ | R | MF | | | 2 | | | | | X,6,P+,R+ | | | | | | 4,8,9,11,12 | 4 | 9 | |
| Platyrinchidae (1) | | | | | | | | | | | | | | | | | | | |
| *Platyrinchus mystaceus* | R,P,C | MF | X | X | 5 | X | | X | | 1,2,5,P+ | | 6 | | | | 1,4,5,7-9,11,12 | 4 | 4,5,7-9 | |
| Rhynchocyclidae (13) | | | | | | | | | | | | | | | | | | | |
| *Mionectes rufiventris* | P,C | MF | X | X | 2 | X | | X | | 1,2,P+ | | | | 6 | | 3,5,7-9,11,12 | | 5,7-9 | 8 |
| *Leptopogon amaurocephalus* | P | MF | X | X | 4 | X | X | | | 1,P+ | | | 11 | 6 | | 5,7,8,10 | | 5,7,8 | 8 |
| *Corythopis delalandi* | A | MF | | | | | | | | | | | | 6 | | | | | |
| *Phylloscartes ventralis* | R,P,C | MF | X | X | 16 | X | X | X | | 1,2,P+ | | | | | | 1-5,7-12 | 4 | 4,5,7-9 | 5,8,9 |
| *Phylloscartes difficilis*$^{end}$ | A | MF | | X | | | | | | 1,2,P+,R+ | | | | | | 1,2,4,5,7-12 | 4 | | |
| *Tolmomyias sulphurescens* | R,C | MF | X | X | 8 | X | X | X | | X,P+ | 8 | 1,6,13 | 11,1 | 6 | 4,7,9,12 | 1-5,7-12 | 4 | 4,5,7-9 | |
| *Todirostrum poliocephalum*$^{end}$ | A | MF | | | 2 | | X | X | X | X,P+ | 9 | 6 | 11 | | 3,7,10,12 | 1,4,5,7-12 | 4 | 4,5,7 | 7,9 |
| *Todirostrum cinereum* | V | MF | | X | | | | | | X,P+ | 8 | 6,13 | 6,11,13 | 6 | 7,8,9,10 | | | | |
| *Poecilotriccus plumbeiceps* | R,P | MF | X | X | 6 | | X | X | X | 1,2,P+ | 10 | | | | | 1-4,7-12 | 4 | 4,5,7,8 | 5,7-9 |
| *Myiornis auricularis*$^{end}$ | A,P | MF | X | | 3 | | X | | | 2,P+ | | | | 6 | | 1-5,9,11,12 | 4 | 4,5 | |
| *Hemitriccus diops*$^{end}$ | V,A | MF | | X | | | | | | | | | | 6 | | | | | |
| *Hemitriccus obsoletus*$^{end}$ | R,P,C | MF | X | X | 3 | X | X | X | | 2,6,P+,R+ | | | | | | 1-5,7,10-12 | 4 | 4,5,7-9 | 7,8 |
| *Hemitriccus nidipendulus*$^{end}$ | A | AA | | X | | | | | | X,P+ | | 6 | | 6 | 10 | | | | |
| Tyrannidae (45) | | | | | | | | | | | | | | | | | | | |
| *Hirundinea ferruginea* | V | AA | | | 1 | | X | | | 1,P+ | | 13 | 11,1 | | 3,12 | 1,4,5,10,12 | | | |
| *Tyranniscus burmeisteri* | A | MF | X | | | | X | X | | 2,P+,R+ | | | | | | 1,2,4,5,7-12 | 4 | 5,7-9 | 8 |
| *Camptostoma obsoletum* | P,C | MF,AA | X | X | 4 | X | X | | | X,P+,R+ | 10 | 1,6,13 | | 6 | | 1,5,7,9-12 | | 5,7,8 | 8,9,11 |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| *Elaenia flavogaster* | A | MF,AA | X | X | S | | | | | X,P+ | | 6,13 | 6,13 | 6,1 | 1,4,7,10 | 2,5 | | | |
| *Elaenia chilensis* | P,C | MF | | X | | | | | | | | | | | | | | | |
| *Elaenia parvirostris* | | | | | | | | | | X | | | | | | | | | |
| *Elaenia mesoleuca* | P,C | MF | X | | | X | X | | X | 1,P+,R+ | 8 | | | | | 2-4,7-10,12 | 4 | 4,8 | 8 |
| *Elaenia obscura* | P,C | MF | X | | | X | | | | P+,R+ | | | | | | 2,5,7-12 | | | 5,7-9 |
| *Myiopagis caniceps* | A | MF | X | | | | | | | X | | | | | | | | | |
| *Capsiempis flaveola* | V | | | | | | | | | X,P+ | | 13 | | | | | | | |
| *Phyllomyias virescens*$^{end}$ | V | MF | | | 2 | X | | | | P+,R+ | | | | | | 1,5,7-12 | | 5,7,8 | |
| *Phyllomyias fasciatus* | R,C | MF | X | | 4 | X | X | | | X,P+,R+ | 10 | 13 | | | | 1-5,7-12 | 4 | 4,5,7-9 | 7-9,11 |
| *Phyllomyias griseocapilla*$^{end}$ | R | MF | X | | 1 | X | X | X | | | | | | | | 2-5,7-12 | 4 | 4,5,8 | 8 |
| *Polystictus superciliaris* | | | | | | | | | | 4,P+ | | | | | | | | | |
| *Serpophaga nigricans* | P | MF,FL | | | | | | | | 2,P+ | 8,9 | 13 | | | 7 | | | | |
| *Serpophaga subcristata* | P | MF | X | X | 2 | | X | | X | 2,P+ | 10 | 13 | 13 | | 7 | 1,3,5,7,9-12 | | 5 | 5,8,9 |
| *Attila phoenicurus* | P,C | MF | X | | | X | X | | X | X,6,P+,R+ | 8 | | | | | 2-5,7,8,10-12 | 4 | 5,7,8 | 8,11 |
| *Attila rufus*$^{end}$ | R,P,C | MF | X | X | 12 | X | X | | X | 1,2,P+ | 10 | 1,6 | | | | 1-5,7-12 | | 5,7-9 | 5,7-9 |
| *Legatus leucophaius* | A | MF | | | | X | | | | X | | | | | | | | | |
| *Myiarchus swainsoni* | R,P,C | MF | X | | 1 | X | X | | X | X,P+,R+ | 10 | 1,6 | | 6 | | 2-5,7-12 | 4 | 4,7 | 7,8 |
| *Myiarchus ferox* | C | MF,AA | | | | X | | | | 1 | 8 | 1,6,13 | 11,1 | 6,1 | 8 | 7 | | | |
| *Sirystes sibilator* | A | MF | X | | | | | | | X | | | | | | | | | |
| *Pitangus sulphuratus* | R | MF | X | X | 4 | X | X | X | X | 2,P+ | 8,9,10,11 | 2,6,13 | 6,11,13 | 6 | 3,4,7-12 | 1-5,7-12 | 4 | 4,5,7-9 | 5,8,9,11 |
| *Machetornis rixosa* | P | AA | X | | S | | | X | | X,P+ | 9 | 2,6,13 | 6,11,13 | 6 | 3-5,7-10,12 | 1-3,8,10-12 | | 5,7,8 | |
| *Myiodynastes maculatus* | A | MF | X | | 2 | X | X | | X | 1,P+ | 10,11 | 1,2,6 | 6 | 6 | 7,11,12 | 2-4,7,8,10-12 | | 7,8 | 7,8,11 |
| *Megarynchus pitangua* | P | MF,AA | X | X | 2 | | X | X | | X | | 2,6,13 | | 6 | 4,7,8,10 | 2,3,5,8-12 | 4 | 4,8 | 7-9,11 |
| *Myiozetetes similis* | V,A | MF,AA | X | X | 2 | X | | | X | X,P+ | 8,9 | 6,13 | 11,1 | 13 | 4,5,7-12 | 1,4,7-12 | 4 | 4 | 9,11 |
| *Tyrannus melancholicus* | V,A,C | MF,AA | X | | 2 | X | X | | X | X,P+ | 8,9,10,11 | 2,6,13 | 6,11,13 | 6 | 1,3-5,7-10,12 | 1-4,7-12 | 4 | 4,7-9 | 7-9,11 |
| *Tyrannus savana* | P | AA,NF | X | | S | X | | | | X,P+ | 8,10 | 2,3,6 | 6 | 6 | 5,7,10,11 | | | | |
| *Empidonomus varius* | V | MF | X | | | X | | | X | X,P+,R+ | 8 | 1,6,13 | 13 | 6 | 3,7,8,12 | 3,8,10-12 | | | 7,8,11 |
| *Colonia colonus* | V | MF | X | | | | | | | 1,2,P+ | | 6,13 | 13 | 6 | | 1 | | | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| *Myiophobus fasciatus* | C | MF | X | | 1 | X | X | | X | X,P+,R+ | 8,11 | 6,13 | 11,1 | 6 | 7 | 1,3,5,7-12 | | 4,5,7,9 | 5,7-9,11 |
| *Fluvicola nengeta* | P | AA | X | | | | | | | X,P+ | 8,9,10 | 6,13 | 6,13 | 6,1 | 5,7,8,12 | 2,10,11 | | 5,8,9 | |
| *Arundinicola leucocephala* | V | AA | X | | | | | | | X | | 1,2,3 | | | | | | | |
| *Gubernetes yetapa* | V | AA,FL | | | | | | | | X | | 2 | | 6 | | | | | |
| *Cnemotriccus fuscatus* | V,A | MF | | | | | | | | X,P+,R+ | | | | 6 | | | | | |
| *Lathrotriccus euleri* | R | MF | X | | 3 | | | | | 1,R+ | | 6 | 13 | 6,1 | | 1,2,5,7,9-12 | | 7,8,9 | 8 |
| *Contopus cinereus* | P | MF | | | | | | X | | 1,2,P+ | | | | | | 5,7-11 | | 7 | |
| *Knipolegus cyanirostris* | P | MF | X | | 1 | | | X | | 1,2,P+ | | | | | | 1-5,7-12 | | 7 | 9 |
| *Knipolegus lophotes* | P | AA | | | S | | | | | X,P+ | | 2,3 | | 6 | 1,3-5,7,10,12 | | | | |
| *Knipolegus nigerrimus*$^{end}$ | P | AA,AL | X | | | | | | | 1,P+ | | | | | | 3 | | | 9 |
| *Satrapa icterophrys* | V | AA,AL | X | | | | | | | 1 | 8 | 6 | | | | | | 7 | |
| *Xolmis cinereus* | V | AA | | | | | | | | | | | | 6 | | | | | 8 |
| *Xolmis velatus* | V | AA | | | | | | | | X,P+ | | 2 | 13 | | 3,12 | 1 | | | |
| *Muscipipra vetula*$^{end}$ | C | MF | X | | 1 | | | | | 1,2,P+ | | | | | | 1,7-10 | | 7,8,9 | 5 |
| Vireonidae (3) | | | | | | | | | | | | | | | | | | | |
| *Cyclarhis gujanensis* | R | MF,AA | X | X | 10 | X | X | X | X | 1,2,5,P+ | 9,10 | 1,2,6,13 | 6,11,13 | 6,1 | 1,7, | 1-5,7-12 | 4 | 4,5,7-9 | 5,7-9,11 |
| *Hylophilus poicilotis*$^{end}$ | R,C | MF | X | X | 8 | X | X | | | 2,P+ | | | | | | 1-5,7-12 | 4 | 4,5,7-9 | 8 |
| *Vireo chivi* | R,C | MF,AA | X | X | 4 | X | X | | X | X,P+ | 8,10 | 1,6 | | 6 | 3,7,10,12 | 1-4,7-12 | 4 | 4,7,8 | 8 |
| Corvidae (1) | | | | | | | | | | | | | | | | | | | |
| *Cyanocorax cristatellus* | V | AA | | | S | | | | | X,P+ | 9,10 | 6,13 | 13 | | 5,7,9 | | | | |
| Hirundinidae (6) | | | | | | | | | | | | | | | | | | | |
| *Pygochelidon cyanoleuca* | R,P,C | AA | X | X | 12 | X | X | X | X | 2,P+ | 8,10 | 1,3,6,13 | 6,11,13 | 6,1 | 3-5,7-12 | 1-5,7-12 | 4 | 4,5,7,8 | 8,9 |
| *Alopochelidon fucata* | | | | | | | | | | X | | | | | | | | | |
| *Stelgidopteryx ruficollis* | V | AA | X | | S | X | | | | 1,P+ | | 2,6,13 | 6,13 | 6,1 | 1,3-5,7-10,12 | 2,5,7, | | 5,7 | |
| *Progne tapera* | V | AA | | | | | | | | X | 10 | 6 | 6 | | 5 | | | | 8 |
| *Progne chalybea* | V | AA | X | X | S | | | | | P+ | | 2,3,6 | 6,11 | 6 | 7,8,10,12 | | | | |
| *Tachycineta leucorrhoa* | V | AA | | | | | | | | X | | 6 | 6 | 6 | | | | | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| Troglodytidae (2) | | | | | | | | | | | | | | | | | | | |
| *Troglodytes musculus* | P | MF,AA | X | X | 2 | X | | X | X | 2,P+ | 8,9,10 | 6,13 | 6,11,13 | 6,1 | 1,4,5,7-12 | 1-3,5,7-12 | | 5,7,8 | 5,7,8 |
| *Cantorchilus longirostris* | A | MF | | | | | | | | X,P+ | | 1,2,6,13 | 13 | 6 | | | | | |
| Donacobiidae (1) | | | | | | | | | | | | | | | | | | | |
| *Donacobius atricapilla* | | | | | | | | | | X | | | | | | | | | |
| Turdidae (6) | | | | | | | | | | | | | | | | | | | |
| *Turdus flavipes* | R,P,C | MF | X | X | 4 | X | X | | X | 1,2,P+,R+ | 8,10 | | | | | 1-5,7-12 | 4 | 4,5,7-9 | 7,8,11 |
| *Turdus leucomelas* | C | MF,AA | X | X | | X | | | | X,P+ | | 1,6,13 | 6,11,13 | 6 | 4,7,10,12 | 1,4,5,7,11 | | 9 | |
| *Turdus rufiventris* | R,P,C | MF,AA | X | X | 8 | X | X | X | X | 2,P+,R+ | 8,9,10,11 | 2,6,13 | 6,11,13 | 13 | 3-5,7,10,12 | 1-5,7-12 | | 4,5,7-9 | 5,7-9,11 |
| *Turdus amaurochalinus* | R,P | MF,AA | X | X | 3 | X | | X | | X,P+ | 8 | 1,6,13 | 13 | 6 | 3 | 1,5,7-12 | | 5,7 | 5,7,11 |
| *Turdus subalaris* | | | | | | | | | | P+ | | | | | | | | | |
| *Turdus albicollis* | R,P,C | MF | X | X | 4 | X | X | X | X | X,P+ | | 1,6, | 13 | 6 | | 1-3,5,7-12 | 4 | 4,5,7,8 | 8 |
| Mimidae (1) | | | | | | | | | | | | | | | | | | | |
| *Mimus saturninus* | V | AA,NF | X | | S | | | | | 1,2, P+ | 10,11 | 2,6,13 | 13 | 6,1 | 1,3-5,7-9,11,12 | | | 7 | |
| Motacillidae (1) | | | | | | | | | | | | | | | | | | | |
| *Anthus hellmayri* | | | | | | | | | | X | | | | | | | | | |
| Passerellidae (3) | | | | | | | | | | | | | | | | | | | |
| *Zonotrichia capensis* | P,C | AA,NF | X | X | 14 | X | | X | X | 1,2,P+ | 8,9,10,11 | 2,3,6,13 | 13 | 6 | 1,3,5,7-9,12 | 1-3,5,7-12 | | 5,7-9 | 5,7-9,11 |
| *Ammodramus humeralis* | V | AA | | | | | | | | X | | 3,6 | 11 | 6 | 3,7,12 | | | | |
| *Arremon semitorquatus*$^{end}$ | A | MF | | X | | | | | | | | 1,6,13 | | | 10 | | | | |
| Parulidae (4) | | | | | | | | | | | | | | | | | | | |
| *Setophaga pitiayumi* | V,A | MF | X | X | | | | | | X,P+ | | 6,13 | 6 | | 10 | 5 | | | |
| *Geothlypis aequinoctialis* | V,A | AA,FL | X | X | S | | | | X | 1,2,P+,R+ | 9,10,11 | 2,6,13 | 11,1 | 6 | 1,7, | 1-3,10 | | 4,7 | 5,8,9,11 |
| *Basileuterus culicivorus* | R,P,C | MF | X | X | 22 | X | X | X | | 1,2,P+ | 8,9,10,11 | 6,13 | 11,1 | 6 | 7,8 | 1-5,7-12 | 4 | 4,5,7-9 | 7-9,11 |
| *Myiothlypis leucoblephara*$^{end}$ | R,P,C | MF | X | X | 14 | X | X | X | | 1,2,P+ | 8,9,10,11 | | | | | 1-5,7-12 | 4 | 4,5,7-9 | 5,7-9,11 |
| Icteridae (7) | | | | | | | | | | | | | | | | | | | |
| *Psarocolius decumanus* | R | AA | X | | 3 | X | X | | X | | 8,9 | 6,13 | | | | 5,7,9-12 | | 7 | 7 |

