*Oecologia Australis*
24(3):615-634, 2020
https://doi.org/10.4257/oeco.2020.2403.07

# BIRD COMMUNITY STRUCTURE IN MACROHABITATS OF THE AQUATIC-TERRESTRIAL TRANSITION ZONE IN THE PANTANAL WETLAND, BRAZIL

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**Abstract:** Ecological responses of bird communities in aquatic-terrestrial transition zones (ATTZs) are only partially understood. The aim of this study was to evaluate community structure of birds in different macrohabitats of ATTZs from a protected area in the Pantanal wetland, Brazil. The survey of birds was carried out in three types of macrohabitats: *Erythrina fusca* Lour. monospecific forest, shrubland and pioneer polyespecific forest, and flooded grassland. The bird community living within the ATTZ varied according to macrohabitat type and period of the wetland landscape. We emphasise the importance of this protected area to biodiversity. Employ greater environmental control is required, since the region is not exempt from direct and indirect impacts derived from the Upper Paraguay River Basin.

**Key-words:** floodplain; flood pulse; richness; waterbirds; migratory bird.

## INTRODUCTION

The Pantanal is one of the largest continental wetlands of the world and provides important ecosystem services such as water regulation, population well-being and the conservation of biodiversity (Brazil 2016). It encompasses complex regions that display environmental heterogeneity and is highly influenced by the local water regime (Junk & Da Silva 1996, Nunes da Cunha & Junk 2009, Miranda *et al.* 2018), which is controlled by the flood pulse (Junk *et al.* 1989). This ecosystem is threatened mainly by extensive agricultural activities, expansion of the hydroelectric sector and waterway transportation (Harris *et al.* 2005, Da Silva *et al.* 2015). These anthropic activities drastically affect the functioning of natural processes as well as the maintenance of biodiversity (Alho 2008).

Among the biological communities adapted to the Pantanal's water dynamics, the avifauna play an important ecological role with respect to the movement of energy and nutrients (Green & Elmberg 2013) and have been considered one of the most well-known groups in the region (Junk *et al.* 2006). The Pantanal wetlands provide shelter to resident birds and are the destinations and routes of several migratory species (Oliveira *et al.* 2016). These types of birds live in different types of environments (Signor & Pinho 2011, Donatelli *et al.* 2014), such as permanently aquatic, terrestrial and aquatic-terrestrial transition zones (ATTZs), with ATTZs comprising the major portion of the Pantanal floodplain in Brazil (Junk *et al.* 2014, 2018).

ATTZs are areas connected to a main waterbody in which gradients rise as a result of fluctuations in the water level determined by climatic and hydrological factors (Junk *et al.* 1989). These fluctuations can cause flooding (Junk *et al.* 1989),

and can also become dry during low water periods (Wantzen *et al.* 2005). In the Pantanal, 27 types of macrohabitats of ATTZs vary in their aquatic or terrestrial predominance, which are characterised by hydrological parameters, physical-chemical properties of water and biological criteria (Junk *et al.* 2014, 2018).

The responses of biological communities to the spatial and temporal variation within ATTZs are still poorly understood. Some studies have shown that terrestrial and aquatic biological communities such as vegetation (Ikeda-Castrillon *et al.* 2011, Catian *et al.* 2018), vertebrate animals (Figueira *et al.* 2011, Lázari *et al.* 2013, Valério *et al.* 2016, Penha *et al.* 2017) and invertebrates (Oliveira-Júnior *et al.* 2013) can respond differently to landscape changes caused by flood and dry cycles of the Pantanal.

The heterogeneity of a landscape can directly influence the composition and abundance of birds (Accordi & Hartz 2006). Further, the community structure of the wetlands is determined by several natural and anthropogenic factors (Tavares *et al.* 2015). The knowledge regarding this community can contribute effectively to defining environments that should be conserved at he highest level of priority (Pinho & Marini 2012). Thus, our objective was to evaluate the community structure of birds in different macrohabitats of ATTZs from a protected area in the Pantanal wetland, Brazil. We hypothesised that the richness, abundance and composition of birds differ in macrohabitats and within varied hydrological periods. We expected higher levels of richness in forest macrohabitats, because they are more structured than open areas; and increased numbers of birds living within the community throughout dry periods, given the arrival of some migrant species.

## MATERIAL AND METHODS

### *Study area*

The study was conducted at Taiamã Ecological Station (TES), an area under the full protection of Federal Law nº 9.985 de 2000 (Brasil 2000). In 2018, it was designated a Ramsar Site, which is a place from around the world identified as key to advancing the conservation of wetlands (Brasil 2019). The TES is located in the Pantanal wetland within the limits of the municipality of Cáceres, State of Mato Grosso, Brazil (16°48'–16°58' S, 57°24'–57°40' W) (Figure 1). The area is a fluvial island formed by both the Paraguay and Bracinho Rivers and comprises 11,555 hectares (Brazil 2017). The climate is of type Aw (Equatorial savannah with dry winter), and it has an annual rainfall of 1,500 mm and maximum and minimum average annual temperatures of 32 ºC and 20 ºC, respectively (Kottek *et al.* 2006).

The TES is characterised by different functional units composed of permanently aquatic areas, swamp areas, and ATTZs. The macrohabitats of ATTZs selected for this study were the Monospecific Forest dominated by *Erythrina fusca* Lour. locally known as *abobral*, found in 16 % of TES on the banks of the Bracinho and Paraguay Rivers; Polyespecific forest formed by shrubs and pioneers, found on the banks of the Bracinho and Paraguay Rivers, which account for 8 % of coverage within the TES; and the flooded grasslands composed of herbaceous plants and aquatic macrophytes, comprising 23 % of the TES (Figure 2; Frota *et al.* 2017). In this study, all evaluated sites were within the limits of the TES, with the exception of areas belonging to the flooded grassland macrohabitat, which were located in the zone of damping (Figure 1).

### *Bird surveys*

Birds were sampled during the hydrologic periods of flood (December, January and April) and dry (October) in the Pantanal of the cycle 2015-2016 (SISBio License nº 50928-1). We used the point count method in six sampling sites represented by macrohabitats of ATTZs, two sites for each type of macrohabitat (Supplementary Material 1).

To sample the bird community, we located eight point count stations in each sampling site, separated from each other by 200 m. A total of 48 point counts were conducted, 16 points per macrohabitat type. We counted birds at each point for 15 min, recording all species seen or heard within a radius of 50 m. Each point count station was sampled for three consecutive days in each hydrological period at dawn (6 h – 8 h) and dusk (16 h – 18 h), with a total of 72 h of census. We identified species of birds and counted individuals by visually or by taking audio recordings with the aid of 10 x 42 mm binoculars, digital recorders, photographic cameras, a bird guide (Gwynne *et al.* 2010), and specialised literature (Sick 1997; del Hoyo *et al.* 2017).