| **Taxa** | **Evidence** | **Habitat** | **Bananal Ecological Station (Field trip)** | | | | | | | **Bananal region (historical and current data)** | **Bananal region (Field trip)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| *Cacicus chrysopterus* | R,P,C | MF | X | X | 10 | X | X | X | | 1,2,5,P+ | 9 | | | | | 1-5,7-12 | 4 | 4,5,7,9 | 5,8,9,11 |
| *Gnorimopsar chopi* | V | AA | | | S | | | | | X,P+ | | 6,13 | 6 | 6 | 4,5,7,9,11,12 | 2 | | | |
| *Chrysomus ruficapillus* | V | AA,FL | X | | | | | | | P+ | | 2,6,13 | 6,13 | 6,1 | 4,7,12 | | | | |
| *Molothrus rufoaxillaris* | | | | | | | | | | X | | | | | | | | | |
| *Molothrus oryzivorus* | P | AA | | | X | | | | | X | | | | | | | | | |
| *Molothrus bonariensis* | P | AA,NF | X | | S | X | | | | 2,P+ | 8 | 2,6 | 6 | 6 | 3,7,8,10,12 | 1,3,5,7,8,10,12 | | 5,8 | |
| Mitrospingidae (1) | | | | | | | | | | | | | | | | | | | |
| *Orthogonys chloricterus*$^{end}$ | R,P | MF | | | 8 | | | | | 1,2 | 9 | | | | | 2,9-11 | | | |
| Thraupidae (42) | | | | | | | | | | | | | | | | | | | |
| *Orchesticus abeillei*$^{end}$ | R | MF | | X | | | | | | 2,5,R+ | | | | | | 5,7-12 | 4 | | |
| *Pipraeidea melanonota* | P,C | MF,AA | X | X | 3 | X | | X | | 1,2,P+,R+ | | | | | | 2,5,7-12 | | 5,7-9 | 5 |
| *Stephanophorus diadematus* | P | MF | X | | | | X | X | | 1,2,P+,R+ | 8 | | | | | 1-5,7-12 | 4 | 4,5,7-9 | 8,9,11 |
| *Cissopis leverianus* | V | MF | X | | | X | | | | X,R+ | | | | | | 12 | | 4 | 5 |
| *Schistochlamys ruficapillus* | V | NF,AA | | | | | | | | X,P+ | | 2,6,13 | 13 | | 3,7 | 3,9,12 | | 7 | 5,8 |
| *Paroaria dominicana* $^{+}$ | V | AA | | | | | | | | P+ | | | | | | | | | 8 |
| *Tangara cyanoventris*$^{end}$ | V | MF | | | | | | | | X,P+ | | 1,13 | 13 | | | | | | |
| *Tangara desmaresti*$^{end}$ | R | MF | X | X | 20 | X | X | X | | 1,2,P+ | 9,10 | | | | | 1-5,7-12 | 4 | 4,7-9 | 8 |
| *Tangara sayaca* | R,C | MF,AA | X | X | 10 | X | X | X | X | X,P+ | 8,10 | 1,2,6,13 | 6,11,13 | 6,1 | 3-5,7-12 | 1-5,7-12 | | 4,5,7,9 | 5,7,8 |
| *Tangara cyanoptera*$^{end}$ | R,C | MF | X | X | 6 | X | | | | 1,2,6,P+,R+ | | | | | | 1,2,5,7-12 | 4 | 4,7-9 | 8 |
| *Tangara palmarum* | V,A | MF,AA | X | X | 2 | X | | | | 1,P+ | | 6,13 | 6 | | 4,5,7,8,12 | 12 | | 5 | |
| *Tangara ornata*$^{end}$ | P | MF | X | | 4 | X | X | X | X | 1,2,5,P+ | 10 | | | | | 1-5,7-12 | 4 | 4,7,8 | 5,8 |
| *Tangara cayana* | P | MF | X | X | 2 | | | | | X,P+ | 10 | 6,13 | 11 | 6,1 | 7,8,10 | 2,3,5,7-12 | | 5,7 | 5 |
| *Nemosia pileata* | V | MF,AA | | | | | | | | | | 6,13 | | | | | | | |
| *Conirostrum speciosum* | V | MF | | | | | | | | X | | 6,13 | 13 | 6 | | | | | |
| *Sicalis citrina* | | | | | | | | | | X | | | | | | | | | |
| *Sicalis flaveola* | P | AA | | | 2 | X | X | X | X | 1,2,P+ | 8,11 | 2,6,13 | 6,13 | 6,1 | 3,4,7-12 | 4,5,8-12 | | 5,7-9 | 8 |
| *Haplospiza unicolor*$^{end}$ | P,C | MF | X | X | 1 | X | X | | | 1,6,P+ | | | | | | 2-4,7-12 | | 4,8,9 | 11 |
| *Hemithraupis ruficapilla*$^{end}$ | V | MF | X | | 1 | | | | | | | | | | | | | | |

| **Taxa** | **Evidence** | **Habitat** | **Bananal Ecological Station (Field trip)** | | | | | | | **Bananal region (historical and current data)** | **Bananal region (Field trip)** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | | **A** | **B1** | **B2** | **B3** | **B4** | **E1** | **E2** | **E3** | **E4** |
| *Volatinia jacarina* | V | AA,NF | X | | | | | | | X,P+ | 8 | 2,3,6,13 | 6,13 | 6,1 | 3,4,7-12 | 2 | | | |
| *Trichothraupis melanops* | R,P,C | MF | X | X | 6 | X | X | X | X | 1,2,P+ | | 6 | 13 | 6 | | 1,2,4,5,7-9,11,12 | 4 | 4,5,7-9 | 5,7 |
| *Coryphospingus pileatus* | V | AA | | | | | | | | 7 | | 2,6 | | | 4 | | | | |
| *Tachyphonus coronatus*$^{end}$ | P,C | MF | X | X | | X | X | | | 1,2, P+,R+ | 8,9,10 | 6,13 | | 6 | 3,7,8,10,12 | 1,3-5,7,12 | 4 | 4,5,7,8 | 7,8,11 |
| *Ramphocelus bresilius*$^{end}$ | V | AA | | | | | | | | X,P+ | | 1,6,13 | 11 | 6 | 7,8,10,12 | | | | |
| *Tersina viridis* | V | MF | | | | | X | | X | X,P+ | 8 | 1,6,13 | | | 4,5,7,8,12 | 8,11,12 | | | |
| *Dacnis cayana* | V | MF,AA | X | X | | X | X | | | X | | 6,13 | 11,1 | | 8 | 2,7,9,11,12 | | | 5 |
| *Coereba flaveola* | V,A | MF,AA | X | X | 1 | X | | | | 2,P+ | | 2,6,13 | 6,11,13 | 6,1 | 3-5,7-10,12 | 7,8,9,10,11,12 | | | |
| *Tiaris fuliginosus* | A | | | | | | | | | 5 | | 13 | | | | | | | |
| *Sporophila lineola* | V | AA,NF | X | | | | | | | P+ | 11 | 13 | 11 | | 4,8,9,11,12 | | | | |
| *Sporophila frontalis*$^{end}$ | A | MF | | | | | | | | | | | | | | 2 | | | |
| *Sporophila nigricollis* | V | AA,NF | X | | | X | | | | X | | | | | | | | | |
| *Sporophila caerulescens* | C | AA,NF | X | | | X | X | | X | 1,2,P+ | 8,11 | 2,3,6,13 | 13 | 13 | 3,4,7-9,11,12 | 2-4,8-12 | | 4,7,8 | 7,8,11 |
| *Sporophila leucoptera* | V,A | AA | | | | | | | | X,P+ | | 2,13 | 13 | 13 | 4,12 | | | | |
| *Sporophila angolensis*$^{\#}$ | C | AA,NF | | | | X | | | | 1,2,P+ | | 6,13 | | | 4 | 10 | | | |
| *Emberizoides herbicola* | V | AA,NF | | | | | | | | X,P+,R+ | | 6 | 13 | | 3,4,7 | | | | |
| *Saltator similis* | P | MF | X | X | 8 | X | X | | X | 1,2,P+ | 8,10 | 1,2,6 | | 6 | | 3-5,7-12 | 4 | 4,5,7,9 | 5,7,8 |
| *Saltator maxillosus*$^{end}$ | R | MF | | | | | | | | 1,P+,R+ | | | | | | 1-5,7,12 | 4 | | |
| *Saltator fuliginosus*$^{end}$ | R | MF | X | | 2 | | | | | 2 | | 2,13 | | | | 1-4,10,12 | | | |
| *Poospiza thoracica*$^{end}$ | V | MF | | | | | | | | 1,P+ | | | | | | 1,2 | | | |
| *Microspingus lateralis* | R,P,C | MF | X | X | 6 | | | | | 1,2,6,P+,R+ | 8 | | | | | 1-5,7-12 | | 5 | 5,8,11 |
| *Thlypopsis sordida* | V | MF | | | | | | | | 2,P+ | | 6,13 | | 6 | 3,5,7,9,12 | | | | |
| *Pyrrhocoma ruficeps*$^{end}$ | V | MF | | | | | | | | X | | | | | | | | 5,7,8 | |
| Cardinalidae (3) | | | | | | | | | | | | | | | | | | | |
| *Piranga flava* | V | MF | | | | | | | | P+ | | | | | | | | | |
| *Habia rubica* | V,A | MF | X | | | X | | | | X | | | | 6 | | | | 8 | |

| Taxa | Evidence | Habitat | Bananal Ecological Station (Field trip) | | | | | | | Bananal region (historical and current data) | Bananal region (Field trip) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | | A | B1 | B2 | B3 | B4 | E1 | E2 | E3 | E4 |
| *Cyanoloxia brissonii*$^{\#}$ | R | MF,AA | | | 1 | | X | | | X | | 2 | | | 7,9,10 | | | | 9 |
| Fringillidae (5) | | | | | | | | | | | | | | | | | | | |
| *Spinus magellanicus* | V | AA,NF | X | | | X | | | | 1,2,P+,R+ | | 6 | | 5 | 8,12 | 1-4,7,9-12 | | 5 | 11 |
| *Euphonia chlorotica* | A | MF | X | | | | | | | X,P+ | | 2,6,13 | 13 | 13 | | 4 | | | |
| *Euphonia violacea* | | | | | | | | | | X,R+ | | | | | | | | | |
| *Euphonia cyanocephala* | V | MF | | | | | | | | X | | | | | | | | | |
| *Euphonia pectoralis*$^{end}$ | A | MF | X | | 5 | X | X | | | 1,P+,R+ | | | | | | 1,37,9-12 | | 5,7,9 | 9 |
| Estrildidae (1) | | | | | | | | | | | | | | | | | | | |
| *Estrilda astrild* | V | AA | | | | | | | | X | | 6 | | | 9,11 | | | | |
| Passeridae (1) | | | | | | | | | | | | | | | | | | | |
| *Passer domesticus* | V | AA | | | | | | | | X,P+ | | 6 | 6 | 6 | 4,5,7-12 | | | | |

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ARTICLE

# Leukocyte profiles and body condition of free-living Burrowing Owls (*Athene cunicularia*) from rural and urban areas in the Argentinean Pampas

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**ABSTRACT:** Animals living in urban areas are exposed to novel and potentially stressful human disturbances. In response to the increased number of stressors in these habitats, they may manifest changes in their immune system, body condition and physiology. Many bird species are negatively impacted by urbanization, whilst other species thrive in urban areas. The capacity to adjust the physiological responses to the stressors associated with urban areas may play a key role in explaining the success of some bird species in these environments. In this study, we compared indicators of physiological stress response and body condition in free-living Burrowing Owls (*Athene cunicularia*) inhabiting urban and rural areas. We calculated a scaled index of body condition, and assessed leukocyte profiles and the heterophil/lymphocyte ratios of chicks and adults. We found no significant differences in these parameters between individuals from rural and urban areas. Chicks showed higher relative leukocyte counts than adults, which may be associated with ontogenetic development and immune system activation processes.

**KEY-WORDS:** heterophil, leukocyte, lymphocyte, stress, urbanization.

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## INTRODUCTION

With natural areas rapidly decreasing as human-altered habitats increase and human populations grow, bird species are finding themselves living ever closer to human habitats (Marzluff 2001). Some species have managed to co-exist with humans in urban areas while others failed to thrive in these new environments. Considering the rapid environmental change that occurs during urbanization, it may be predicted that only individuals capable of coping with challenges of urban life would succeed (Shanahan *et al.* 2014). Species living in urban habitats are exposed to many novel and potentially stressful anthropogenic disturbances, such as permanent presence of humans, higher densities of non-native predators (*e.g.*, cats and dogs), noise and light pollution as well as traffic (Sol *et al.* 2013). Such urban challenges are predicted to trigger physiological and behavioural reactions that ultimately increase the levels of stress responses (Partecke *et al.* 2006, Bonier *et al.* 2007, Bonier 2012, Johnstone *et al.* 2012). However, it is to be expected that if individuals are able to cope with different levels of urban disturbance, then living in urban contexts should not be perceived as more stressful than living in rural ones since a process involved in maintaining stability may occur (Wada 2015).

Two classes of hormones are involved in the modulation of physiological responses to stressors in vertebrates: catecholamines and glucocorticoids. The first involve the release of noradrenaline and adrenaline from the sympathetic nervous system and the adrenal medulla within seconds after detection of stressors, resulting in rapid physiological responses (Wada 2015). On the other hand, glucocorticoids are secreted through the hypothalamic-pituitary-adrenal axis and are mainly involved in recovery from stressors or preparing from future stressors. Glucocorticoids are secreted from adrenal cortex within minutes after detecting a stressor and acts redirecting energy and behavior to essential adjustments (Wada 2015). The release of glucocorticoid hormones after a stressor is one of the mechanisms involved in physiological coping mechanisms to long-term stress and, in vertebrates, is one of the mechanisms that ensure survival under adverse environmental conditions (Bonier 2012). However, prolonged or frequent stress responses can result in an individual entering a disease-like state of chronic stress leading to reduced fecundity and reduced chances of survival (Siegel 1980, Wingfield & Sapolsky 2003).

Measuring chronic physiological stress in free-living vertebrates can be problematic since reliable measurements of baseline levels of glucocorticoids are often difficult to obtain in the field because their levels rise immediately after capture (Davis 2005, Romero & Reed 2005). The use of haematological parameters such as relative leukocyte (or white blood cell) counts made from blood smears represents an alternative method for measuring stress in birds since their values are related to levels of glucocorticoids hormones such as corticosterone, the avian stress hormone (Davis *et al.* 2008). A prolonged increase of corticosterone levels in birds causes changes in the relative numbers of various specific leukocyte types present within the immune system. For example, in response to corticosterone, circulating lymphocytes adhere to the endothelial cells and subsequently a significant reduction in their circulating numbers is evidenced (Davis *et al.* 2008). Also, corticosterone stimulates an influx of heterophils (the avian equivalent of the mammalian neutrophils) into the blood from the bone marrow and attenuates the egress of heterophils from the blood to other compartments (see Davis *et al.* 2008).

Given the effect of stress hormones on leukocytes, leukocyte profiles and the heterophil/lymphocyte ratio have been widely used as indicators of response of individuals to several stressors such as temperature, muscular exhaustion, food or water deprivation, captivity and contaminants among others (Siegel & Gross 2000, Davis *et al.* 2008). Even though relative leukocyte ratios have been widely used as an estimator of long-term stress or baseline hormones levels (Davis *et al.* 2008), some studies have shown that in some avian species the handling stress can significantly affect leukocyte counts within 30 and 60 min after capture (Cirule *et al.* 2012), showing that leukocyte response to stress may be quicker than traditionally assumed. For this reason, the interval between bird capture and sample collection should be minimized to obtain a more precise estimation of baseline stress level. Also, Müller *et al.* (2011) found in free-living kestrel nestlings that baseline corticosterone levels and the heterophil/lymphocyte ratio differ in the sensitivity to various stressors suggesting that both measures should be taken when possible.

The Burrowing Owl (*Athene cunicularia*) is a ground-nesting raptor widely distributed throughout the mid to low latitude regions of Americas. Burrowing Owls' habitat has experienced important changes in the last decades due to human activities, such as agriculture, tourism and urbanization. It has been reported that some Burrowing Owl populations have been strongly affected by habitat change in its northern range, to the point of being considered as threatened in some areas of North America (Poulin *et al.* 2011). In contrast, at its southernmost distribution this species has managed to survive and prosper in urban habitats, often reaching higher densities in such heavily disturbed habitats than in their natural habitats (Martínez *et al.* 2017). Living in close proximity to humans presupposes a frequent exposure to anthropogenic stress factors, which Burrowing Owls have overcome mainly through behavioral plasticity (Cavalli *et al.* 2016a, 2016b).

The aim of this study was to compare leukocyte profile, the heterophil/lymphocyte ratio and body condition of Burrowing Owls inhabiting urban and rural habitats of southeastern Pampas region. Considering that Burrowing Owls showed no breeding and behavioural limitations to establish in urban habitats (Cavalli *et al.* 2016a, 2016b, Martínez *et al.* 2017) and have demonstrated a good ability to live in a wide variety of habitat types and with different levels of disturbance (Baladrón *et al.* 2016, Martínez *et al.* 2017), we hypothesize that this species presents good adaptability to live in urban areas and should not perceive urban habitats as more stressful than rural areas.

## METHODS

The study was conducted in the southeast portion of the Pampas region of Argentina. The area was dominated in the past by sand dunes, wetlands and grasslands (Vervoost 1967), and is nowadays a mosaic of different land-uses where agroecosystems (grazing fields, croplands, and pasturelands) and thriving urban centers share the landscape (Pedrana *et al.* 2008). Here, Burrowing Owls inhabit rural habitats, vegetated sand dunes, and urban habitats (Baladrón *et al.* 2016). Urban and rural habitats were sampled in Mar Chiquita district (37°44.6'S; 57°25.7'W) and General Pueyrredón district (38°00.8'S; 57°33.1'W). In these regions, urban habitat is mostly represented by peri-urban areas (small touristic villages with < 800 inhabitants and scattered houses) and, to a lesser extent, suburban areas of larger cities (Pedrana *et al.* 2008, Zelaya *et al.* 2016). Rural habitats are mostly devoted to livestock production, thus grazing fields are the dominant landscape unit, whereas croplands are limited to best-quality upland soils. In this context, we defined urban habitats as built-up areas where owls will regularly encounter humans and considered as urban owls those whose nests were surrounded by more than 35 houses within a radius of 200 m. Rural habitat comprised open farmlands, grazing fields, and croplands, and distance from owl nests to houses in rural habitats was always greater than 1 km.

Adults and chicks (~10 days old) from different nests were sampled during January 2014 and 2015. Burrowing Owls were captured with noose carpets (Bloom *et al.* 2007). Two researchers remain constantly watching traps with binoculars from a blind and run to handle owls immediately after they were trapped. Owls were weighed using a spring scale (d = 5 g, precision ± 0.3%). A preliminary inspection of each captured individual was performed in order to register health status. Health status of each individual was classified as healthy (*i.e.*, no external signs of illness based on the brightness of plumage, good flight capacity in adults owls, absence of feather damage from ectoparasites, and standard body mass: 198.5 ± 22.8 g for adults, Baladrón *et al.* 2015) or non-healthy (*i.e.*, missing feathers, presence of ectoparasites, below normal body mass), and only those of the former group were used for further analyses. A drop of blood was extracted from their brachial vein using 0.5 mm needles. Samples were collected within 5 min of capture to minimize capture and handling stress (Davis 2005). After collecting a blood sample and taking morphometric measurements, we released owls at the same place that they were captured. For all these procedures, we adhered to guidelines for the use of animals in research and to the legal requirements of Argentina (permit numbers: 2145-14331 and 22500-24871).

Thin smears from fresh blood were prepared on individual slides, air dried, fixed with methanol (Reagents, Inc.) for 10 min and then stained with May-Grünwald (BIOPUR®) and Giemsa (BIOPUR®). Smears were examined using a light microscope scanning monolayer fields with similar densities of erythrocytes for all individuals (Campbell 1994). The proportion of each leukocyte type was obtained from a sample of 100 leukocytes viewed in 1000× magnification (oil immersion) and expressed as percentage of basophils (B%), heterophils (H%), eosinophils (E%), lymphocytes (L%), and monocytes (M%) (Campbell 1994). The heterophil/lymphocyte ratio (H/L) was calculated from the leukocyte counts and was used as an indicator of stress (Davis *et al.* 2008). In general, higher H/L ratio values indicate higher levels of individual stress while lower values indicate the opposite. Relative leukocyte count (RLC) per 10,000 erythrocytes was estimated by counting the number of all erythrocytes in one microscopic visual field and multiplied by the number of the microscopic visual fields that were scanned until reaching 100 leukocytes, following Lobato *et al.* (2005).

Body mass (g) and tarsus length (mm, measured with a digital caliper) was measured to calculate a body condition index (Peig & Green 2009). Since both variables do not differ between Burrowing Owls sexes (see Baladrón *et al.* 2015) we pooled them indistinctly. To quantify body mass in relation to body size, we calculated a scaled mass index of body condition following the procedure described by Peig & Green (2009). The index was calculated as follows:

$$\text{Body mass of individual } i \times \left( \frac{\text{Average tarsus length of the study population}}{\text{Individual tarsus length of individual } i} \right) \text{bSMA}$$

The scaling exponent bSMA was calculated indirectly by dividing the slope from an ordinary least squares regression on log transformed tarsus length and body mass variables by the Pearson's correlation coefficient ($r$). We chose tarsus length as the proxy for skeletal body size as this measure has been routinely taken during all captures.

Leukocyte values were compared between owls from rural and urban habitats (only for adult owls since no chicks were captured at rural habitats) and between age groups (chicks and adults) using Student's $t$-test and the nonparametric Mann-Whitney test when data did not show a normal distribution. Normality was assessed by performing Shapiro-Wilk's test (Zar 2010). RLC was compared between habitats (rural and urban adult owls) and between age groups (chicks and adults) using Mann-Whitney test. Scaled mass index of body condition were compared between rural and urban adult owls by Student's $t$-test (Zar 2010). A part of the data used to calculate body condition belonged to a previous data set that was partly published by Baladrón *et al.* (2015), but none of the blood smears examined in this study were obtained from owls examined in that study.

## RESULTS

Relative leukocyte counts, H/L ratios and RLC showed no significant differences between rural and urban adult Burrowing Owls ($P > 0.05$, see Table 1). No significant difference was found between adult rural and urban Burrowing Owls in scaled mass index of body condition (mean urban owls = 205.5 g, SE = 3.8, $n = 42$; mean rural owls = 204.1 g, SE = 11.1, $n = 9$; $t = 0.15$, $df = 49$, $P = 0.88$). Only one adult owl from a rural habitat was excluded from our data set since it was classified as a non-healthy individual (missing feathers, body mass below the population mean: scaled mass index of body condition 149.7 g, had only one eye while the other showed infection signs evidenced by its color).

No significant differences were identified between age groups in heterophils (H), monocytes (M), basophiles (B) and relative leukocyte counts (RLC) ($P > 0.05$, see Table 2). Percentage of lymphocytes (L) was higher for chicks than for adult Burrowing Owls while percentage of eosinophils (E) was higher for adults (Table 2). The H/L ratio was higher for adult than for chick Burrowing Owls. Fig. 1 shows the morphology of erythrocytes, heterophils, eosinophils, lymphocytes, monocytes and thrombocytes.

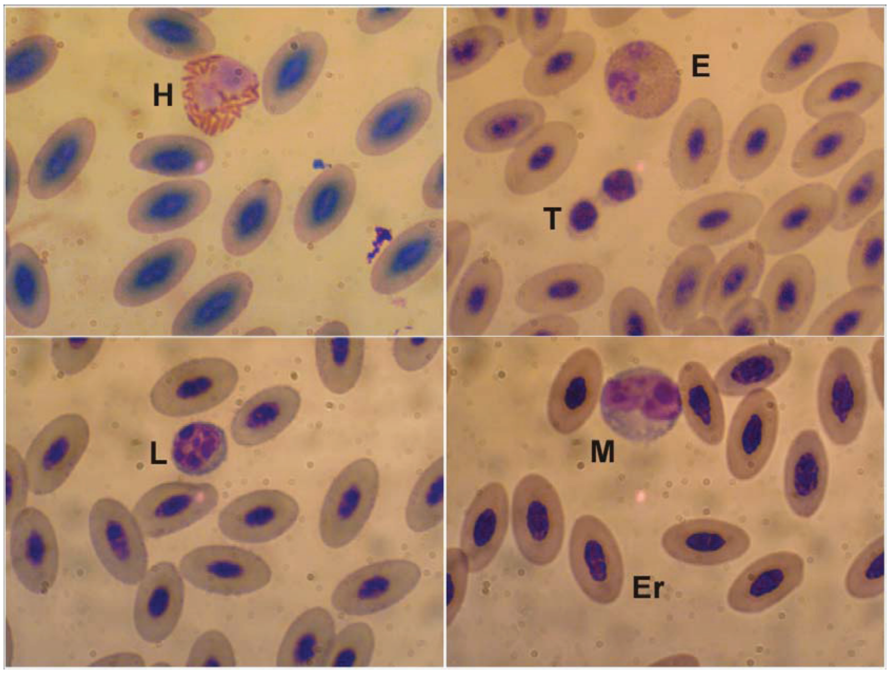

**Figure 1.** Burrowing Owl (*Athene cunicularia*) blood smears. Erythrocytes (Er), thrombocytes (T), heterophils (H), lymphocytes (L), eosinophils (E) and monocytes (M). × 100 objective.