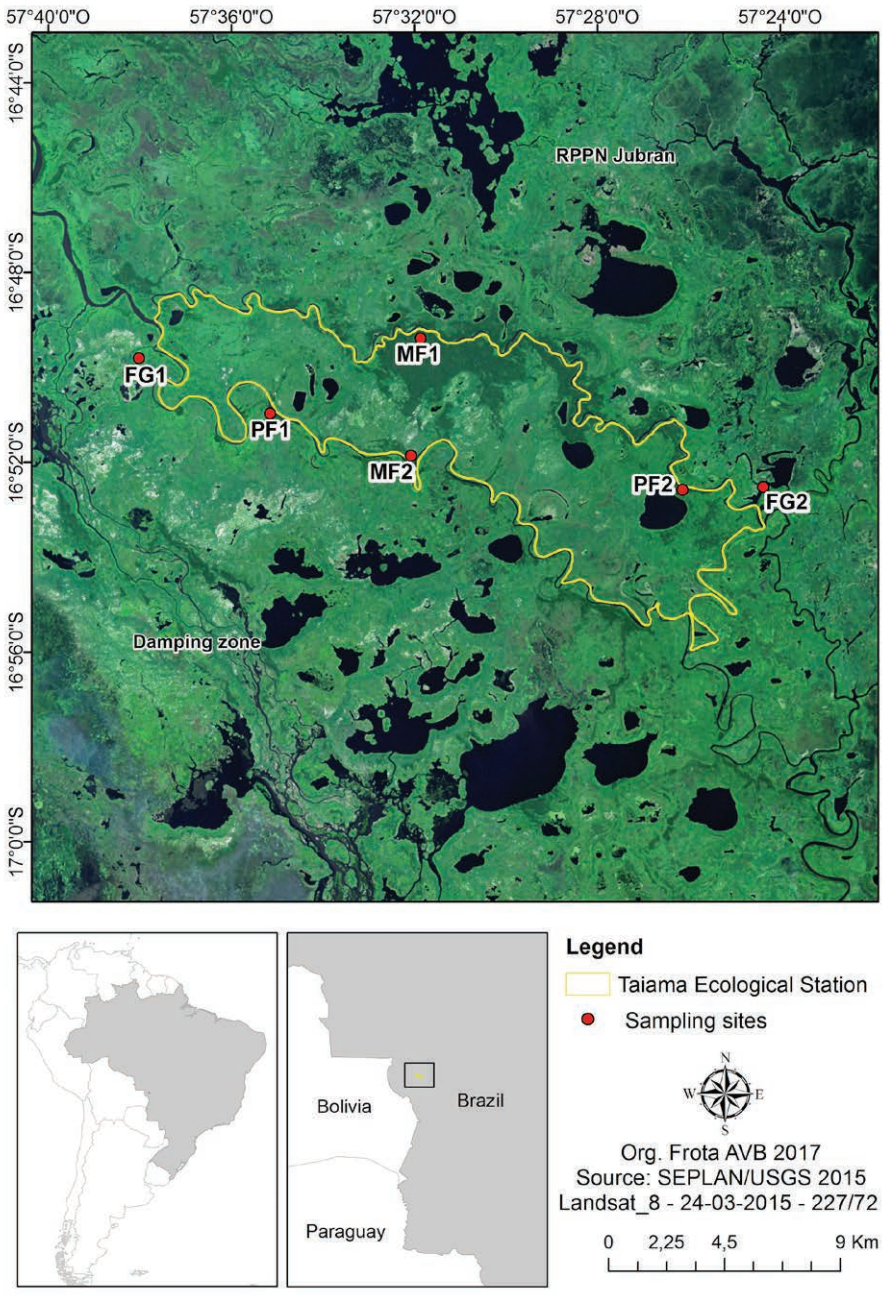


**Figure 1.** Taiamã Ecological Station, Pantanal, Brazil, and six sites for sampling bird species were designated. Macrohabitats sampled included *Erythrina fusca* Lour. Monospecific Forest (MF1, MF2); Shrubland and Pioneer Polyespecific Forest (PF1, PF2) and Flooded Grassland (FG1, FG2).

### *Data analysis*

To describe the structure of the bird community within macrohabitats, we evaluated species richness, the number of individuals identified, and species composition (Magurran 1988). Species rarefaction curves were obtained using the Mao Tau method (employing a 95 % confidence interval) to evaluate sampling efforts within the sites. Species richness was estimated by using the non-parametric procedure Jackknife 1, which considered the number of species found in only one sample (*unique*) (Heltshe & Forrester 1983). The relative abundance of species was calculated by considering the individual proportion of a species in relation to the total of individuals in the community for each type of macrohabitat. Differences in species richness and the number of individuals living in different macrohabitats (factor 1) and periods (factor 2) were tested using two-way ANOVA. The Tukey

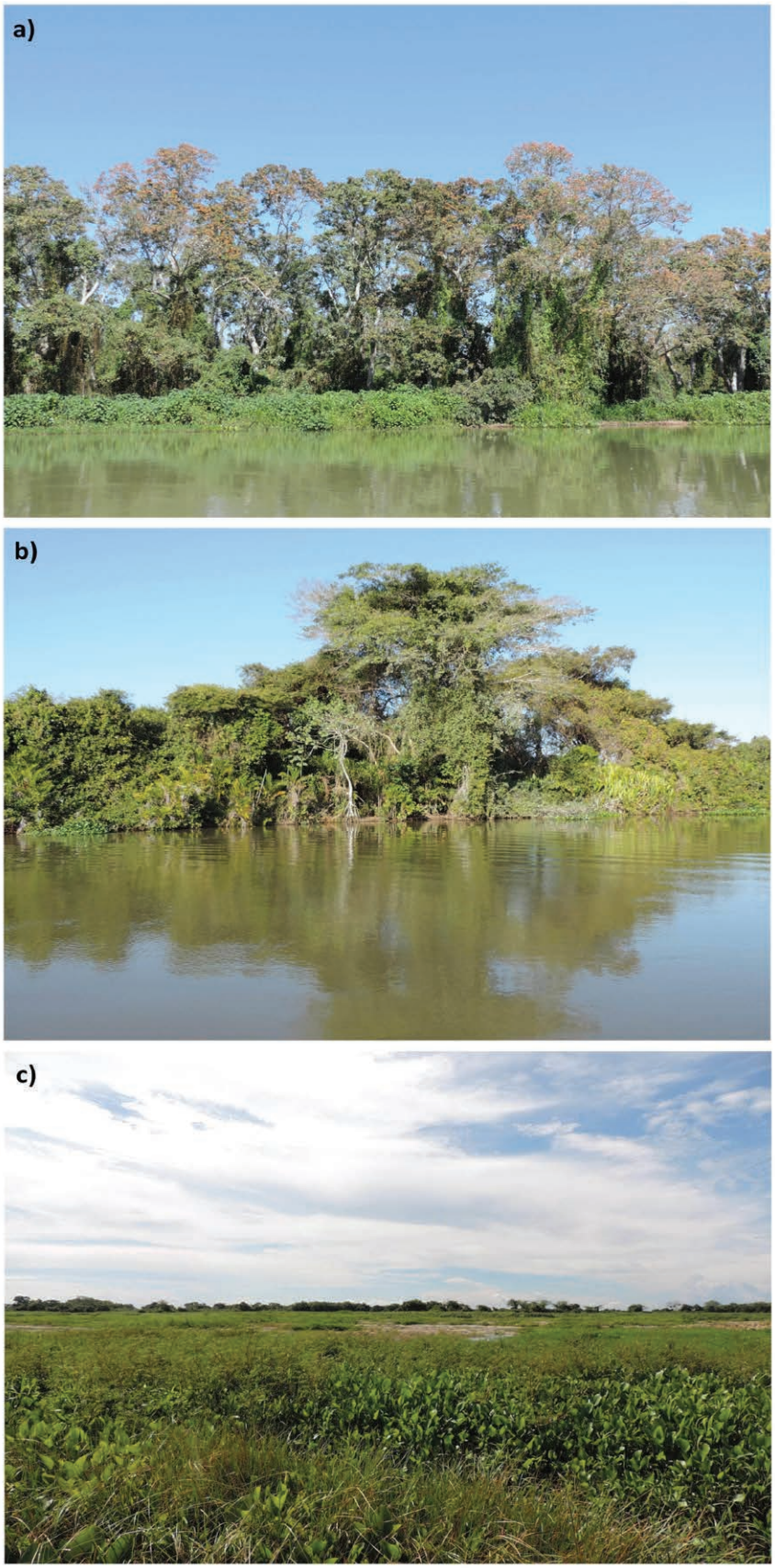


**Figure 2.** Macrohabitats of the aquatic-terrestrial transition zone (ATTZ) in the Pantanal wetland, Brazil include (a) *Erythrina fusca* Lour. monospecific forest areas, (b) shrubland and pioneer polyspecific forest and (c) flooded grassland.

test was done *a posteriori* when the result was significant.