**Table 1.** Mean ± standard error (SE), range (minimum – maximum) of relative leukocyte counts, relative leukocyte count (RLC) and heterophil/lymphocyte ratio (H/L) from rural and urban adult Burrowing Owls (*Athene cunicularia*) from southeast of Pampas region in Argentina. Sample size (n) is shown in parentheses. Leukocyte types are expressed as percentage of heterophils (H%), lymphocytes (L%), monocytes (M%), basophils (B%) and eosinophils (E%).

| | **Rural (*n* = 4)** | | **Urban (*n* = 11)** | | **Statistical test** | ***P*-values** |
|---|---|---|---|---|---|---|
| | **Mean ± SE** | **Range** | **Mean ± SE** | **Range** | | |
| H% | 36.1 ± 0.4 | 33.6 – 37.1 | 37.5 ± 3.6 | 19.0 – 61.4 | *t* = - 0.2 | 0.81 |
| L% | 40.3 ± 0.7 | 38.9 – 42.0 | 35.7 ± 1.9 | 25.8 – 47.6 | *t* = 1.3 | 0.13 |
| M% | 1.0 ± 0.7 | 0.88 – 3.1 | 0.9 ± 0.3 | 0.75 – 3.3 | *U* = 21 | 0.94 |
| B% | 0.2 ± 0.2 | 0.0 – 0.7 | 0.1 ± 0.1 | 0.0 – 1.7 | *U* = 19 | 0.58 |
| E% | 22.3 ± 1.9 | 18.1 – 27.2 | 25.5 ± 2.6 | 15.3 – 37.1 | *U* = 27 | 0.55 |
| H/L | 0.9 ± 0.02 | 0.8 – 0.9 | 1.1 ± 0.1 | 0.4 – 1.5 | *U* = 29 | 0.39 |
| RLC | 94.5 ± 25.2 | 121.0 – 160.0 | 91.0 ± 9.5 | 59.0 – 132.0 | *U* = 23.5 | 1.00 |

**Table 2.** Mean ± standard error (SE), range (minimum – maximum) of relative leukocyte counts, relative leukocyte count (RLC) and heterophil/lymphocyte ratio (H/L) from chick and adult Burrowing Owls (*Athene cunicularia*) from southeast of Pampas region in Argentina. Sample size (*n*) is shown in parentheses. Leukocyte types are expressed as percentage of heterophils (H%), lymphocytes (L%), monocytes (M%), basophils (B%) and eosinophils (E%).

| | **Chicks (*n* = 10)** | | **Adults (*n* = 15)** | | **Statistical test** | ***P*-values** |
|---|---|---|---|---|---|---|
| | **Mean ± SE** | **Range** | **Mean ± SE** | **Range** | | |
| H% | 34.3 ± 2.2 | 27.3 – 46.4 | 37.2 ± 2.5 | 19.0 – 61.4 | *U* = 91 | 0.36 |
| L% | 51.9 ± 2.3 | 39.5 – 63.0 | 36.9 ± 1.5 | 25.8 – 47.6 | *t* = -5.6 | <0.001 |
| M% | 0.5 ± 0.2 | 0.0 – 1.4 | 0.9 ± 0.3 | 0.0 – 3.3 | *U* = 82 | 0.69 |
| B% | 0.0 ± 0.0 | 0.0 – 0.0 | 0.2 ± 0.1 | 0.0 – 1.6 | *U* = 85 | 0.26 |
| E% | 13.3 ± 2.3 | 6.0 – 27.2 | 24.7 ± 1.9 | 12.9 – 37.1 | *t* = 3.7 | 0.001 |
| H/L | 0.6 ± 0.1 | 0.5 – 1.0 | 1.1 ± 0.1 | 0.4 – 2.4 | *U* = 120 | 0.01 |
| RLC | 76.6 ± 7.1 | 48.0 – 127.0 | 92.0 ± 9.3 | 39.0 – 160.0 | *U* = 96.5 | 0.24 |

## DISCUSSION

Animals often respond to the challenges found in urban areas through changes in their body condition and physiological stress responses (Davis *et al.* 2008). The magnitude and prevalence of stress levels may vary according to the species and its tolerance to the different stressor agents associated to urban life (*i.e.*, if it is an avoider, adaptable or exploiter of urban areas; Blair 1996, McKinney 2002). Our results show that leukocyte profiles and the body condition of wild Burrowing Owls did not differ significantly between urban and rural habitats, corroborating the notion that this is an urban-adaptable species. This finding is similar to that reported for other urban-exploiter such as House Sparrows (*Passer domesticus*). Urban and rural House Sparrows have been show to display similar levels of stress hormones (Bókony *et al.* 2012) and their immunological status does not vary among urbanization levels (Chávez-Zichinelli *et al.* 2010). However, the range of indicators of physiological stress response (immunoglobulin and corticosterone concentrations) is wider in habitats with more stressful stimuli. In line with this idea, we found that urban areas housed both high- and low-stressed owls, as relative counts for all leukocyte types showed wider ranges in urban areas in comparison to rural areas.

In addition, we found that the heterophil-lymphocyte (H/L) ratio, a parameter widely used as indicators of stress response, does not differ between urban and rural Burrowing Owls. This is similar to the pattern reported by Fokidis *et al.* (2008) for the Northern Mockingbird (*Mimus polyglottos*), which is also an urban-adaptable species. However, these authors also reported the same for the Curve-billed Thrasher (*Toxostoma curvirostre*), an urban avoider species. This suggests that the ability to cope with human stressors in urban habitats might be associated with intrinsic characteristics of each species and with its capacity to adapt to new environmental conditions, or alternately it could be interpreted as indicating that the physiological responses to urban stressors might not necessarily involve substantial changes to the H/L ratio.

Even though leukocyte counts and the H/L ratio are considered reliable stress indicators in birds (Davis *et al.* 2008), some authors argue that these variables should be interpreted cautiously since they may vary in response to inflammatory or infectious processes. In this sense, it has been suggested that the H/L ratio should be considered a complementary measure to the corticosterone level in blood and that these parameters are not interchangeable (Müller *et al.* 2011). Regarding this, it would be interesting to incorporate corticosterone level information into future studies comparing physiological stress between urban and rural owls. Rebolo-Ifrán *et al.* (2015) recently reported that feathers from urban and rural Burrowing Owls showed similar values of corticosterone, suggesting that life in urban settings might not represent an additional source of stress for individuals living in this environment.

The percentage of eosinophils we observed in circulating blood was similar between owls from rural and urban habitats and, in both habitats, values were higher than the typical reported for birds in general (*e.g.*, E% = 2.5 – 5.6; Davis *et al.* 2008). This type of cell is strongly associated with helminth parasite load and activity (Johnstone *et al.* 2012). However, the high counts of eosinophils observed for Burrowing Owls in our study is consistent with numbers reported for most healthy raptor species studied to date (Copete-Sierra 2013). In addition, the low percentages of other leukocyte types, such as monocytes (associated with defense against infections and bacteria) and basophils (associated with inflammatory processes) (Campbell 1994), support the idea that the Burrowing Owls examined in this study were healthy.

We found that chicks and adult Burrowing Owls showed differences in relative leukocyte counts, which could be explained by different developmental stages of the immune system in young Burrowing Owls. The thymus and bursa are proportionally up to 10 times larger in chicks than in adults, and lymphocytes are naturally more abundant in earlier stages of development (Maxwell & Robertson 1998). As chicks grow, the number of lymphocyte cells decrease and the thymus and bursa decrease in size (Maxwell & Robertson 1998, Dunbar *et al.* 2005). For these reasons, even though the H/L ratio has been considered a reliable index to determine individual physiological condition and a stress indicator (Maxwell & Robertson 1998, Davis *et al.* 2008), the differences observed in Burrowing Owls' H/L ratio between ages is probably related to the ontogenetic development rather than to a difference in how they respond to stress situations.

In summary, our study indicates that urban Burrowing Owls show similar relative leukocyte counts, H/L ratios, and body condition than rural individuals. Even when such similarity may be influenced by the analytical tool employed (*e.g.*, another parameter different of H/L ratio and RLC should have been used) or the limited sample (*e.g.*, a relatively small number of rural individuals was sampled), our findings suggest that living in urban habitats might not significantly affect the haematological parameters of Burrowing Owls.

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SHORT-COMMUNICATION

# Diet of the Spectacled Owl (*Pulsatrix perspicillata*) in Zapotillo, southwestern Ecuador

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**ABSTRACT:** We describe the diet of the Spectacled Owl (*Pulsatrix perspicillata*) based on the collection and analysis of pellets between 20 to 24 December 2016, from a reproductive territory located in Zapotillo, southwestern Ecuador. Mammals were the main food source of the species, accounting for 80% of the identified prey items and 94% of the biomass. Other taxonomic groups, such as amphibians, reptiles and crabs were also identified. Based on our results and the existing observations, *P. perspicillata* consumed a big amount of arboreal prey or those that are located at medium height within the forest. This may be due to their hunting habits, the abundance of available prey or a combination of both. Our observation is the first to document the diet of the subspecies *P. perspiciliata chapmani*, and increases scarce knowledge about the trophic ecology of this species.

**KEY-WORDS:** owls, pellets, prey, trophic ecology, tropical dry forest.

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One of the most important natural history observations to understand the ecology of a species is the knowledge of its diet, especially the taxonomy of the ingested prey (Pardiñas & Cirignoli 2002, Cadena-Ortiz *et al.* 2011). Knowing the diet of a species helps to determine, among other aspects, its intra and interspecific relationships (Marti *et al.* 1993). Nevertheless, study of the trophic ecology of birds faces methodological limitations, such as the difficulty in identifying the consumed prey (Rosenberg & Cooper 1990) and in nocturnal species, their stealth behavior and difficulty of detection, further complicate this type of research (Karr *et al.* 1990).

The level of knowledge about owls (Strigidae) in the Neotropics and even more so in Ecuador remains low (Enríquez *et al.* 2006, Freile *et al.* 2012, 2017), although there is information about their distribution and habitat, information on the ecological aspects such as behavior and trophic niche are deficient (Cadena-Ortiz *et al.* 2013).

*Pulsatrix perspicillata* (Latham, 1790) is distributed from southern Mexico and Central America, to northern Argentina (König & Weick 2008). In Ecuador it is distributed in the lowlands to the east and west of the Andes, primarily under the 1000 m a.s.l. (Ridgely & Greenfield 2001, Freile *et al.* 2017). With two subspecies, *Pulsatrix perspicillata chapmani* (Griscom, 1932) occupies west of the Andes, and *Pulsatrix perspicillata perspicillata* (Latham, 1790) occupies the east of the mountain range (McMullan & Navarrete 2017). This species inhabits the dense rainforest, savanna forests, and tropical dry forest, as well as areas with scattered trees, coffee plantations, and forest galleries (Holt *et al.* 2017). These authors suggest that their populations are numerous, but there is scarce information on their abundance, population ecology, and behavior. The Spectacled Owl is a species with nocturnal activity, although it can occasionally be found on cloudy days, where it usually rests on leafy trees at banks of streams or near bodies of water, at medium height with dense foliage (König & Weick 2008).

Knowledge about the diet of *P. perspicillata* is mentioned in some field guides (*e.g.*, Stiles & Skutch 1989, Sick 1993, König & Weick 2008), on the online database (Holt *et al.* 2017), and report data of prey published in Panama (Voirin *et al.* 2009), Brazil (Carvalho *et al.* 2011), and Ecuador (Cadena-Ortiz *et al.* 2013, Daza *et al.* 2017). There is a single detailed study based on pellets of the Mexican subspecies *P. perspicillata saturata* (Silva *et al.* 1997), but information is lacking for the rest of its distribution. However, the subspecies of our study, *P. perspicillata chapmani*, is distributed throughout the Caribbean from Costa Rica, eastern Panama to Colombia, western Ecuador and northwestern Peru (Holt *et al.* 2017). This subespcies lacks detailed studies and only occurrence records are available (Voirin *et al.* 2009, Cadena-Ortiz *et al.* 2013).

In this study, we present information on the diet of *P. p. chapmani* in southwestern Ecuador, based on the analysis of pellets in a reproductive territory. The purpose of this study was to identify its main prey in pellets in the tropical dry forest and thus, widen the knowledge about its diet. This is the second detailed study on the trophic ecology of this species and the first of the subspecies *P. p. chapmani*.

We collected pellets from a breeding territory of *P. p. chapmani* located in Zapotillo, southwest of Ecuador (4°07'S; 80°20'W, 481 m a.s.l.), between 20 to 24 December 2016, corresponding to the dry season (Maldonado 2002). The nest of a family, composed by two adults and one fledgling (Fig. 1A), was located in a *Ficus* sp. tree, about 4.5 m height in an area with steep slopes and a few meters from a ravine with permanent water. The type of forest corresponds to dry semi-deciduous forest (Cueva & Chalán 2010). The forest is patchy with discontinuous clearings, natural or induced, and the presence of isolated trees. Characteristic species of this type of vegetation are Ceiba (*Ceiba trichistandra* (A. Gray) Bakh.), Guayacan (*Tabebuia chrysantha* G. Nicholson), Laurel (*Cordia macrantha* Chodat), and Pretino (*Cavanillesia platanifolia* (Bonpl.) Kunth), among others (Fig. 1B) (Cueva & Chalán 2010).

The analysis of the pellets was performed in the laboratory, where we measured the length and width of each pellets with a Stainless Hardened digital caliper (precision ± 0.01 mm), and dry mass using a Sartorius LA-230P precision balance. We analyzed the pellets and separated the elements according to their identification and quantification (Marti *et al.* 2007).

The analyzed material in pellets was separated according to the taxonomic groups to which they belonged and later classified at the species level. The minimum number of individuals consumed (MNI), was determined by counting homologous mandibles and discarding the other skeletal remains to avoid recounting (Manning & Jones-Jr. 1990), except for *Hypolobocera aequatorialis* (Ortmann, 1897) (Decapoda) which was identified by carapace remains. To calculate the biomass, the average mass of the species consumed was multiplied by the MNI of the species (Herrera & Jaksic 1980). The different food components were identified using available guides (Brito *et al.* 2016, Torres-Carvajal *et al.* 2016, Ron *et al.* 2017) and comparisons were made with reference material deposited in the Museum of the Escuela Politécnica Nacional (MEPN).

The nine pellets samples were of the following sizes: length (mean = 44 mm, range = 34 – 59 mm), width (mean = 21 mm, range = 13 – 33 mm), mass (mean = 4.3 g, range = 2.4 – 8.5 g). There were 15 prey items belonging to four taxonomic classes: Mammalia (3 sp.), Reptilia (1 sp.), Amphibia (1 sp.) and Malacostraca (1 sp.), (Table 1). The body mass of prey varied from *Stenocercus puyango* Torres-Carvajal, 2005 (Reptilia) (13 g) to *Proechimys decumanus* Thomas, 1899 (Mammalia) (285 g).

Mammals were recorded in 100% of the dissected pellets and were the main prey group, both in the minimum number of individuals consumed (80%) and in biomass (93.6%) (Fig. 2). The consumption of amphibians, reptiles, and crustaceans was similar. The most consumed species was the rodent *Rhipidomys leucodactylus* (Tschudi, 1845) and the marsupial *Marmosa simonsi* Thomas, 1899, with six and five individuals respectively (Table 1). For biomass, species that contributed most was *R. leucodactylus* with 53.6%. The absence of birds and invertebrates in their diet is striking,

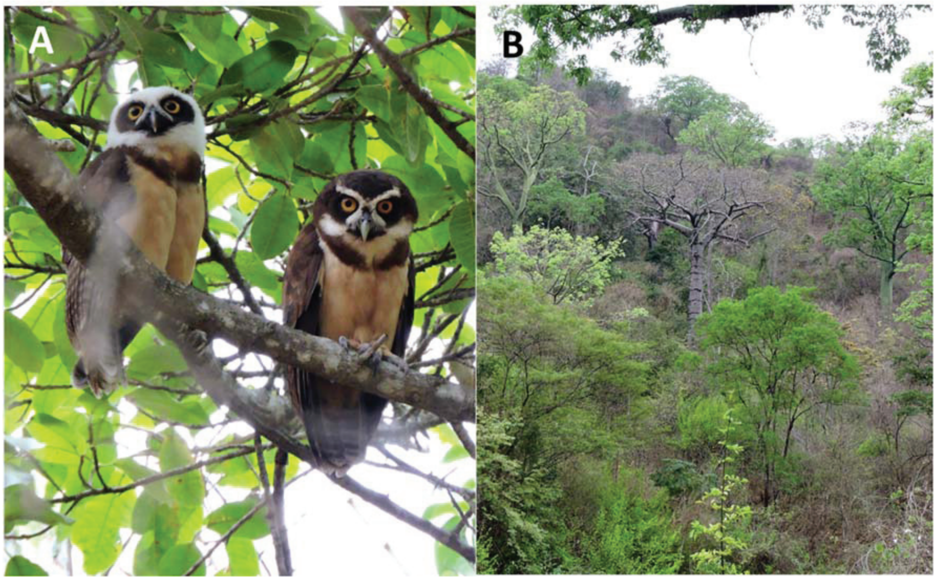

**Figure 1.** Young (left) of Spectacled Owl *Pulsatrix perspicillata chapmani* next to an adult (right), in Zapotillo, southwestern Ecuador (**A**). Typical ecosystem where the study of the diet of the Spectacled Owl was carried out (**B**). Photo author: A. Orihuela-Torres.

except the observation of *H. aequatorialis* (Decapoda).

According to previous information published on the diet of *P. perspicillata* (Stiles & Skutch 1989, Sick 1993, Silva *et al.* 1997, König & Weick 2008, Holt *et al.* 2017), their main prey are mammals. This is further corroborated by our findings, in which mammals contributed almost all the biomass (93.6%). One of the most abundant prey items was *M. simonsi* (MNI = 33.3%, B = 22%), a nocturnal marsupial with arboreal habits (Rossi *et al.* 2010, Astúa 2015). This genus, belonging to the family Didelphidae, is very common in the diet of *P. perspicillata* (Silva *et al.* 1997, König & Weick 2008, Holt *et al.* 2017). The other most abundant species was *R. leucodactylus*, a rodent of nocturnal and arboreal habits (Tribe 2015, Tirira 2017), which contributed with 53.6% in biomass. The only mammalian prey species with primarily terrestrial habits was the Pacific Spiny Rat *P. decumanus* (Tirira 2017).

In Mexico, Silva *et al.* (1997) showed a greater intake of *P. perspicillata* for a semi arboreal rat (*Tylomys nudicaudus* Peters, 1866). It appears that *P. perspiciliata* hunts preferentially over arboreal prey or prey located in the middle stratum of the forest (Silva *et al.* 1997), although it can occasionally hunts terrestrial prey. Additional studies will be required to determine if this intake can be attributed to hunting habits, the availability

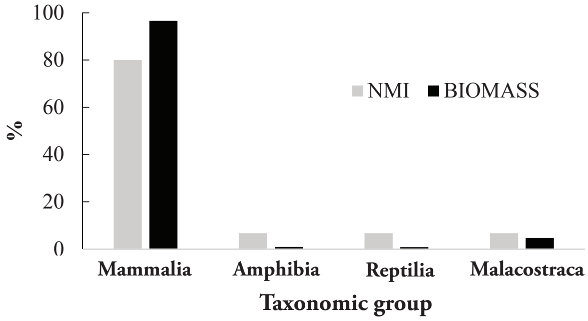

**Figure 2.** Minimum number of individuals consumed (MNI%) and biomass consumed (B%) in the diet of *Pulsatrix perspicillata chapmani* in a breeding territory of Zapotillo, southwestern Ecuador.

**Table 1.** Composition of the diet of *Pulsatrix perspicillata chapmani* in a breeding territory of Zapotillo, southwestern Ecuador. The mass of each species is shown (Mass, in g), the number of individuals and their percentage (MNI, in %), the total biomass in grams and the percentage (Biomass, in %).

| Taxa | Mass (g) | MNI (%) | Biomass (%) |
|---|---|---|---|
| Mammalia | | 12 (80) | 1487 (93.6) |
| Didelphimorphia | | | |
| Didelphidae | | | |
| *Marmosa simonsi* | 70 | 5 (33.3) | 350 (22.0) |
| Rodentia | | | |
| Cricetidae | | | |
| *Rhipidomys leucodactylus* | 142 | 6 (40) | 852 (53.6) |
| Echyimidae | | | |
| *Proechimys decumanus* | 285 | 1 (6.7) | 285 (18.0) |
| Amphibia | | 1 (6.7) | 14 (0.9) |
| Anura | | | |
| Hylidae | | | |
| *Trachycephalus quadrangulum* | 14 | 1 (6.7) | 14 (0.9) |
| Reptilia | | 1 (6.7) | 13 (0.8) |
| Squamata: Sauria | | | |
| Tropiduridae | | | |
| *Stenocercus puyango* | 13 | 1 (6.7) | 13 (0.8) |
| Malacostraca | | 1 (6.7) | 75 (4.7) |
| Decapoda | | | |
| Pseudothelphusidae | | | |
| *Hypolobocera aequatorialis* | 75 | 1 (6.7) | 75 (4.7) |
| **Total** | | **15** | **1589** |

of prey, or a combination of both. Voirin *et al.* (2009) reported the attack of *P. perspicillata* on a *Bradypus variegatus* Schinz, 1825 (Mammalia) when it descended to the ground to defecate. These attacks are not common in owls, as they usually swallow their whole prey and therefore do not consume prey greater than their own body mass (Marti 1974). However, it evidences that the species effectively exploits every opportunity to get food.

The absence of birds and insects in our study may be biased due to the small sample size. Although, we found a small proportion of crustaceans, similar to those reported in other studies (Silva *et al.* 1997, König & Weick 2008, Holt *et al.* 2017). As far as we know, the record of the anuran *Trachycephalus quadrangulum* (Peters, 1867) constitutes the first evidence of amphibian consumption within the diet of the Spectacled Owl.

In the two specific reports on the diet of *P. perspicillata* in Ecuador (Cadena-Ortiz *et al.* 2013, Daza *et al.* 2017), only reptiles are documented. In our study, reptiles were represented by *S. puyango*, a common species in the tropical dry forest of southwestern Ecuador (Yánez-Muñoz *et al.* 2016). A report of the diet of its congener *Pulsatrix melanota* (Tschudi, 1844) in Ecuador showed differences in the diet of these species, in this case, only arthropods appeared in the stomach contents (Cadena-Ortiz *et al.* 2011). However, the sample sizes were small in these reports and are unable to represent the changes in diet due to the availability of food throughout the year, the breeding and non-breeding season and other environmental conditions.

Although the study by Silva *et al.* (1997) was carried out in Mexico on another subspecies (*P. perspicillata saturata*), in another season (rainy season) and with a small sample size (19 pellets), it showed important similarities with our study. In both cases, mammals were the main prey and Didelphidae played an important role in their diet, constituting themselves as a potential prey for this nocturnal raptor throughout its range of distribution.

Owing to the limited knowledge about owls in the Neotropics (Enríquez 2017), this type of study is of particular importance, as it will allow us to understand the role of these cryptic species in their environment, and to better understand how organisms interact. Trophic ecology is a fundamental element to understand this complex and important group of birds and contribute to their conservation.

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ARTICLE

# Rapid southward and upward range expansion of a tropical songbird, the Thrush-like Wren (*Campylorhynchus turdinus*), in South America: a consequence of habitat or climate change?

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**ABSTRACT:** The Thrush-like Wren (*Campylorhynchus turdinus*) is a polytypic, non-migratory, cooperatively breeding species of bird widely distributed in central South America. In recent decades it has expanded its range by approximately 24%, based on a published map of its distribution in the mid-1980s and recent reports submitted to eBird up through March 2017. The northwestern subspecies, *C. t. hypostictus*, dramatically expanded its elevation range upward from approximately 1200 m to 4200 m a.s.l. in the Peruvian Andes. During 1977–2015 the southwestern subspecies, *C. t. unicolor*, dramatically expanded the southern border of its range from central Brazil and northern Paraguay (approximately 22°06'S) southward into northeastern Argentina and throughout Paraguay to 29°40'S in southeastern Brazil, extending its range east-southeast approximately 934 km at a rate of 24.6 km/yr, and latitudinally southward 838 km at a rate of 22.1 km/yr. It also expanded its range westward into the relatively dry Chaco of western Paraguay and north-central Argentina. Midwinter records near the southern border of its range in northeastern Argentina suggest it is non-migratory. Because of its affinity for disturbed habitats, its range expansion has been attributed to deforestation, but its range expansion is also consistent with the prediction that organisms are extending their geographic distribution toward higher latitudes and elevations as a consequence of climate change.

**KEY-WORDS:** Argentina, Brazil, Colombia, distribution, elevation, global warming, Paraguay, Peru.

## INTRODUCTION

Because birds are abundant and conspicuous organisms that can be easily monitored, they represent ideal bellwethers for the impacts of anthropogenic habitat change and climate change on biodiversity (Morrison 1986, Hutto 1998). Short-term changes in the distributional ranges of birds are usually caused by stochastic population fluctuations or habitat change, but may also be attributed to climate change (Parmesan & Yohe 2003, Root *et al.* 2003, Hickling *et al.* 2006, Parmesan 2006, Chen *et al.* 2011). Birds may respond to recent increases in temperature and changes in precipitation by either attempting to adapt to changes *in situ* or by spatially shifting their distribution to areas with more optimal conditions (Huntley *et al.* 2006). Distributional shifts toward higher latitudes and elevations, in concert with phenological shifts toward earlier breeding, occur globally across a wide array of taxonomic groups, providing a fingerprint of climate change (Parmesan & Yohe 2003, Root *et al.* 2003, Hickling *et al.* 2006, Parmesan 2006, Chen *et al.* 2011). For example, analyses of the breeding ranges of birds in the temperate northern hemisphere reveal that they are shifting northward at an average rate of 2.4 km/year in North America (Hitch & Leberg 2007), 1.6 km/year in Finland (Brommer 2004), and 1.0 km/year in Britain (Thomas & Lennon 1999). The winter ranges of temperate North American birds are also shifting northward at an average rate of about 1.5 km/year (La Sorte & Thompson-III 2007).

Distributional range shifts by birds in the southern hemisphere are not as well documented, but many species of birds in South Africa and some in Australia appear to be rapidly expanding their ranges southward (Chambers *et al.* 2005, Olsen 2007, Hockey *et al.* 2011). In South America, several tropical bird species appear to be rapidly expanding their ranges southward into subtropical Argentina, Paraguay, and Brazil (*e.g.*, Straube *et al.* 2006, 2007, Piacentini *et al.* 2009, del Castillo *et al.* 2012, Pagano & Bodrati 2017). And several species of birds appear to be rapidly expanding their ranges upward in elevation in the Andes (*e.g.*, Henry 2005, 2012, Solano-Ugalde & Real-Jibaja 2010, Gibbons *et al.* 2011, Avendaño *et al.* 2013). The driver of such rapid changes in bird distribution in South America is usually attributed to habitat change, even though such changes are predicted by a warming climate (Parmesan & Yohe 2003, Root *et al.* 2003, Hickling *et al.* 2006, Parmesan 2006, Jetz *et al.* 2007, Chen *et al.* 2011). More detailed analyses of individual species are needed to assess the validity of claims that distributional ranges are shifting toward higher latitudes and elevations, and to document the rate of change. In this paper we document unusually rapid range expansion, both southward and upward in elevation, in a tropical songbird, providing evidence that climate change in addition to (or instead of) habitat change may be accelerating its range expansion.

## METHODS

### Study subject

The Thrush-like Wren (*Campylorhynchus turdinus*) is a polytypic species of the avian family Troglodytidae with three distinct subspecies inhabiting tropical South America (Hellmayr 1934, Ridgely & Tudor 1989, Kroodsma & Brewer 2005). The northwestern subspecies, *C. t. hypostictus*, occurs from the east slope of the Andes of Colombia, Ecuador, Peru, and northern Bolivia eastward through Amazonian Brazil. The southwestern subspecies, *C. t. unicolor*, occurs in the lowlands of Bolivia, Paraguay, and southwestern Brazil (Ridgely & Tudor 1989, Kroodsma & Brewer 2005), but has recently expanded its range southward into northern Argentina (Contreras & Contreras 1986) and southeastern Brazil (Bencke *et al.* 2008). The eastern subspecies, nominate *C. t. turdinus*, occurs in a disjunct population along the coast of eastern Brazil.

### Data gathering

To document the southward and upward range expansion of *C. turdinus*, we reviewed published distributional records and unpublished reports submitted to eBird (ebird.org) through mid-March 2017. The latitude and longitude of each location were obtained from the original source or, if absent, estimated by consulting either an ornithological gazetteer for each country (Paynter-Jr. & Traylor 1981, 1991, Stephens & Traylor-Jr. 1983, Paynter-Jr. 1985, 1989) or Google Earth (www.google.com/earth). The elevation of each location was obtained from the original source. Using ArcGIS software (www.arcgis.com), we constructed maps and calculated the area (km$^2$) of its range in the 1980s, based on Ridgely & Tudor (1989), and the area of its current range, based on reports submitted to eBird through March 2017 plus the southernmost record published by Vargas-Peixoto & Bosholn (2016). Google Earth was used to measure the rate of range expansion as a straight line between two points and in a southward line between degrees of latitude.

## RESULTS

A comparison of the past and present ranges of *C. turdinus* revealed that its range has expanded by about 24% (Fig. 1), from approximately 4,329,243 km$^2$ in the mid-1980s (Ridgely & Tudor 1989) to approximately 5,671,727 km$^2$ by March 2017 (eBird). In the following accounts we describe its range expansion by country.

### Colombia

Although the northwestern subspecies, *C. t. hypostictus*, has not expanded its range northward, it has expanded its range northeastward along the Inírida River and Guaviare River in Guaviare (eBird; Fig. 1). The northeasternmost record is from Guainía-Puerto Inírida (04°01'S; 67°45'W), only about 5 km west of the Venezuelan border, on 24 August 2016 (Valerie La May, Marie Lister & Warren Stevens in eBird).

### Peru

The northwestern subspecies, *C. t. hypostictus*, has expanded its range westward up into the Peruvian Andes. Fjeldså & Krabbe (1990) did not include it in their book on birds of the Andes because it had not been recorded in the temperate zone above 2300 m a.s.l. Ridgely & Tudor (1989) reported its maximum elevation range along the east slopes of the Andes as 1200 m a.s.l., which was repeated by Clements & Shany (2001). In 1998, Hornbuckle (1999) reported it at a site with an elevation range of 1300–1600 m a.s.l. east of Abra Patricia Pass, San Martín (05°41'S; 77°41'W), which may account for Kroodsma & Brewer (2005) reporting its maximum elevation as 1300 m a.s.l. Schulenberg *et al.* (2007) reported it occurring up to 1500 m a.s.l. In 2009, Robbins *et al.* (2011) observed it at an elevation of about 1700 m a.s.l. at Alto Materiato, Cusco (12°42'S; 72°53'W). It has now expanded its distribution dramatically upward to well over 3000 m a.s.l. in Cusco (several 2016 records in eBird), with a maximum elevation of about 4200 m a.s.l. at ACP Ábra Málaga Thastayoc, Cusco (13°09'S; 72°18'W), on 18 October 2014 (Celeste Morien in eBird).