To evaluate the composition of bird species in macrohabitats, we used non-metric multidimensional scaling (NMDS) with *Bray-Curtis* distance functioning as a measure of dissimilarity, which also considers species abundance. We explored a graphic representation of NMDS axis ordering for both, a flood and dry period. The stress level for each period was used to evaluate the results of ordinations, in accordance with the accepted limit of 0.20 (Clarke, 1993). We subsequently performed the ANOSIM test in order to evaluate similarities between the clusters within periods. Analyses were performed with the "vegan" software package version 2.5.4 (Oksanen *et al.*, 2019) using R programming (R Development Core Team, 2019). Values in which $p \leq 0.05$ were considered significant.

The list of species followed the taxonomic order proposed by the Brazilian Ornithological Records Committee's lists (Piacentini *et al.* 2015). To evaluate migratory behaviour, migrant (MGT), partially migratory (MPR), vagrant (VAG) and not defined (ND) categories were used according to guidelines outlined in Somenzari *et al.* (2018). We used the Red Book of Threatened Species of Brazilian Fauna (Brasil 2018) to determine the national conservation status of birds and the Red List of Threatened Species (IUCN 2018) to provide the international conservation status of species.

## RESULTS

We recorded the presence of 16,610 individuals from 161 species across 51 families in the macrohabitats of the ATTZ (Appendix 1). Among the species, 23 had migratory behaviour. Of these, 13 were partially migratory, nine were migratory and, the migratory status of one species was not defined. For the *E. fusca* monospecific forest, 10 species identified were partially migratory and four were migratory; for the polyespecific forest, eight species identified were partially migratory and two were migratory; and for the flooded grassland, 10 were partially migratory and six were migratory. We recorded only one species, *Crax fasciolata* Spix, 1825, designated as having a vulnerable status by the IUCN, and no species were threatened according to national conservation status designations. This species was observed in the forest macrohabitats of the TES, as well as in the head office of this protected area.

### *Richness and Abundance*

The polyespecific forest macrohabitat contained the greatest number of species identified, producing a total observed richness value of 130 and an estimated richness by rarefaction value of 161.87 ± 10.51. The number of species identified in the polyespecific forest was followed by the monoespecific forest (116; 141.31 ± 8.51) and flooded grassland (93; 113.63 ± 8.25) (Figure 3). With respect to the number of individuals identified, 6,738 were identified within the flooded grassland (mean = 421.12; SD = 227.80), 5,313 were identified within flooded forest habitats (mean = 332.06; SD = 117.35) and 4,559 were identified within the polyespecific forest (mean = 284.93; SD = 119.77).

The interaction between the macrohabitat and period varied with respect to species richness ($F = 8.70$, $df = 2$, $p < 0.001$), but not number of individuals identified ($F = 0.35$, $df = 2$, $p = 0.70$) (Figure 4). When we evaluated factors separately, there was an observed difference in the richness of macrohabitats ($F = 34.58$; $df = 2$; $p < 0.001$), but no differences between periods were determined ($F = 0.07$; $df = 1$; $p = 0.79$). Regarding the number of individuals identified, differences were observed between each macrohabitat ($F = 0.58$; $df = 2$; $p = 0.56$) and no differences were observed between periods assessed ($F = 0.06$; $df = 1$; $p = 0.80$). Monoespecific and polyespecific forests varied with regard to richness relative to flooded grassland macrohabitats. The richness of monoespecific forests and flooded grasslands differed according to period (flood and dry). This is in accordance with the observed increases in the number of species recorded in monospecific forests in dry periods, while similar increases in richness were recorded in flooded grassland areas in flooded periods (Supplementary Material 2).

### *Bird composition*

There were distinct clusters of macrohabitats observed within monoespecific and polyespecific forests and flooded grasslands (Figure 5). During the flood period (stress level = 0.18), the samples were increasingly dispersed; however, dissimilarity was observed between clusters represented by forest macrohabitats and grasslands. A higher level

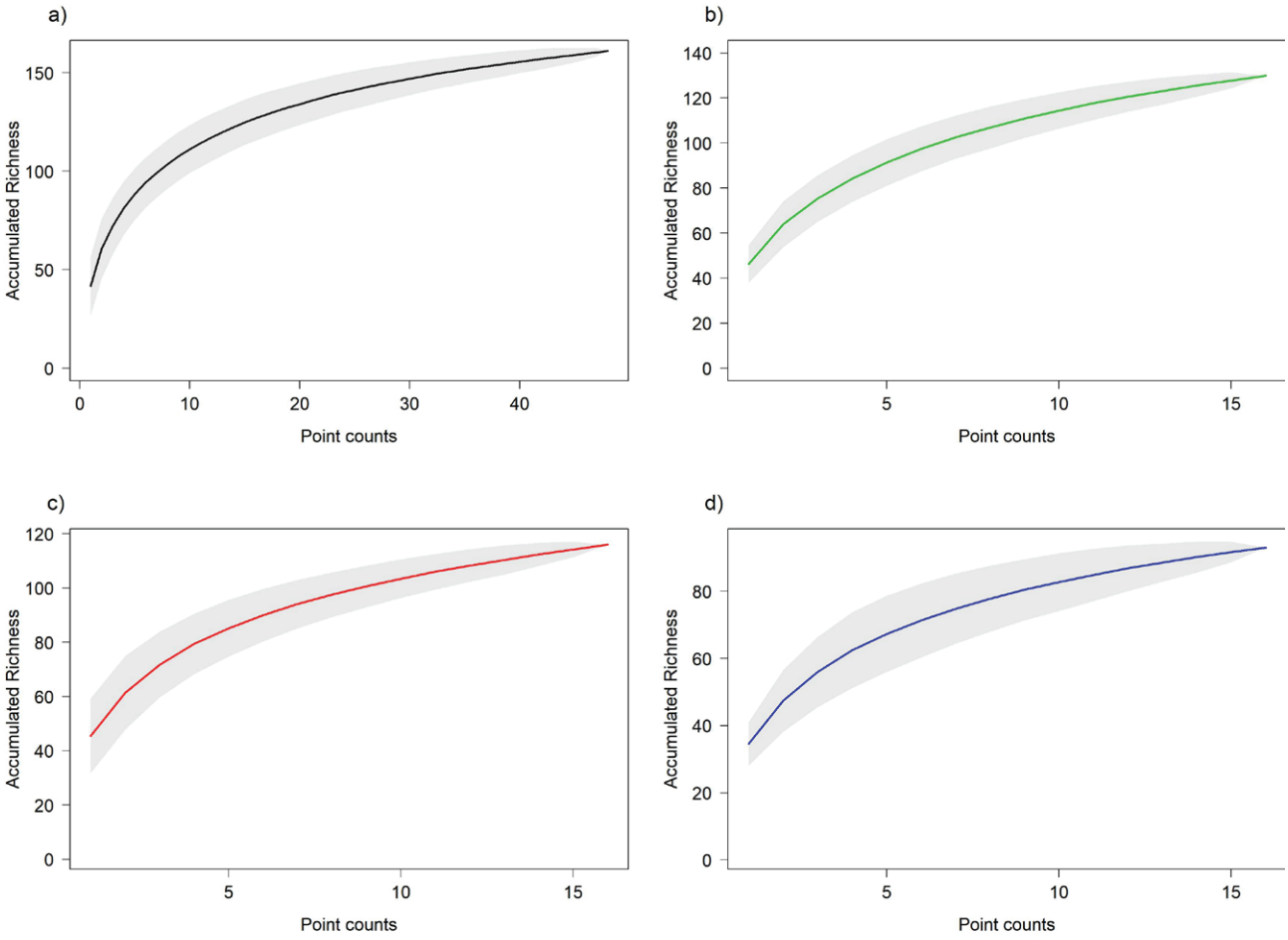


**Figure 3.** Rarefaction curves of bird species recorded in macrohabitats of the aquatic-terrestrial transition zone (ATTZ) of the Pantanal wetland, Brazil. a) Total richness; b) shrubland and pioneer polyespecific forest (PF); c) *Erythrina fusca* Lour. monospecific forest (MF); and d) flooded grassland (FG) were considered.