### Paraguay

The first record of *C. turdinus* in Paraguay was a specimen collected in 1928 on the west bank of the upper Paraguay

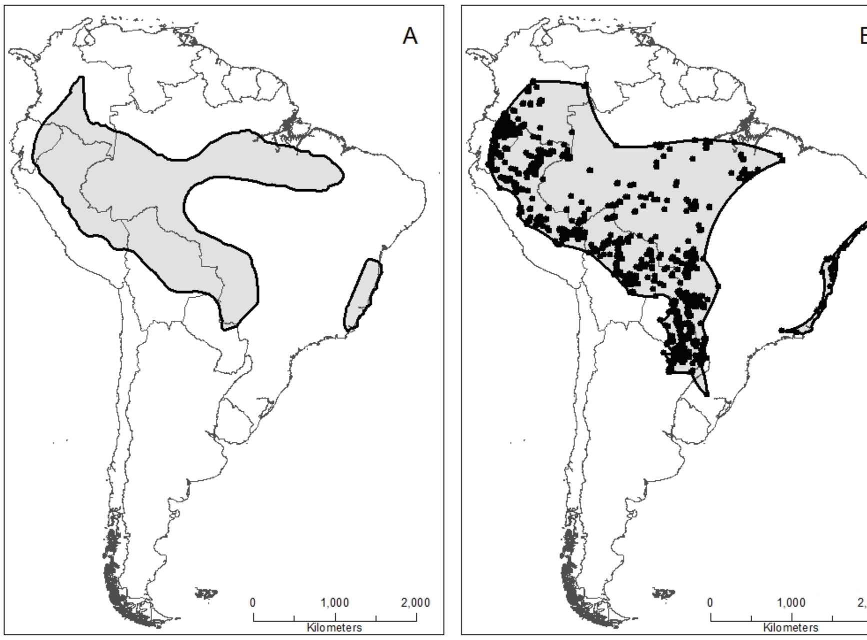

**Figure 1.** The known distribution of the Thrush-like Wren (*Campylorhynchus turdinus*) in the mid-1980s (**A**), based on Ridgely & Tudor (1989), and in February 2017 (**B**), based on observations reported to eBird (ebird.org) and Vargas-Peixoto & Bosholn (2016).

River at Puerto Guaraní in southeastern Alto Paraguay (21°17'S; 57°55'W; Zotta 1940). Given the paucity of specimen records at the time from the upper Paraguay River region, it remains uncertain whether the specimen was within the ancestral range of the species or represented an actively expanding population.

In July 1977, Robert Ridgely observed several along the Apa River in northern Concepción (Ridgely & Tudor 1989). The specific locality was not reported, so we assume it was in the vicinity of San Lázaro in northwestern Concepción (22°06'S; 57°58'W), which was relatively accessible at the time. By 1988 and 1989 *C. turdinus* had become common along both banks of the Paraguay River as far south as Puerto Militar (formerly Villa Militar) in northeastern Presidente Hayes (23°24'S; 57°28'W) and Concepción in western Concepción (23°24'S; 57°26'W; Hayes *et al.* 1990). Nesting was subsequently confirmed at Puerto Militar in 1991 (Contreras *et al.* 1993). Because no *C. turdinus* had been collected during extensive field work resulting in the collection of perhaps more than a thousand bird specimens in southeastern Alto Paraguay (*e.g.*, Puerto La Victoria, formerly Puerto Casado; 22°17'S; 57°57'W), northeastern Presidente Hayes (*e.g.*, Puerto Pinasco; 22°43'S; 57°57'W), and northern Concepción (*e.g.*, Apa River; 22°05'S) up through 1945 (Paynter-Jr. 1989, Hayes 1995), all records south of 22°S almost certainly represented a subsequent range expansion rather than a previously undetected population.

In 1986 a specimen was collected 140 km west of the Paraguay River at Pozo Colorado in central Presidente Hayes (23°25'S; 58°50'W; Contreras & Contreras 1986), in a region of the Paraguayan Chaco where a few thousand bird specimens, but none of *C. turdinus*, had been collected prior to 1975 (Hayes 1995). Numerous individuals were seen in the area, indicating a population had recently become established. The first record for southern Presidente Hayes occurred at Estancia La Golondrina (24°59'S; 57°43'W) during 6–9 November 1995 (James Lowen). It is now widespread throughout the eastern Paraguayan Chaco (eBird).

On 16 July 1993, one was observed on the east side of the Paraguay River 5 km east of Villeta in western Central (25°30'S; 57°31'W; Contreras *et al.* 1993), providing the first record for southern Paraguay. The first for Bahía de Asunción, Central, which had been frequently visited by ornithologists since 1987, was noted in October 1998 (H.C., unpub. data).

In subsequent years *C. turdinus* spread rapidly throughout eastern Paraguay (eBird), although the first department records occurred sporadically rather than progressively southward. During 3–4 October 1989, six were observed at Puerto Olivares (25°09'S; 57°15'W), providing the first record for Cordillera (Paul Scharf). One was observed during 4–5 May 1990 somewhere between Curuguaty (24°35'S; 55°25'W) and Colonia Nueva Durango (24°15'S; 55°50'W), representing the first record for Canendiyú (Paul Scharf). On 8 June 1999 it was recorded at Ybytyruzú (25°50'S; 56°13'W), providing the first record for Guairá (Guyra Paraguay, in eBird). The first record for San Pedro occurred on 23 January 2000 at Laguna Blanca (23°49'S; 56°17'W; Guyra Paraguay in eBird). By 2000 it appeared in several areas of Alto Paraná, including Presidente Franco (27°03'S; 58°37'W; Nelson Pérez in Savigny 2010). On

22 January 2005 it was observed at Mamoreí (26°23'S; 57°02'W), representing the first record for Paraguarí (Guyra Paraguay in eBird). The first record for Amambay occurred on 24 March 2005, when it was noted south of Bella Vista Norte (22°10'S; 56°30'W; Guyra Paraguay in eBird). In 2005 it was observed at Estancia Tapytá (26°14'S; 55°58'W), providing the first record for Caazapá (Velázquez *et al.* 2016). The first records for Itapúa occurred on 18 February 2006 in the vicinity of Estación Biológica Kanguery (26°26'S; 55°48'W; Guyra Paraguay in eBird). During 2–4 February 2010 it was recorded at Estancia La Graciela (26°35'S; 56°49'W), providing the first record for Misiones (Silvia Centrón & Cristina Morales). By 2012 multiple *C. turdinus* had reached the southern border of Paraguay at Encarnación in southern Itapúa (27°21'S; 55°52'W; Smith *et al.* 2013). It was not recorded in Caaguazú until 9 January 2013, when it was reported from Rancho Rosalba (25°15'S; 56°17'W; A. Lesterhuis in eBird). The first record for Ñeembucú occurred on 16 September 2014, when one was observed at Humaitá (27°04'S; 58°30'W; Sergio Rios in eBird), in southwestern Paraguay.

In addition to expanding its range southward and eastward, *C. turdinus* has also expanded its range westward, albeit more slowly, into the dry Alto Chaco region of western Paraguay. The first record for Boquerón comprised a pair observed at Estancia Teniente Montania in eastern Boquerón (21°57'S; 60°07'W), representing the westernmost record in Paraguay, on 29 September 2016 (Alberto Esquivel in eBird).

### Argentina

Dabbene (1910) reported a specimen collected in 1880 from Córdoba in Córdoba (31°24'S; 64°11'W), but Hellmayr (1934, p. 135) stated that the locality "can hardly be correct" and Zotta (1940) concurred. Thus, a sight record by Pablo Canevari at Parque Nacional Río Pilcomayo (25°04'S; 58°09'W) in eastern Formosa (Contreras & Contreras 1986) provided the first accepted record for Argentina. Unfortunately the date of Canevari's observation was not published, not even in his own book (Canevari *et al.* 1991), but occurred no later than the publication of Contreras & Contreras (1986). Canevari's sighting was subsequently verified by sightings of multiple birds in 1988 (Finch 1991) and 1993 (Fortabat *et al.* 1995). Canevari's sighting represented a remarkable southward range extension of at least 330 km since Ridgely's observations in 1977 along the Apa River of Paraguay (Ridgely & Tudor 1989). Assuming Canevari's sighting was in the year 1986, *C. turdinus* had extended its range southward at a rate of 36.7 km/yr from 1977–1986.

In subsequent decades *C. turdinus* continued to disperse southward in the Argentinian Chaco. In September 2009, two vocalizing *C. turdinus* were observed at Puerto Las Palmas in eastern Chaco (27°03'S; 58°37'W; Bodrati *et al.* 2012). On 6 October 2016 a group of eight was building a nest at Isla del Cerrito in eastern Chaco (27°17'S; 58°37'W; Pagano & Bodrati 2016). And on 10 October 2012, two were observed at Puerto Antequeras in eastern Chaco (27°27'S; 58°51'W; Fabricio Gorleri in eBird), providing the southernmost record for Argentina. Since Ridgely's observations in 1977 along the Apa River of Paraguay (Ridgely & Tudor 1989), *C. turdinus* extended its range slightly west of south about 595 km at a rate of 17.1 km/yr and southward 593 km at a rate of 17 km/yr. And since its first arrival in the Argentinian Chaco in about 1986 (Contreras & Contreras 1986), *C. turdinus* extended its range slightly west of south 274 km at a rate of about 10.5 km/yr and southward 265 km at a rate of 10.2 km/yr.

The first record in northeastern Argentina occurred on 23 May 2003, when three *C. turdinus* were observed at Puerto Iguazú, Misiones (25°37'S; 54°35'W; Rey & Zurita 2004). The southernmost records from northeastern Argentina are from Posadas, Misiones (27°23'S; 55°57'W), where it was reported in four localities in 2016 (eBird).

In addition to expanding its range southward and eastward, *C. turdinus* continues to expand its range westward into the dry Argentinian Chaco, with the westernmost record at Bartolomé de las Casas, Formosa (25°24'S; 59°35'W), on 14 December 2016 (Sebastán Dardanelli in eBird).

There are midwinter records from July near the southernmost extent of its range at Posadas (Joel Martínez in eBird), suggesting that the southernmost populations are non-migratory or, possibly, partially migratory.

### Brazil

In central Brazil, *C. turdinus* has expanded its range into the gap between Pará and Mato Grosso do Sul states since the 1980s (Fig. 1), but it is unclear whether the northwestern subspecies *C. t. hypostictus* or the southwestern subspecies *C. t. unicolor* inhabits this area.

In the isolated population along the coast of eastern Brazil, nominate *C. t. turdinus* has not expanded its range southward, but it has expanded its range northward (Fig. 1). The northernmost record is from Reserva Biológico de Saltinho, Pernambuco, Brazil (8°44'S; 35°11'W), on 30 October 2013 (Forest Rowland in eBird).

In 1941, a specimen of *C. t. unicolor* was collected on the east bank of the Paraguay River at Pôrto Quebracho (21°50'S; 57°53'W), in southwest Mato Grosso do Sul (Contreras *et al.* 1993), representing the southwesternmost record for Brazil (Naumburg 1930, Hellmayr 1934). This locality is about 60 km south of where the nearest specimen had been previously collected at Puerto Guaraní (21°17'S), Paraguay. Again, given the paucity of specimen records at the time from the upper Paraguay River region, it remains uncertain whether the specimen was within the ancestral range of the species or represented an actively expanding population.

Farther south, in southern Rio Grande do Sul, Helmut Sick (in Belton 1985) reported hearing a *C. turdinus* vocalizing at Fazenda da Invernada (31°05'S; 52°52'W), on 25 November 1972. According to Belton (1985, p. 105), Sick felt "absolutely sure of it, as voice is very easy to recognize with nothing similar to it". Nevertheless, the record was considered unreliable and rejected by Bencke *et al.* (2010). In 2008, a singing *C. turdinus* was heard at Foz do Iguaçu in central Paraná (25°37'S; 54°29'W; Bencke *et al.* 2008). A remarkable range extension occurred in 2015, when a singing *C. turdinus* was photographed at Santa Maria in central Rio Grande do Sul (29°40'S; 53°48'W; Vargas-Peixoto & Bosholn 2016), providing the southernmost confirmed record for the species. Although the authors did not assign it to a subspecies, photographs reveal the bird's unspotted creamy underparts, which are typical of *C. t. unicolor*, contrasting with the spotted underparts of nominate *C. t. turdinus* of coastal eastern Brazil (Ridgely & Tudor 1989, Sick 1993). Since Ridgely's observations in 1977 along the Apa River of Paraguay (Ridgely & Tudor 1989), by 2015 *C. turdinus* had extended its range slightly east of south 934 km at a rate of 24.6 km/yr and southward 841 km at a rate of 22.1 km/yr (Fig. 2).

## DISCUSSION

*Campylorhynchus turdinus* is just one of several tropical bird species in southern South America that is rapidly expanding its range southward into subtropical latitudes (*e.g.*, Straube *et al.* 2006, 2007, Piacentini *et al.* 2009, del Castillo *et al.* 2012, Pagano & Bodrati 2017). Vagrancy, the long-distance dispersal of individuals beyond their normal distribution or migratory path (*e.g.*, Thomson 1964, Veit 2000), occurs less frequently among non-migratory than migratory species of birds (Lees & Gilroy 2009). Data from eBird indicate that *C. turdinus* occurs near its southernmost limit in Argentina throughout the winter, indicating that it is non-migratory or, possibly, partially migratory. Vagrancy was thought to occur less frequently among cooperatively breeding than among non-cooperatively breeding species of birds (Zack 1990), but Rusk *et al.* (2013) provided evidence that vagrancy occurs just as frequently in cooperatively breeding species. Rabenold (1990) reported that *C. turdinus* breeds cooperatively, although no data have been published. Despite its apparent non-migratory and cooperatively breeding habits, long-distance vagrancy appears to be a life history trait in *C. turdinus*, and is presumably increasing as a consequence of rapid demographic population growth (Veit 2000).

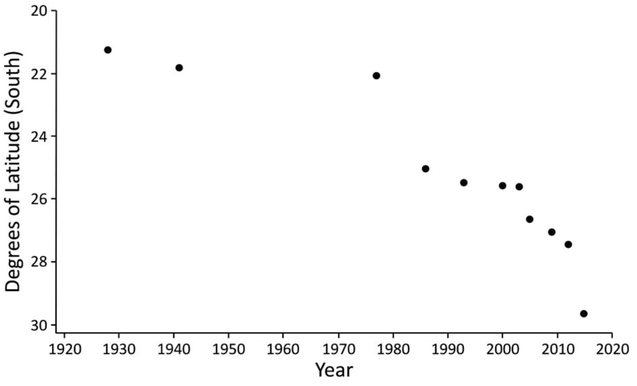

**Figure 2.** Southward range expansion of the Thrush-like Wren (*Campylorhynchus turdinus*) illustrated by the southernmost record *vs.* year, based on data in the Results section.

It is difficult to attribute changes in the spatial distribution of any single species to either habitat or climate change. Because of its affinity for disturbed habitats, *C. turdinus*'s rapid southward range expansion has been attributed to deforestation (Rey & Zurita 2004, Bodrati *et al.* 2012). The subtropical moist broadleaf forests of eastern Paraguay, southern Brazil, and northeastern Argentina have been subjected to extensive deforestation in recent decades (Hansen & DeFries 2004, Fleytas 2007, Huang *et al.* 2007, Aide *et al.* 2013, Hansen *et al.* 2013), plausibly facilitating the southward range expansion of *C. tudinus*. However, the rate of deforestation on the east slopes of the Andes, including the region east of Cusco, Peru, has been considerably slower (Aide *et al.* 2013, Zegarra & Gayoso 2015), suggesting that habitat change may not adequately account for the rapid upward range expansion of *C. turdinus* in Cusco, Peru.