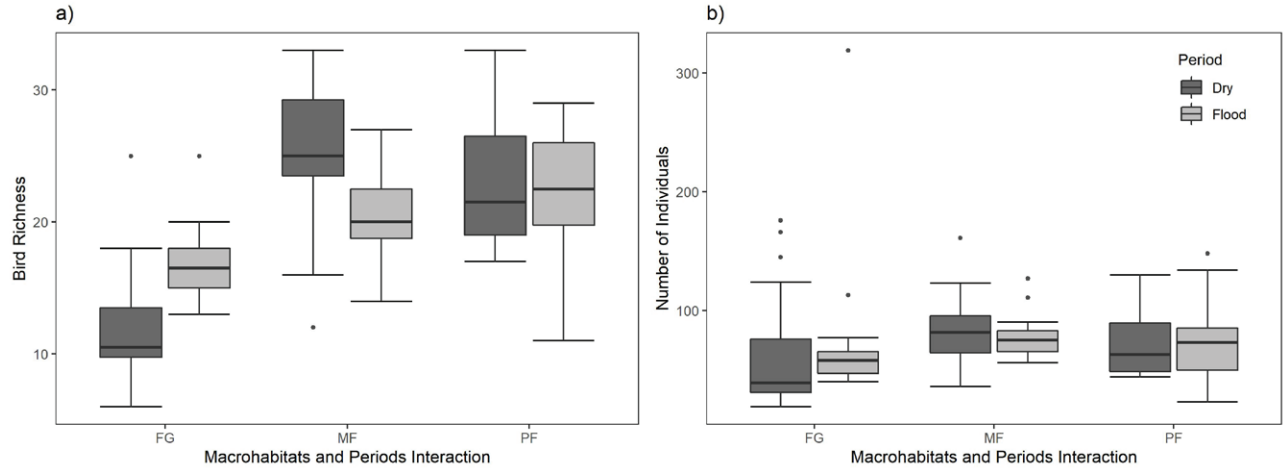


**Figure 4.** Richness (a) and the number of individuals (b) observed in macrohabitats and hydrological periods in the aquatic-terrestrial transition zone (ATTZ), Pantanal wetland, Brazil. Boxplots show median values (thick centre line), quartiles (lower and upper portions of boxes), maximum and minimum values (whiskers), and outliers (dots). Legend: *Erythrina fusca* Lour. monospecific forest (MF); Shrubland and Pioneer polyespecific forest (PF); Flooded grassland (FG).

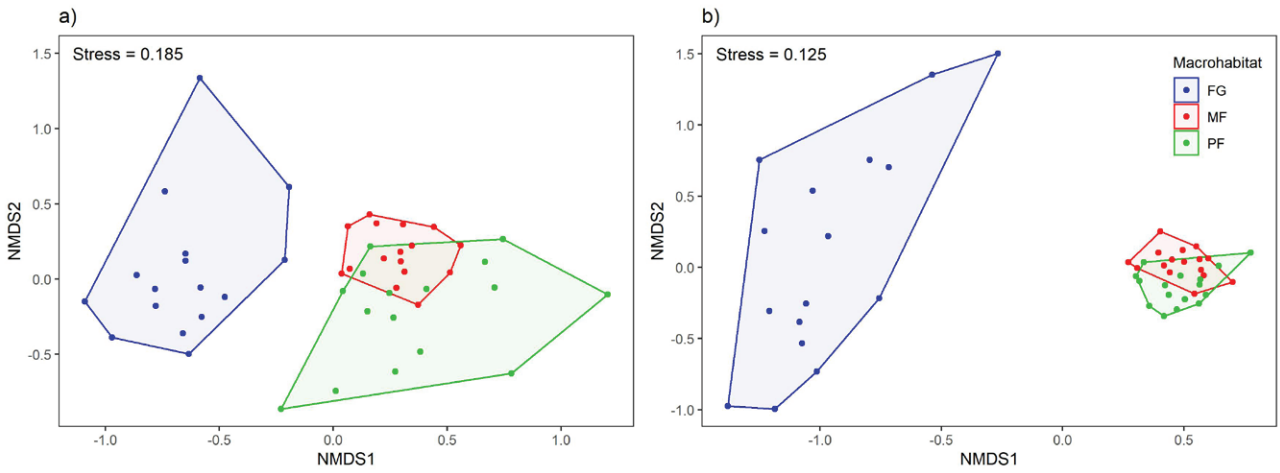


**Figure 5.** Non-metric multidimensional scaling (NMDS) analysis using Bray-Curtis distance based on 48 samples determining bird richness and abundance in ATTZ macrohabitats during flood (a) and dry (b) periods of the 2015–2016 hydrological cycle in the Pantanal wetland, Brazil. Legend: *Erythrina fusca* Lour. monospecific forest (MF); Shrubland and pioneer polyespecific forest (PF); Flooded grassland (FG).

of overlap of forest groups occurred during the dry period, and there was a difference between forests and flooded grasslands. Further the two areas of flooded grasslands also differed (stress level = 0.12). We observed a significant difference in species composition for both flood (ANOSIM, R = 0.53, $p < 0.01$) and dry (ANOSIM, R = 0.55, $p < 0.01$) periods.

We highlight that 72 % of the bird species recorded were identified in two or more types of macrohabitats and 27 % were found in a single type of macrohabitat. Of these, 65 species were distributed in multiple macrohabitats, 20 were exclusively present within the polyespecific forest, 18 were exclusively present within the flooded grassland and 10 were specific to the monoespecific forest. For example, *Phalaropus tricolor*, *Calidris fuscicollis* and *Egretta caerulea* were recorded exclusively in the flooded grassland macrohabitat. With regard to period, 58 % of the bird species identified were present in all sampling periods, while 32 % were exclusively identified in the dry period and 10 % were exclusive identified during periods of flooding (Appendix 1).

The relative abundance of birds present in macrohabitats should be considered with respect to ordering. Some species present in multiple macrohabitats, such as *Ageslaticus cyanopus*, had relatively high levels of abundance in the flooded grassland macrohabitat (8.15) relative to its abundance in polyespecific forest (1.12) and monoespecific forest (2.67) macrohabitats. This was also observed in other species, like *Phaetusa simplex*, which had levels of abundance reaching 3.44 in the flooded grassland habitat and 0.57 and 0.28 in polyespecific and monoespecific forests, respectively.

## DISCUSSION

We recorded 58% of birds known for this protected area and buffer zone (Frota et al. 2020). ATTZs composed of forested areas contained the greatest number of bird species. Islands in this region of the Paraguay River usually have high levels of tree diversity (Ikeda-Castrillon *et al.* 2011), and become habitats and the source of essential resources for even the most demanding birds, with regard to use of different vertical strata within the wetland environment. Grasslands had lower levels of observed richness than forest areas, possibly due to the limited number of places, such as perches in trees and shrubs, that provide shelter for species throughout the forest strata (Almeida *et al.* 2018).

Throughout drought periods in the Pantanal, there are an increased number of birds, which is associated with the reproductive season of plant species. This seasonal change results in increases in food supply (Yabe & Marques 2001), which include *E. fusca* flowers that are considered an important source of food (Parrini & Raposo 2010) and are monodominant in the TES (Frota *et al.* 2017). The richness of birds present in the monoespecific forest in the dry season is also affected by the breeding season of some birds

(Pinho & Marini 2014), as well as the partial or total movement of migratory species (Pinho *et al.* 2017, Somenzari *et al.* 2018). Bird abundance in the Pantanal may vary according to habitat type and species occurrence throughout the year (Cintra & Yamashita 1990). Riparian areas usually have a high abundance of bird species (Donatelli *et al.* 2017). The area contained within the TES is a refuge for biodiversity, as demonstrated by the richness and abundance recorded throughout both sampling periods. We emphasise here, that increases in abundance of birds in macrohabitats were affected by the presence of *Petrochelidon pyrrhonota*, a migratory bird that occurs in large flocks and forages.

Differences between the composition of macrohabitats revealed the environmental heterogeneity of this ATTZ. When comparing macrohabitats in flood and dry periods, we found that, despite dissimilarities, a good representation of bird species was achieved. We highlight the distinction between the flooded grassland and other macrohabitats evaluated, especially with respect to its range of species abundance. This sample unit is located in a region with a large degree of coverage of aquatic macrophytes and has been recognised as a breeding ground for aquatic organisms such as fish and invertebrates, which provide food and shelter for birds. However, it is only part of the buffer zone of the TES (Brasil 2017).

In addition, these flooded grasslands emerge during temporary drought areas such as sandy beaches and limnicolous habitats (i.e., mudflats), becoming essential for migratory birds such as *Rynchops niger* during their reproductive period (Schuchmann *et al.* 2018) and Scolopacidae during wintering (Oliveira *et al.* 2016). Moreover, during the flooded period, there is a high level of coverage of aquatic macrophytes that provide shelter for swamp birds that use this type of habitat for shelter, rest, nesting, courtship and foraging.

Most of the birds recorded in our study were considered to be generalists in ATTZs, following a trend observed by Figueira *et al.* (2006) in the Pantanal. However, we show that there are some preferences with respect to the use of macrohabitats when we observed forest and grasslands groupings in the evaluation of species composition. There was a distinction between the composition of birds observed in forest macrohabitats and grasslands in the two periods. Further a greater proximity (higher similarity) between the forest point count stations during the dry season was observed than throughout times of flooding. Increased levels of similarity observed between forest macrohabitats in the dry season may be related to water level decreases in the Paraguay River in the region of Cáceres (Frota *et al.* 2017), which could result in the spread of understory and ground species, such as *Furnarius leucopus* and *Synallaxis albilora*, to additional macrohabitats.

In floodplains, habitat use and distribution of species depend on hydrological characteristics of the area that influence the richness, abundance, and composition of birds (Donatelli *et al.* 2014, 2017, Almeida *et al.* 2016). This was also observed in our study, since there was a difference in the arrangement of bird community represented by point counts within macrohabitats in both hydrological periods. Among the factors that influence changes in the bird community are structural aspects of macrohabitats that increased resource availability in forests, and the emergence of temporary habitats (e.g. beaches) in flooded grassland areas.

The community structure for birds in ATTZs evaluated in our study varied according to the habitat availability, type and period of this wetland landscape. The fact that ATTZs undergo natural changes caused by the flood pulse in the Pantanal suggests that birds occur in different patterns in macrohabitats over the years in accordance with the hydrological regime, which we observed in our analysis of species composition between periods.

The TES is a protected area important for the maintenance of biodiversity associated with heterogeneous macrohabitats of ATTZs. We emphasise the need to expand this protection area, since its buffer zone has been determined to be ecologically important. Biodiversity and the water habitat of the region are affected both directly and indirectly by the exploitation of natural resources in the Upper Paraguay River Basin. In addition, we encourage the implementation of an increasingly integrated and detailed monitoring system that will help researchers understand the ecological dynamics of birds and other organisms in this wetland ecosystem.

## ACKNOWLEDGMENTS

We thank *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior* (CAPES) for a scholarship granted to AVBF and BDV. To the *Programa de Pós-Graduação em Ciências Ambientais, Centro de Pesquisa em Limnologia, Biodiversidade e Etnobiologia do Pantanal* and *Universidade do Estado de Mato Grosso* (PPGCA/CELBE/UNEMAT) for technical support. Thank *Instituto Chico Mendes de Conservação da Biodiversidade* and *Taiamã* Ecological Station (ICMBio/TES) for the logistic support. To *Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis* (IBAMA) by the license number 50928-1 provided to execution out this research. We also thank to anonymous referees for all the suggestions and valuable contributions in the early version of the article.

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*Submitted: 10 June 2019*
*Accepted: 12 December 2019*
*Published on line: 20 December 2019*
*Associate Editor: Nuria Pistón*

**Supplementary Material 1.** Sampling sites represented by macrohabitats of ATTZs with two sites for each type of macrohabitat.

**Supplementary Material 2.** Interaction between macrohabitat and period with respect to species richness.

**Appendix 1.** List of bird species recorded in a macrohabitat survey of an Aquatic-Terrestrial Transition Zone (ATTZ) in the Ramsar site within the Taiamã Ecological Station, Pantanal Wetland, Brazil. Legend: Migratory behaviour (Somenzari *et al.* 2018): Migrant (MGT), Parcial migrant (MPR) and Not defined (ND). Type of macrohabitat: *Erythrina fusca* Lour. Monospecific forest (MF); Shrubland and Pioneer polyespecific forest (PF); Flooded grassland (FG).

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| Anseriformes Linnaeus, 1758 | | | | | |
| Anhimidae Stejneger, 1885 | | | | | |
| *Chauna torquata* (Oken, 1816) | Southern Screamer | | 0.51 | 0.61 | 2.05 |
| Anatidae Leach, 1820 | | | | | |
| *Dendrocygna viduata* (Linnaeus, 1766) | White-faced Whistling-Duck | | | | 0.55 |
| *Dendrocygna autumnalis* (Linnaeus, 1758) | Black-bellied Whistling-Duck | | 0.75 | 0.11 | 0.03 |
| *Cairina moschata* (Linnaeus, 1758) | Muscovy Duck | | 0.02 | 0.04 | |
| Galliformes Linnaeus, 1758 | | | | | |
| Cracidae Rafinesque, 1815 | | | | | |
| *Aburria cumanensis* (Jacquin, 1784) | Blue-throated Piping-Guan | | 0.26 | 0.07 | |
| *Aburria cujubi* (Pelzeln, 1858) | Red-throated Piping-Guan | | 0.02 | 0.04 | |
| *Ortalis canicollis* (Wagler, 1830) | Chaco Chachalaca | | 2.54 | 3.66 | 0.19 |
| *Crax fasciolata* Spix, 1825 | Bare-faced Curassow | | 0.11 | 0.09 | |
| Ciconiiformes Bonaparte, 1854 | | | | | |
| Ciconiidae Sundevall, 1836 | | | | | |
| *Jabiru mycteria* (Lichtenstein, 1819) | Jabiru | | | 0.02 | 0.12 |
| *Mycteria americana* Linnaeus, 1758 | Wood Stork | | 0.06 | | 0.07 |
| Suliformes Sharpe, 1891 | | | | | |
| Phalacrocoracidae Reichenbach, 1849 | | | | | |
| *Nannopterum brasilianus* (Gmelin, 1789) | Neotropic Cormorant | | 7.1 | 6.49 | 7.85 |
| Anhingidae Reichenbach, 1849 | | | | | |
| *Anhinga anhinga* (Linnaeus, 1766) | Anhinga | | 1.92 | 1.6 | 0.31 |
| Pelecaniformes Sharpe, 1891 | | | | | |
| Ardeidae Leach, 1820 | | | | | |
| *Tigrisoma lineatum* (Boddaert, 1783) | Rufescent Tiger-Heron | | 0.96 | 0.64 | 0.45 |
| *Cochlearius cochlearius* (Linnaeus, 1766) | Boat-billed Heron | | 0.17 | 0.37 | |
| *Ixobrychus exilis* (Gmelin, 1789) | Least Bittern | | 0.87 | 0.13 | 0.83 |
| *Butorides striata* (Linnaeus, 1758) | Striated Heron | | 2.13 | 2.06 | 0.86 |
| *Bubulcus ibis* (Linnaeus, 1758) | Cattle Egret | | 0.09 | 0.04 | 0.12 |
| *Ardea cocoi* Linnaeus, 1766 | Cocoi Heron | | 1.13 | 2.02 | 2.23 |
| *Ardea alba* Linnaeus, 1758 | Great Egret | | 1.02 | 1.67 | 3.13 |