The rapid range expansion of *C. turdinus* both southward and upward is consistent with the prediction that organisms are extending their geographic distribution toward higher latitudes and elevations as a consequence of global warming (Parmesan & Yohe 2003, Root *et al.* 2003, Hickling *et al.* 2006, Parmesan 2006, Chen *et al.* 2011). The region in which *C. turdinus* is expanding its range southward in southern South America is warming relatively rapidly (Easterling *et al.* 1997, Rosenblüth *et al.* 1997, Vincent *et al.* 2005). Because the northern boundaries of North American songbirds appear to be limited by winter nighttime temperatures (Root 1988), the southern boundaries of South American songbirds may also be limited by winter nighttime temperatures. If so, songbirds in southern South America may be able to extend their ranges southward as winter nighttime temperatures increase, which may be the case with *C. turdinus* and several other species of birds in southern

South America (*e.g.*, Straube *et al.* 2006, 2007, Piacentini *et al.* 2009, del Castillo *et al.* 2012, Pagano & Bodrati 2017). However, temperatures are not rising much in the Peruvian Andes (Easterling *et al.* 1997, Vincent *et al.* 2005), suggesting that climate change may not adequately account for the rapid upward range expansion of *C. turdinus* in Cusco, Peru. Perhaps habitat change and climate change combined best accounts for its rapid upward range expansion in Cusco, Peru.

Because tropical species of birds tend to have relatively small distributional ranges resulting in a high degree of endemicity, and occur in climatically stable environments where they tend to be K-selected with greater longevity and smaller clutch sizes, resulting in lower demographic flexibility, they are thought to be more vulnerable to anthropogenic changes in habitat and climate than temperate species of birds (Jetz *et al.* 2007, Şekercioğlu *et al.* 2012, Reif & Štěpánková 2016). Tropical birds may be adversely affected by climate change in many different ways, such as susceptibility to extreme weather events, habitat loss, emerging diseases, invasive species, and hunting (Jetz *et al.* 2007, Şekercioğlu *et al.* 2012, Botero 2015). Nevertheless, some tropical bird species, such as *C. turdinus*, may benefit from anthropogenic changes in the environment by expanding their ranges into disturbed habitats in response to habitat change or expanding their ranges toward higher latitudes and elevations in response to climate change. It remains uncertain which of these two drivers, or both combined, or if there is another yet to be identified, best explains the rapid range expansion of *C. turdinus*. More research is needed to evaluate whether range expansion southward and upward are general trends among a large number of bird species in South America, and what the drivers may be for such range expansion.

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ARTICLE

# New and noteworthy records of waterbirds from Paraguay

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**ABSTRACT:** Previously unpublished new and noteworthy Paraguayan reports of Anatidae, Ardeidae, Podicipedidae and Rallidae are provided. The first documented records of Speckled Teal *Anas flavirostris*, Yellow-billed Pintail *Anas georgica*, Blue-winged Teal *Anas discors* and Red-gartered Coot *Fulica armillata* are detailed with a review of previous undocumented reports of the species. Additional records of a further five rarely-recorded waterbird species are also reported: Silvery Grebe *Podiceps occipitalis*, Great Grebe *Podiceps major*, Little Blue Heron *Egretta caerulea*, Cinnamon Teal *Anas cyanoptera* and Red Shoveler *Anas platalea*. The new additions add up to a total of 123 waterbird species documented to occur in Paraguay.

**KEY-WORDS:** Anatidae, Ardeidae, distribution, Podicipedidae, Rallidae.

## INTRODUCTION

Less is known about waterbirds in the Neotropics than in any other region of the world (Wetlands International 2012). Within South America, data are especially limited for Paraguay, where very few studies of waterbirds have been undertaken despite 26% of the avifauna being wetland dependent (Clay *et al.* 2004). Paraguayan waterbirds are distributed amongst 19 families, of which 60% (74 species) are considered resident (Guyra Paraguay 2004). However, even among these resident species field observations by the authors and others suggest some unusual patterns of movement, with species becoming momentarily abundant in a given locality or region and then become rare or even completely unrecorded for many years. With Paraguay's position at the centre of the continent, the documentation of such records takes on renewed significance for helping to understand regional movements and population dynamics.

Previously unpublished waterbird counts have been taking place in Paraguay since 2001, stimulated in part by the Neotropical Waterbird Census. These have led to a number of new and interesting records, including four species which are documented here for the first time in Paraguay (three Anatidae and one Rallidae). Furthermore, we present a full summary of records for five other rarely recorded waterbirds (two Podicipedidae, one Ardeidae and two Anatidae) that show irregular patterns of occurrence. We also speculate on some of the factors that may influence their movements.

## METHODS

The Paraguayan waterbird records presented here were compiled from the published literature, museum specimens, on-line databases like Worldbirds (www.worldbirds.org) and e-Bird (www.ebird.org), the Guyra Paraguay Biodiversity Database, the authors' own field observations and through consultations with ornithologists and birdwatchers. Abbreviations used in the text are: dept. – departamento (a geopolitical division of Paraguay); USNM – National Museum of Natural History, Washington, USA (formerly the US National Museum of Natural History); UMMZ – University of Michigan Museum of Zoology (Ann Arbor, USA). Nomenclature follows the South American Classification Committee (Remsen-Jr. *et al.* 2017).

### Newly documented species

Speckled Teal *Anas flavirostris* (Anatidae): a specimen of *Anas flavirostris* in the US National Museum of Natural History (USNM 59140) labelled "Paraguay" was supposedly collected by Captain T.J. Page in the mid-1800s during a US Navy exploration of the La Plata

River Basin. However, no additional locality information was provided (J. Dean, *in litt*. 2004), and Page did not include it in his appendix of "natatores – swimming birds" collected during the expedition (Page 1859: 602). If this specimen was indeed collected by Page, then it was probably collected outside of the current borders of Paraguay. Page collected widely in southern South America, at a time when the political limits of Paraguay were much greater than they are today. Given that the species is much more common to the south, the balance of probability is that he collected the bird within what is now Argentine territory. Berlepsch (1887) included the species in a list of birds of likely occurrence in Paraguay, but it was omitted from the next list of Paraguayan species (Bertoni 1901). Phillips (1923) categorically stated that the species "does not occur" in the country.

Consequently, the first concrete mention of "Paraguay" in the species range appears to be Zotta (1935). This was cited by Laubmann (1939) who added that the presence of the species in Paraguay had not yet been established. Bertoni (1939) provided the first locality of "R. Paraguay", having omitted the species entirely from Bertoni (1914), but no details accompanied the record. More recently undocumented observations of 14 individuals were reported during July 1991 in the Paraguayan Chaco (López 1992) and 80 individuals at Laguna Millón in July 1992 (López 1993).

Hayes (1995) considered the occurrence of Speckled Teal in Paraguay to be hypothetical. He stated that though it is often cited to occur in Paraguay, no details of records are available. However, he added that it "may occur as an austral migrant".

On 26 May 2001, R.P.C. observed a single Speckled Teal with a group of eight White-cheeked Pintail *Anas bahamensis* at Campo María, Presidente Hayes dept. (22°34'1''S; 59°20'52''W). The bird was easily identified because of its combination of bright yellow sides to the bill, clearly rounded dark brown head, and speckled breast contrasting with the clear unmarked flanks. In flight, the bright green speculum bordered buff in front and narrowly with white at the rear was clearly visible in the otherwise dark brown wing. The species was considered "pending documentation" on the basis of this well-described report (Guyra Paraguay 2004) and was later documented photographically at the same location by Hemme Batjes (Fig. 1A) on 29 July 2006 (P.S., H. del Castillo, H. Batjes and A. Betuel). Additional subsequent records are provided in Table 1. Although the nominate race of *A. flavirostris* appears to be a partial austral migrant (Blake 1977, Johnsgard 1978, Madge & Burn 1988), in Paraguay the species is apparently of only intermittent occurrence. We feel that it is best considered an irregular vagrant to Paraguay.

Yellow-billed Pintail *Anas georgica* (Anatidae): Berlepsch (1887) included the species in a list of birds of likely occurrence in Paraguay. It was omitted from the next list of Paraguayan species (Bertoni 1901). Bertoni (1914) listed the species for "Alto Paraná" but he never published any details of any record.

Wetmore (1926) referred to a small series of specimens from Chile, Argentina, Paraguay and Peru, but failed to provide information as to where these specimens are located, and none are located in the USNM where he worked. Zotta (1935) then included "Paraguay" in the range, perhaps following Bertoni (1914), who was in close contact with him. This locality was then updated to "Alto Paraná (Puerto Bertoni)" in Bertoni (1939), suggestive that it was a first-hand record by the author, who resided there.

According to Laubmann (1939) and Hayes (1995), Kerr (1892) reported the species from Paraguay from "near Fortín Donovan", but the coordinates provided (stated to be "approximate" by Kerr 1892) place the locality in Formosa province, Argentina.

López (1992) reported flocks of 60 and 24 from the central Chaco during July 1992, but Hayes considered these large numbers to be "unsubstantiated". Given the lack of available details for any of these records, Hayes (1995) opted to treat the species as hypothetical, noting however that it possibly occurs in Paraguay as an austral migrant.

On 16 June 2004, A.J.L. observed a pair of *A. georgica* among a flock of *A. bahamensis* and Black-headed Duck *Heteronetta atricapilla*, at Laguna Sanidad, Estero Patiño, Presidente Hayes dept. (24°08'S; 59°00'W). They were readily identifiable by their large size, with overall mottled brown plumage, a much paler chin and foreneck, and yellow bill with black culmen stripe. The following day (17 June 2004), a bird was observed flying in a westerly direction at the same site (A.J.L.). The first documented record is of a single bird photographed (Fig. 1B) loafing with a group of *A. bahamensis* at Campo María, Presidente Hayes dept. on 13 October 2008 (P.S., Hugo del Castillo and M. Martin). There is one subsequent record, of two birds with a small flock of *A. bahamensis* in the Bahía de Asunción, Central dept. (25°20'S; 57°35'W) on 26 April 2009 (R.P.C.). *Anas georgica spinicauda* is considered an austral migrant, wintering into southern Brazil (Johnsgard 1978, Madge & Burn 1988). Individuals occurring in Paraguay are most likely to be of this subspecies, and the species can be considered of intermittent occurrence or at best an irregular vagrant.

Blue-winged Teal *Anas discors* (Anatidae): Hayes (1995) considered two female or immature *Anas* observed in the Bahía de Asunción on the 15 February 1989 to possibly refer to Blue-winged Teal, but most likely Cinnamon Teal *A. cyanoptera*. This appears to be the only reference to Blue-winged Teal potentially occurring in Paraguay.

On the 13 January 2003, R.P.C. found a drake

**Figure 1.** (**A**) Distant individual of *Anas flavirostris* at Campo Maria Private Nature Reserve, Cuenca Upper Yacaré Sur, Presidente Hayes dept. (Photo author: Hemme Batjes); (**B**) Adult *Anas georgica*, Campo Maria Private Nature Reserve, Cuenca Upper Yacaré Sur, Presidente Hayes dept. (Photo author: Paul Smith); (**C**) Adult male *Anas discors*, Laguna Capitán, Presidente Hayes dept. (Photo author: Oscar Bordón); (**D**) Adult *Fulica armillata*, Estancia La Graciela, Misiones dept. (Photo author: Arne Lesterhuis).

**Table 1.** New records of Speckled Teal *Anas flavirostris*, Red-gartered Coot *Fulica armillata*, Silvery Grebe *Podiceps occipitalis*, Little Blue Heron *Egretta caerulea*, Cinnamon Teal *Anas cyanoptera*, Red Shoveler *Anas platalea* in Paraguay.

| Date | Locality | Number of individuals | Observer |
|---|---|---|---|
| **Speckled Teal (*Anas flavirostris*)** | | | |
| 16 January 2004 | Laguna Buena Vista (22°36'22''S; 59°42'00''W) | 1 | J. Klavins |
| 16–17 June 2004 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | At least 2 | A.J.L., H. del Castillo, M. de Bernard, M. Montiel |
| 02 July 2005 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | 2 | R.P.C. |
| **Red-gartered Coot (*Fulica armillata*)** | | | |
| 17 June 2004 | Laguna Sanidad, Presidente Hayes dept. | 13 | A.J.L. |
| 09 October 2004 | Laguna Sanidad, Presidente Hayes dept. | 19 | R.P.C. |
| 02–04 July 2005 | Laguna Sanidad, Presidente Hayes dept. | 13 | R.P.C., H. del Castillo |
| 23 September to 14 October 2004 | Bahía de Asunción, Central dept. | 1–3 | R.P.C., A.J.L., P.S., H. del Castillo |
| 20 September 2009 | Bahía de Asunción, Central dept. | 1 | R.P.C., A.J.L. |
| **Silvery Grebe (*Podiceps occipitalis*)** | | | |
| 15 June 2004 | Laguna Sanidad, Estero Patiño, President Hayes dept. | 7 (non-breeding plumage) | A.J.L. |
| 17 June 2004 | Laguna Sanidad, Estero Patiño, President Hayes dept. | 61 | A.J.L. |
| 13 July 2004 | Chaco Lodge, President Hayes dept. | 175 | Lesterhuis *et al.* (2005) |
| 13 July 2004 | Campo Maria, President Hayes dept. | 78 | Lesterhuis *et al.* (2005) |
| 16 October 2005 | Campo Maria, President Hayes dept. | 100+ | P.S., R.P.C., R. Elsam, R. McCann |

| **Date** | **Locality** | **Number of individuals** | **Observer** |
|---|---|---|---|
| 14 July 2006 | Campo Maria, President Hayes dept. | 6 | P.S., H. del Castillo, A. Holman |
| 27 July 2006 | Campo Maria, President Hayes dept. | 1 | Adam Betuel |
| **Little Blue Heron (*Egretta caerulea*)** | | | |
| 20 April 2001 | Bahía de Asunción, Central dept. | 1 (non-breeding adult) | A.J.L., F. Fragano |
| 06 February 2005 | Bahía de Asunción, Central dept. | 1 (immature) | R.P.C. |
| 21 February 2010 | Bahía de Asunción, Central dept. | 1 (immature) | R.P.C. |
| 10 October 2010 | Bahía de Asunción, Central dept. | 1 (immature) | R.P.C., A.J.L., H. del Castillo |
| 30 October 2010 | Cercanías del Rió Aquidaban, Amambay dept. | 1 (adult) | O. Rodríguez |
| 02 July 2012 | Campo María, Presidente Hayes dept. | 1 (immature) | P.S. |
| 19 August 2012 | Asunción, Central dept. | 1 (adult) | R.P.C. |
| 13 December 2014 | Asunción, Central dept. | 1 (adult) | R.P.C. |
| 10 November 2015 | Asunción, Central dept. | 1 (adult) | R.P.C. |
| 23 July–14 Sep 2016 | Bahía de Asunción, Central dept. | 1 (immature) | R.P.C., O. Bordon, J.L. Mendez, A. Martin |
| **Cinnamon Teal (*Anas cyanoptera*)** | | | |
| May 1997 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | a few individuals (including adult males) | H. del Castillo |
| 20–25 July 1999 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | 1 male | H. del Castillo |
| 16 June 2004 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | 2 pairs | A.J.L., H. del Castillo |
| 02–03 July 2005 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | 2 pairs and a female | R.P.C., H. del Castillo, L. López |
| **Red Shoveler (*Anas platalea*)** | | | |
| May 1997 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | Up to 30 individuals (pair shot by hunters photographed) | H. del Castillo |
| 20–25 July 1999 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | Few individuals | H. del Castillo |
| 05–16 May 2004 | Bahía de Asunción, Central dept. | 1 male (presumably the same bird? Remains later found on 21 May) | R.P.C., A.J.L., H. del Castillo |
| 30 May 2004 | Estancia La Graciela, Misiones dept. | 12 | H. del Castillo, M. de Bernard, M. Montiel, A. Stroessner |
| 03 June 2004 | Estancia La Graciela, Misiones dept. | 7 | A.J.L., H. del Castillo, R. Elsam, M. Ibarra |