**Appendix 1:** Continued on next page...

**Appendix 1:** ...Continued

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| *Egretta thula* (Molina, 1782) | Snowy Egret | | 0.06 | 1.23 | 0.04 |
| *Egretta caerulea* (Linnaeus, 1758) | Little Blue Heron | | | | 0.03 |
| Threskiornithidae Poche, 1904 | | | | | |
| *Mesembrinibis cayennensis* (Gmelin, 1789) | Green Ibis | | 0.24 | 0.26 | 0.09 |
| *Theristicus caerulescens* (Vieillot, 1817) | Plumbeous Ibis | | | 0.04 | |
| *Theristicus caudatus* (Boddaert, 1783) | Buff-necked Ibis | | | 0.04 | 0.07 |
| *Platalea ajaja* Linnaeus, 1758 | Roseate Spoonbill | MPR | | | 0.13 |
| Cathartiformes Seebohm, 1890 | | | | | |
| Cathartidae Lafresnaye, 1839 | | | | | |
| *Cathartes aura* (Linnaeus, 1758) | Turkey Vulture | | 0.09 | 0.13 | 0.15 |
| *Cathartes burrovianus* Cassin, 1845 | Lesser Yellow-headed Vulture | | 0.49 | 0.39 | 0.09 |
| *Coragyps atratus* (Bechstein, 1793) | Black Vulture | | 0.17 | 0.75 | 0.34 |
| Accipitriformes Bonaparte, 1831 | | | | | |
| Accipitridae Vigors, 1824 | | | | | |
| *Ictinia mississippiensis* (Wilson, 1811) | Mississippi Kite | MGT | 0.02 | | |
| *Busarellus nigricollis* (Latham, 1790) | Black-collared Hawk | | 0.09 | 0.09 | 0.04 |
| *Rostrhamus sociabilis* (Vieillot, 1817) | Snail Kite | MPR | 6.78 | 1.56 | 0.39 |
| *Geranospiza caerulescens* (Vieillot, 1817) | Crane Hawk | | 0.06 | 0.18 | 0.04 |
| *Heterospizias meridionalis* (Latham, 1790) | Savanna Hawk | | | 0.04 | 0.06 |
| *Urubitinga urubitinga* (Gmelin, 1788) | Great Black Hawk | | 0.13 | 0.09 | 0.06 |
| *Rupornis magnirostris* (Gmelin, 1788) | Roadside Hawk | | | 0.07 | |
| Gruiformes Bonaparte, 1854 | | | | | |
| Aramidae Bonaparte, 1852 | | | | | |
| *Aramus guarauna* (Linnaeus, 1766) | Limpkin | | 0.17 | 0.04 | 0.06 |
| Rallidae Rafinesque, 1815 | | | | | |
| *Aramides cajaneus* (Statius Muller, 1776) | Gray-necked Wood-Rail | | | 0.02 | |
| *Mustelirallus albicollis* (Vieillot, 1819) | Ash-throated Crake | | | 0.02 | 0.15 |
| *Porphyrio flavirostris* (Gmelin, 1789) | Azure Gallinule | ND | | | 0.22 |
| Heliornithidae Gray, 1840 | | | | | |
| *Heliornis fulica* (Boddaert, 1783) | Sungrebe | | 0.13 | 0.09 | 0.07 |
| Charadriiformes Huxley, 1867 | | | | | |
| Charadriidae Leach, 1820 | | | | | |
| *Vanellus cayanus* (Latham, 1790) | Pied Lapwing | | | | 0.03 |
| *Vanellus chilensis* (Molina, 1782) | Southern Lapwing | | | 0.07 | 0.25 |
| *Charadrius collaris* Vieillot, 1818 | Collared Plover | | | | 0.12 |

**Appendix 1:** Continued on next page...

**Appendix 1:** ...Continued

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| Recurvirostridae Bonaparte, 1831 | | | | | |
| *Himantopus melanurus* Vieillot, 1817 | White-backed Stilt | | | | 0.04 |
| Scolopacidae Rafinesque, 1815 | | | | | |
| *Actitis macularius* (Linnaeus, 1766) | Spotted Sandpiper | MGT | 0.04 | | |
| *Tringa solitaria* Wilson, 1813 | Solitary Sandpiper | MGT | | | 0.03 |
| *Tringa flavipes* (Gmelin, 1789) | Lesser Yellowlegs | MGT | | | 0.12 |
| *Calidris fuscicollis* (Vieillot, 1819) | White-rumped Sandpiper | MGT | | | 0.01 |
| *Calidris melanotos* (Vieillot, 1819) | Pectoral Sandpiper | MGT | | | 0.01 |
| *Phalaropus tricolor* (Vieillot, 1819) | Wilson's Phalarope | MGT | | | 0.01 |
| Jacanidae Chenu & Des Murs, 1854 | | | | | |
| *Jacana jacana* (Linnaeus, 1766) | Wattled Jacana | | 0.7 | 0.39 | 2.15 |
| Sternidae Vigors, 1825 | | | | | |
| *Sternula superciliaris* (Vieillot, 1819) | Yellow-billed Tern | | 0.04 | 0.2 | 1.31 |
| *Phaetusa simplex* (Gmelin, 1789) | Large-billed Tern | | 0.28 | 0.57 | 3.44 |
| Rynchopidae Bonaparte, 1838 | | | | | |
| *Rynchops niger* Linnaeus, 1758 | Black Skimmer | MPR | 0.02 | | 0.37 |
| Columbiformes Latham, 1790 | | | | | |
| Columbidae Leach, 1820 | | | | | |
| *Columbina talpacoti* (Temminck, 1810) | Ruddy Ground-Dove | | | | 0.03 |
| *Claravis pretiosa* (Ferrari-Perez, 1886) | Blue Ground-Dove | | 0.02 | | |
| *Patagioenas picazuro* (Temminck, 1813) | Picazuro Pigeon | | | 0.09 | 0.04 |
| *Patagioenas cayennensis* (Bonnaterre, 1792) | Pale-vented Pigeon | | 6.12 | 5.07 | 1.01 |
| *Leptotila verreauxi* Bonaparte, 1855 | White-tipped Dove | | 0.51 | 0.77 | 0.04 |
| *Leptotila rufaxilla* (Richard & Bernard, 1792) | Gray-fronted Dove | | 0.08 | 0.13 | |
| Cuculiformes Wagler, 1830 | | | | | |
| Cuculidae Leach, 1820 | | | | | |
| *Coccycua minuta* (Vieillot, 1817) | Little Cuckoo | | 0.09 | 0.07 | 0.22 |
| *Piaya cayana* (Linnaeus, 1766) | Squirrel Cuckoo | | 0.04 | 0.22 | |
| *Crotophaga major* Gmelin, 1788 | Greater Ani | | 1.58 | 1.14 | |
| *Crotophaga ani* Linnaeus, 1758 | Smooth-billed Ani | | 1.39 | 0.97 | 1.62 |
| *Tapera naevia* (Linnaeus, 1766) | Striped Cuckoo | | 0.04 | 0.02 | 0.31 |
| Strigiformes Wagler, 1830 | | | | | |
| Strigidae Leach, 1820 | | | | | |
| *Bubo virginianus* (Gmelin, 1788) | Great Horned Owl | | | 0.04 | |
| *Glaucidium brasilianum* (Gmelin, 1788) | Ferruginous Pygmy-Owl | | 0.04 | 0.04 | |

**Appendix 1:** Continued on next page...

**Appendix 1:** ...Continued

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| Nyctibiiformes Yuri et al., 2013 | | | | | |
| Nyctibiidae Chenu & Des Murs, 1851 | | | | | |
| *Nyctibius griseus* (Gmelin, 1789) | Common Potoo | | 0.02 | 0.02 | |
| Caprimulgiformes Ridgway, 1881 | | | | | |
| Caprimulgidae Vigors, 1825 | | | | | |
| *Nyctidromus albicollis* (Gmelin, 1789) | Common Pauraque | | 0.02 | 0.22 | |
| Apodiformes Peters, 1940 | | | | | |
| Trochilidae Vigors, 1825 | | | | | |
| *Phaethornis subochraceus* Todd, 1915 | Buff-bellied Hermit | | | 0.09 | |
| *Phaethornis pretrei* (Lesson & Delattre, 1839) | Planalto Hermit | | | 0.02 | |
| *Hylocharis chrysura* (Shaw, 1812) | Gilded Hummingbird | | 0.06 | 0.04 | |
| *Polytmus guainumbi* (Pallas, 1764) | White-tailed Goldenthroat | | | | 0.04 |
| Trogoniformes A. O. U., 1886 | | | | | |
| Trogonidae Lesson, 1828 | | | | | |
| *Trogon curucui* Linnaeus, 1766 | Blue-crowned Trogon | | 0.24 | 0.42 | |
| Coraciiformes Forbes, 1844 | | | | | |
| Alcedinidae Rafinesque, 1815 | | | | | |
| *Megaceryle torquata* (Linnaeus, 1766) | Ringed Kingfisher | | 0.55 | 0.37 | 0.06 |
| *Chloroceryle amazona* (Latham, 1790) | Amazon Kingfisher | | 0.15 | 0.02 | 0.01 |
| *Chloroceryle aenea* (Pallas, 1764) | American Pygmy Kingfisher | | 0.02 | 0.11 | 0.04 |
| *Chloroceryle americana* (Gmelin, 1788) | Green Kingfisher | | 0.32 | 0.11 | 0.1 |
| *Chloroceryle inda* (Linnaeus, 1766) | Green-and-rufous Kingfisher | | 0.09 | 0.07 | |
| Galbuliformes Fürbringer, 1888 | | | | | |
| Galbulidae Vigors, 1825 | | | | | |
| *Galbula ruficauda* Cuvier, 1816 | Rufous-tailed Jacamar | | 0.56 | 0.88 | 0.01 |
| Bucconidae Horsfield, 1821 | | | | | |
| *Monasa nigrifrons* (Spix, 1824) | Black-fronted Nunbird | | 0.26 | 0.42 | |
| Piciformes Meyer & Wolf, 1810 | | | | | |
| Ramphastidae Vigors, 1825 | | | | | |
| *Ramphastos toco* Statius Muller, 1776 | Toco Toucan | | 0.04 | 0.04 | 0.03 |
| *Pteroglossus castanotis* Gould, 1834 | Chestnut-eared Aracari | | | 0.07 | |
| Picidae Leach, 1820 | | | | | |
| *Veniliornis passerinus* (Linnaeus, 1766) | Little Woodpecker | | 0.17 | 0.39 | 0.01 |
| *Piculus chrysochloros* (Vieillot, 1818) | Golden-green Woodpecker | | 0.06 | 0.07 | |

**Appendix 1:** Continued on next page...

**Appendix 1:** ...Continued

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| *Colaptes melanochloros* (Gmelin, 1788) | Green-barred Woodpecker | | 0.02 | | |
| *Celeus lugubris* (Malherbe, 1851) | Pale-crested Woodpecker | | 0.06 | 0.07 | |
| *Celeus flavus* (Statius Muller, 1776) | Cream-colored Woodpecker | | | 0.02 | |
| *Campephilus melanoleucos* (Gmelin, 1788) | Crimson-crested Woodpecker | | 0.09 | | |
| Falconiformes Bonaparte, 1831 | | | | | |
| Falconidae Leach, 1820 | | | | | |
| *Caracara plancus* (Miller, 1777) | Southern Caracara | | 0.19 | 0.2 | 0.36 |
| *Herpetotheres cachinnans* (Linnaeus, 1758) | Laughing Falcon | | | 0.02 | |
| *Falco rufigularis* Daudin, 1800 | Bat Falcon | | 0.06 | 0.07 | |
| Psittaciformes Wagler, 1830 | | | | | |
| Psittacidae Rafinesque, 1815 | | | | | |
| *Primolius auricollis* (Cassin, 1853) | Yellow-collared Macaw | | 0.11 | 0.09 | 0.03 |
| *Diopsittaca nobilis* (Linnaeus, 1758) | Red-shouldered Macaw | | 0.23 | 0.55 | |
| *Psittacara leucophthalmus* (Statius Muller, 1776) | White-eyed Parakeet | | 0.47 | 0.09 | 0.7 |
| *Myiopsitta monachus* (Boddaert, 1783) | Monk Parakeet | | 4.97 | 4.91 | 2.06 |
| *Brotogeris chiriri* (Vieillot, 1818) | Yellow-chevroned Parakeet | | 1.51 | 0.39 | 0.37 |
| *Pionus maximiliani* (Kuhl, 1820) | Scaly-headed Parrot | | 0.04 | 2 | |
| *Amazona amazonica* (Linnaeus, 1766) | Orange-winged Parrot | | 0.02 | 0.02 | |
| *Amazona aestiva* (Linnaeus, 1758) | Turquoise-fronted Parrot | | 1.47 | 1.97 | |
| Passeriformes Linnaeus, 1758 | | | | | |
| Thamnophilidae Swainson, 1824 | | | | | |
| *Thamnophilus doliatus* (Linnaeus, 1764) | Barred Antshrike | | 0.06 | | |
| *Taraba major* (Vieillot, 1816) | Great Antshrike | | 1.22 | 0.92 | 1.02 |
| *Hypocnemoides maculicauda* (Pelzeln, 1868) | Band-tailed Antbird | | | 0.04 | |
| *Cercomacra melanaria* (Ménétriès, 1835) | Mato Grosso Antbird | | 0.21 | 2 | 0.93 |
| Dendrocolaptidae Gray, 1840 | | | | | |
| *Xiphorhynchus guttatoides (Lafresnaye, 1850)* | Buff-throated Woodcreeper | | 0.02 | 0.02 | |
| *Campylorhamphus trochilirostris* (Lichtenstein, 1820) | Red-billed Scythebill | | 0.02 | 0.04 | |