| Date | Locality | Number of individuals | Observer |
|---|---|---|---|
| 05 June 2004 | Bahía de Asunción, Central dept. | 3 (adult male and female, and an immature male) | R.P.C. |
| 15–18 June 2004 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | 125 | A.J.L., H. del Castillo, M. de Bernard, M. Montiel |
| 14 July 2004 | Laguna Campo Leon, Presidente Hayes dept. | 8 | A.J.L., E. Coconier |
| 29 June–04 July 2005 | Bahía de Asunción, Central dept. | 2 males | R.P.C., P.S., C. Morales, S. Centrón, L. López, H. Batjes, C. Hesse |
| 03 July 2005 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | 950 | R.P.C., H. del Castilo, L. López, S. Centrón, H. Cabral Beconi |
| 02 September 2005 | Laguna Sanidad, Estero Patiño, Presidente Hayes dept. | <1000 | H. del Castillo, H. Cabral Beconi, R. Zarza, F. Fragano |
| 26 April 2009 | Bahía de Asunción, Central dept. | 18 | R.P.C. |
| 21 June 2009 | Bahía de Asunción, Central dept. | 2 males | P.S. |
| 05 October 2009 | Bahía de Asunción, Central dept. | 1 | R.P.C., A.J.L., M. Jeffrey, K. Pierson |
| 07 July 2015 | Laguna Lucero, Presidente Hayes dept. (22°33'S; 59°26'W). | 10 | A.J.L., H. Cabral Beconi |

Blue-winged Teal in the company of *c.* 100 Ringed Teal *Callonetta leucophrys* and Brazilian Teal *Amazonetta brasiliensis* at Campo María, Presidente Hayes dept. The bird was easily identified through a combination of small size, longish body, bluish-grey head contrasting with warm brown underparts heavily marked with dark spotting, white facial crescent, white flank patch and black vent. In flight, the pale blue forewing, bordered by a white greater covert bar (broadening distally) and green speculum were obvious, while the largely white underwing with broad blackish leading edge was also conspicuous. An adult male, was observed at Laguna Capitán, Presidente Hayes dept. (22°32'S; 59°40'W) during November 2004 by N. López (pers. comm. 2005). The first documented record of the species in Paraguay was a male at Campo Leon (22°34'S; 59°32'W) photographed by O. Bordon on 6 August 2016 (Fig. 1C).

*Anas discors* is found with some regularity as far south as Argentina (Mazar-Barnett & Pearman 2001), thus its occurrence in Paraguay is not surprising. All three records have been in relative proximity and given that the species can live for over 20 years (USGS Patuxent Wildlife Research Center 2015), it is possible that the records refer to the same individual.

Red-gartered Coot *Fulica armillata* (Rallidae): Hayes (1995) considered the occurrence of this species in Paraguay as hypothetical based on a lost specimen collected by Félix Posner at Monte Sociedad Colony (now Benjamín Aceval), Presidente Hayes dept. (Bertoni 1930). In that publication, Bertoni (1930) stated that he had never recorded the species in the forested area of the Oriental region. Bertoni's (1939) listing of Villa Hayes is in reference to the same record. However, numerous previous citations of the species in Paraguay also exist.

Vieillot (1817) described the species based on Azara 448 "Focha de ligas roxas" and gave the type locality as "Paraguay", but in fact Azara (1802) states that his two specimens came from Buenos Aires, Argentina and he makes no mention of the species in Paraguay, *contra* Hartlaub (1854) and Laubmann (1939). Hartlaub (1854) and Berlepsch (1887) included the species for Paraguay based on Azara 448, but also cite a specimen from "Misiones" Paraguay collected by Bonpland, and deposited in the Museum d'Histoire Naturelle de Paris, though we were unable to trace this specimen. Though Aimé Bonpland lived in the town of Santa María de Fé in Paraguay for many years, he also spent much of his time in Corrientes, Argentina (at that time part of Paraguay) and thus the exact collection locality of this bird is of some relevance. Subsequent to this, it was also included in the Paraguayan avifauna by Sharpe (1894), Bertoni (1901, 1914), Ihering (1904), Peters (1934) and Hellmayr & Conover (1942), amongst others. In August 1995, the species was reported by Kevin Burns at Rancho

Chaco (Presidente Hayes dept.), but no further detail of the record was provided. However there have been very few concrete, well-documented reports.

On the 30 May 2004, H. del Castillo, M. de Bernard, A. Stroessner and M. Montiel found a *F. armillata* with eight White-winged Coots *Fulica leucoptera* in a small artificial lagoon at Estancia La Graciela, Misiones Department (26°34'52''S; 56°49'18''W). The bird was still present on 03 June 2004, when it was also seen by A.J.L., J. Klavins, R. Elsam, A. Spiridonoff and M. Ibarra. This bird was documented by photos taken by A.J.L. which clearly show the wine-red band separating the rather broad yellowish bill from the frontal shield (Fig. 1D). The bird was also noticeably larger than the accompanying *F. leucoptera*. Additional subsequent records are provided in Table 1.

The population of northeastern Argentina is considered to consist of austral migrant birds (Taylor 1998). In Paraguay it appears to occur in small numbers as a rare but regular austral migrant during the austral winter, probably as part of the same northward movement.

## Noteworthy records

Silvery Grebe *Podiceps occipitalis* (Podicipedidae): Hayes *et al.* (2004) summarized records of the species in Paraguay to that point, considering *P. occipitalis* to be an uncommon austral migrant to Paraguay. He reported one individual at Estancia Golondrina, Presidente Hayes dept. (24°56'S; 57°42'W) and observations of up to ten birds at Laguna Salada, Presidente Hayes dept. (22°32'S; 59°18'W). Details of additional new records, including flocks of 175 and 78 birds simultaneously in the central Chaco (Lesterhuis *et al.* 2005), are provided in Table 1.

It seems likely that *P. occipitalis* has been somewhat overlooked in Paraguay, occurring as an irregular and irruptive austral migrant. Large numbers, such as those observed in 2004 and 2005, seem to occur during very cold winters and are most likely to be observed in the Paraguayan Chaco west of the Paraguay River.

Great Grebe *Podiceps major* (Podicipedidae): Bertoni (1901) and presumably also Ihering (1904) listed the species for Paraguay on the basis of Azara No. 443 "Macá Cornudo". Azara (1805) does not clarify the origin of his birds, but does state in the introduction to the family that he "described them all from Paraguay" and that he "released them in his room". Schlegel (1867) reported two specimens from "Paraguay" in "perfect plumage", one of which is sexed as a male, but no more details were provided and we have been unable to trace them. Berlepsch (1887) listed the species with a query, Bertoni (1914, 1939) listed it as requiring confirmation, and the species was omitted entirely by Laubmann (1939).

The first verifiable Paraguayan records of the species were specimens collected 235 km W of Río Negro (Presidente Hayes dept.) in June and September 1939 (Storer 1989). One of these birds was a juvenile with wings too short for flight, suggestive of local breeding (Storer 1989, Hayes 1995). Two further specimens in USNM (59894, 59896) with locality "Paraguay, Santa Fe, Rio Salado" seem certain to have come from Argentina and not Paraguay (Storer 1989). Contreras *et al.* (1989a, 1989b) provided a review of Paraguayan records of the species until that point, citing additional records from Lago Ypoá, Paraguarí dept., on 27 August 1989; the Paraná River at Refugio Biológico Mbaracayú, Canindeyú dept. (28 August to 09 September 1985); Ruta Transchaco km 416, Boquerón dept. (07 December 1990); the Paraguay River near the mouth of the Bermejo River (07 July 1992) and the Paraguay River at Puerto Naranjito (17 September 1992), both at Ñeembucú dept.

Additional subsequent records include one individual on 25 July 2009 at Laguna Blanca (Smith *et al.* 2016), one individual observed at Bahía de Asunción on 10 and 14 October 2010 (R.P.C., A.J.L., P.S. and H. del Castillo) and three at Laguna León (Chaco Central) on 11 July 2012 and 26 August 2012 (R.P.C.).

This species seems to occur fairly regularly in the country. However, the species is not resident and the pattern of records is not suggestive of migration so much as random dispersal or nomadism. Consequently, we consider this species to be a regular vagrant in Paraguay, noting that it might occasionally breed when conditions are suitable.

Little Blue Heron *Egretta caerulea* (Ardeidae): first listed for Paraguay in a catalogue by Pinto (1938), with no details provided, and then by Bertoni (1939) who cited it as his source. Hellmayr & Conover (1948) specifically stated that the species had "never been recorded in Paraguay" and the country was subsequently omitted from the range of the species in an updated edition of the same catalogue (Pinto 1978), suggesting a retraction of the earlier report.

The first record with a locality is thus Peris & Suárez (1985) who reported small flocks of 2–3 birds in southern Presidente Hayes dept. along the Ruta Trans Chaco between km 100 and km 260 during December 1983. However, Hayes (1995) considered these as hypothetical due to a lack of details. The first documented record was a non-breeding individual photographed by F. Hayes on 18 August 1988 at Puerto Bahía Negra, Alto Paraguay dept. (Hayes *et al.* 1990). Subsequently, R. Ryan observed one bird at Ruta Trans Chaco km 79, President Hayes dept., on 08 August 1994 (Hayes 1995). Additional unpublished records are provided in Table 1. This species seems to be occurring with increasing frequency in central South America and may be undergoing range expansion. For the time being we consider this species to be an increasingly regular vagrant in Paraguay.

Cinnamon Teal *Anas cyanoptera* (Anatidae): Berlepsch (1887) included the species in his list of "potential" additions to the Paraguayan avifauna. Bertoni (1914, 1939) however, included the species as confirmed in Paraguay, though he provided no locality or reference to support this. Hayes (1995) reported just two localities for the species, one of which "near Fortín Donovan" (Kerr 1892) is actually in Argentina according to the coordinates provided. Consequently, the first documented record is a specimen of the subspecies *A. c. cyanoptera* collected 170 km W of Puerto Casado on 01 March 1938 (UMMZ 96201) (Storer 1989).

Two additional specimens of Cinnamon Teal are purportedly from Paraguay. A specimen labelled as "*Anas cyanoptera* or *Anas discors*" in the Jacob Unger Museum in Filadelfia, Boquerón Department, is clearly this species, identifiable by the large broad bill, plain head pattern and rufous wash to the plumage, especially on the flanks and breast sides. Although no locality data are provided, all specimens in the museum were collected by Jacob Unger, who is only known to have collected in the central Paraguayan Chaco. An additional specimen held in the USNM (USNM 571248) was collected during the 1850s or 1860s by Captain T.J. Page of the US Navy Steamer Water Witch. The only locality information is "Paraguay", but the specimen probably originates from Argentina.

The latest records of the species are all from the same locality, Laguna Sanidad, Estero Patiño, Presidente Hayes dept. Details are provided in Table 1. This species is known from very few records of a small number of individuals from March to July. We consider this species to be a rare and irregular straggler to Paraguay, with records representing overshooting migrants from further south.

Red Shoveler *Anas platalea* (Anatidae): first reported for Paraguay by Azara (1802) as his No. 431 "Pato Espátula", where he notes that "Noséda killed two of three birds in Paraguay during July". Padre Nóseda was based at San Ignacio, Misiones dept., and this may be presumed to be the collection site. Berlepsch (1887), Bertoni (1901, 1914, 1939), Ihering (1904) and Hellmayr & Conover (1948) then all listed the species for Paraguay, without providing any additional locality data.

Hayes (1995) listed six reports of Red Shoveler in Paraguay, one of which from the vicinity of Fortín Donovan (Kerr 1892) is actually in Argentina, according to the coordinates provided. The author reported his own sight records of a single bird at Estancia La Golondrina, Presidente Hayes dept. on 09 July 1989; a pair at Bahía de Asunción, Central dept. on 11 January 1989, a female only at the same locality on 18 January 1989 and a single female on 15 February 1989. Additionally, he reported three older specimen records, one held in the UMMZ (a male, 105029) and two in the USNM (a male and female, USNM 390658 and 399450). An additional specimen record, a female collected by Alberto Schulze and Jacob Unger on 17 February 1939, 170 km W of Puerto Casado (UMMZ 105030) was apparently overlooked by Hayes (J. Hinshaw, *in litt*. 2004). It would appear that all of these are from the same series of specimens, as all four birds were collected in February 1939, at least three from the same general area (there is no locality information for USNM 399450; J. Dean, *in litt*. 2004, J. Hinshaw, *in litt*. 2004). Additional subsequent records are provided in Table 1.

Hayes (1995) considered Red Shoveler to be a breeding resident, presumably on the basis of the records in January and February. However, we are not aware of any evidence of breeding, and the recent records in discrete windows of time, sometimes involving quite large numbers, suggests the species may be somewhat nomadic, mainly during winter and in response to favourable local conditions.

## DISCUSSION

With these new additions to the list of Paraguayan avifauna, including the recently added gull and tern species described in Clay *et al.* (2017), the total of true waterbird species in Paraguay is 123, comprising 19 families. Most of these new additions are a direct result of a growing interest in birding amongst Paraguayans, leading to a "mini-revival" of waterbird watching in the country. The subsequent increase in field effort is having a positive effect on the amount of data available to researchers and previously undetected patterns of movement are beginning to emerge. Whilst it is still too early to begin to formulate hypotheses, the signs for being able to do so in the near future are positive. On the other hand, just as interest in the local fauna is beginning to take off, the country is also facing severe environmental challenges with accelerating deforestation rates in the Chaco region (one of the hotspots for "waterbirding") and the draining of wetlands and seasonally flooded grasslands in southern Paraguay amongst the most serious conservation issues affecting the country and its waterbird populations. The availability and publication of data that contributes to a better understanding of the patterns and processes affecting waterbird distribution in Paraguay is thus an obligation to field researchers working in the country.

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Volume 26 – Issue 1 – March 2018

## CONTENTS

### BEHAVIOR

### ECOLOGY & CONSERVATION

### SYSTEMATICS, TAXONOMY AND DISTRIBUTION

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9 770103 565003