**Appendix 1:** Continued on next page...

**Appendix 1:** ...Continued

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| *Dendroplex picus* (Gmelin, 1788) | Straight-billed Woodcreeper | | 0.06 | | |
| Furnariidae Gray, 1840 | | | | | |
| *Furnarius leucopus* Swainson, 1838 | Pale-legged Hornero | | 0.68 | 1.01 | 0.04 |
| *Pseudoseisura unirufa* (d'Orbigny & Lafresnaye, 1838) | Rufous Cacholote | | 0.04 | 0.09 | 0.01 |
| *Phacellodomus ruber* (Vieillot, 1817) | Greater Thornbird | | 0.02 | 0.02 | 0.03 |
| *Certhiaxis cinnamomeus* (Gmelin, 1788) | Yellow-chinned Spinetail | | 0.51 | 0.02 | 0.61 |
| *Synallaxis hypospodia* Sclater, 1874 | Cinereous-breasted Spinetail | | | | 0.04 |
| *Synallaxis albilora* Pelzeln, 1856 | White-lored Spinetail | | 0.21 | 0.11 | |
| *Cranioleuca vulpina* (Pelzeln, 1856) | Rusty-backed Spinetail | | 0.36 | 0.18 | |
| Tityridae Gray, 1840 | | | | | |
| *Pachyramphus polychopterus* (Vieillot, 1818) | White-winged Becard | MPR | 0.02 | 0.02 | |
| Rhynchocyclidae Berlepsch, 1907 | | | | | |
| *Todirostrum cinereum* (Linnaeus, 1766) | Common Tody-Flycatcher | | 0.3 | 0.18 | 0.13 |
| *Poecilotriccus latirostris* (Pelzeln, 1868) | Rusty-fronted Tody-Flycatcher | | | 0.09 | |
| Tyrannidae Vigors, 1825 | | | | | |
| *Camptostoma obsoletum* (Temminck, 1824) | Southern Beardless-Tyrannulet | | | 0.02 | |
| *Elaenia spectabilis* Pelzeln, 1868 | Large Elaenia | MPR | 0.06 | | |
| *Attila bolivianus* Lafresnaye, 1848 | Dull-capped Attila | | | 0.07 | |
| *Myiarchus ferox* (Gmelin, 1789) | Short-crested Flycatcher | | | 0.07 | |
| *Pitangus sulphuratus* (Linnaeus, 1766) | Great Kiskadee | MPR | 4.97 | 4.21 | 1.42 |
| *Philohydor lictor* (Lichtenstein, 1823) | Lesser Kiskadee | | 0.17 | 0.33 | |
| *Megarynchus pitangua* (Linnaeus, 1766) | Boat-billed Flycatcher | | | 0.09 | |
| *Myiozetetes cayanensis* (Linnaeus, 1766) | Rusty-margined Flycatcher | | 0.9 | 0.77 | 0.15 |
| *Tyrannus melancholicus* Vieillot, 1819 | Tropical Kingbird | MPR | 2.11 | 0.86 | 0.73 |
| *Pyrocephalus rubinus* (Boddaert, 1783) | Vermilion Flycatcher | MPR | | | 0.01 |
| *Fluvicola albiventer* (Spix, 1825) | Black-backed Water-Tyrant | | 0.11 | 0.07 | 0.15 |
| *Arundinicola leucocephala* (Linnaeus, 1764) | White-headed Marsh Tyrant | | 0.04 | 0.02 | 0.25 |

**Appendix 1:** Continued on next page...

**Appendix 1:** ...Continued

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| Vireonidae Swainson, 1837 | | | | | |
| *Cyclarhis gujanensis* (Gmelin, 1789) | Rufous-browed Peppershrike | | 0.51 | 0.72 | |
| *Hylophilus pectoralis* Sclater, 1866 | Ashy-headed Greenlet | | | 0.04 | |
| Corvidae Leach, 1820 | | | | | |
| *Cyanocorax cyanomelas* (Vieillot, 1818) | Purplish Jay | | 0.06 | 0.02 | |
| Hirundinidae Rafinesque, 1815 | | | | | |
| *Stelgidopteryx ruficollis* (Vieillot, 1817) | Southern Rough-winged Swallow | MPR | 0.19 | 0.44 | 0.22 |
| *Progne tapera* (Vieillot, 1817) | Brown-chested Martin | MPR | 0.28 | 0.18 | 0.25 |
| *Tachycineta albiventer* (Boddaert, 1783) | White-winged Swallow | | 0.04 | 0.04 | |
| *Riparia riparia* (Linnaeus, 1758) | Bank Swallow | MGT | 0.28 | 0.02 | |
| *Hirundo rustica* Linnaeus, 1758 | Barn Swallow | MGT | 0.51 | 1.4 | 1.48 |
| *Petrochelidon pyrrhonota* (Vieillot, 1817) | Cliff Swallow | MPR | 5.51 | 15.49 | 39.92 |
| Troglodytidae Swainson, 1831 | | | | | |
| *Campylorhynchus turdinus* (Wied, 1831) | Thrush-like Wren | | 4.39 | 1.47 | |
| *Pheugopedius genibarbis* (Swainson, 1838) | Moustached Wren | | | 0.04 | |
| *Cantorchilus leucotis* (Lafresnaye, 1845) | Buff-breasted Wren | | | 0.02 | |
| Donacobiidae Aleixo & Pacheco, 2006 | | | | | |
| *Donacobius atricapilla* (Linnaeus, 1766) | Black-capped Donacobius | | 5.99 | 2.54 | 5.08 |
| Turdidae Rafinesque, 1815 | | | | | |
| *Turdus leucomelas* Vieillot, 1818 | Pale-breasted Thrush | | 0.04 | | |
| *Turdus rufiventris* Vieillot, 1818 | Rufous-bellied Thrush | | 0.08 | 0.09 | |
| Motacillidae Horsfield, 1821 | | | | | |
| *Anthus lutescens* Pucheran, 1855 | Yellowish Pipit | | | | 0.01 |
| Icteridae Vigors, 1825 | | | | | |
| *Procacicus solitarius* (Vieillot, 1816) | Solitary Black Cacique | | 2.15 | 1.93 | 0.33 |
| *Cacicus cela* (Linnaeus, 1758) | Yellow-rumped Cacique | | 6.78 | 7.15 | |
| *Icterus pyrrhopterus* (Vieillot, 1819) | Variable Oriole | | 0.11 | 0.37 | |
| *Icterus croconotus* (Wagler, 1829) | Orange-backed Troupial | | 1.39 | 0.81 | |
| *Amblyramphus holosericeus* (Scopoli, 1786) | Scarlet-headed Blackbird | | 0.06 | | 0.12 |

**Appendix 1:** Continued on next page...

**Appendix 1:** ...Continued

| Taxa | English Name | Migratory behavior | Relative Abundance (%) | | |
|---|---|---|---|---|---|
| | | | MF | PF | FG |
| *Agelasticus cyanopus* (Vieillot, 1819) | Unicolored Blackbird | | 2.67 | 1.12 | 8.15 |
| Thraupidae Cabanis, 1847 | | | | | |
| *Paroaria capitata* (d'Orbigny & Lafresnaye, 1837) | Yellow-billed Cardinal | | 2.52 | 1.51 | 1.68 |
| *Tangara sayaca* (Linnaeus, 1766) | Sayaca Tanager | | 0.08 | | |
| *Tangara palmarum* (Wied, 1821) | Palm Tanager | | | 0.11 | |
| *Ramphocelus carbo* (Pallas, 1764) | Silver-beaked Tanager | | 2.2 | 3.66 | 0.03 |
| *Sporophila collaris* (Boddaert, 1783) | Rusty-collared Seedeater | | 0.28 | 0.18 | 1.02 |
| *Sporophila caerulescens* (Vieillot, 1823) | Double-collared Seedeater | MPR | | | 0.04 |
| *Sporophila leucoptera* (Vieillot, 1817) | White-bellied Seedeater | | | 0.11 | 0.01 |
| *Saltator coerulescens* Vieillot, 1817 | Grayish Saltator | | 0.94 | 0.99 | 0.22 |
| *Saltator similis* d'Orbigny & Lafresnaye, 1837 | Green-winged Saltator | | 0.06 | 0.02 | |
| Fringillidae Leach, 1820 | | | | | |
| *Euphonia chlorotica* (Linnaeus, 1766) | Purple-throated Euphonia | | | 0.02 | |