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Distribution of birds in a naturally patchy forest environment in the Pantanal wetland, Brazil

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RESUMO. **Distribuição de espécies de aves em um mosaico natural de ambientes florestais na Planície do Pantanal, Brasil.** Habitats florestais contribuem consideravelmente para a diversidade de espécies em biomas dominados por fisionomias abertas, como o Cerrado e o Pantanal. Levantamentos por transectos foram realizados em cinco habitats florestais para examinar como a ocorrência e a freqüência relativa de espécies de aves estão associadas com a área do habitat na sub-região da Nhecolândia, Pantanal. Habitats florestais com maior área apresentaram um maior número de espécies do que aqueles de área mais reduzida, sendo este padrão também observado para as espécies exclusivas dos locais estudados. A freqüência relativa da maioria das espécies de aves diminuiu com a redução da área dos habitats; espécies de habitats abertos do Cerrado foram mais frequentes nos capões menores. Mudanças nas comunidades de aves covariaram significativamente com mudanças na área dos habitats (teste de Mantel: Z = 0,0371; t =2 ,8835; g.l. = ∞; P = 0,004; r = 0,904). Comunidades de aves mais similares tenderam a ser apresentadas por pares de habitats com as menores diferenças proporcionais entre suas áreas. Espécies habitat-generalistas dominaram a composição das comunidades em todos os locais. A proporção de espécies florestais nas comunidades diminuiu com a redução da área do habitat, enquanto que a proporção de espécies generalistas e de habitats abertos foi maior nos capões menores. O sítio com maior área apresentou a maior riqueza de espécies florestais, generalistas e aquáticas. Contudo, capões também podem desempenhar importante papel no mosaico de habitats da região, pois possivelmente funcionam como fonte de recursos e meio de dispersão para muitas espécies, apesar de aparentemente não suportarem toda a área de vida de muitas delas. O trabalho também sugere que uma eventual fragmentação de cordilheiras, pelo desmatamento que atualmente ocorre na região, poderá causar um considerável impacto negativo sobre a diversidade de espécies de aves da região.
PALAVRAS-CHAVE: comunidade de aves, manchas de floresta, ambiente em mosaico, planície, Pantanal, Brasil, Neotropical.

ABSTRACT. Forested habitats contribute considerably to species diversity in biomes dominated by open physiognomies, like the Cerrado and Pantanal. Transect surveys were conducted in five natural forest patches in the Nhecolândia sub-region of the Pantanal to determine how the occurrence and relative frequency of bird species were related to habitat patch size. Larger forest patches had more species than smaller ones, and this pattern also held for species restricted to each patch. The relative frequency of most bird species decreased with habitat size; species that use open habitats in the Cerrado were more frequent in the smaller patches. Changes in bird communities significantly covaried with changes in habitat patch areas (Mantel's Statistics: Z = 0.0371; t = 2.8835; d.f. = ∞; P = 0.004; r = 0.904). Higher similarity of bird communities tended to occur for pairs of habitats with proportionally less difference in area. Habitat generalists dominated the community composition of all sites. The proportion of forest species in communities decreased, but the proportion of generalist and open habitat species increased with decreasing patch area. The largest patch contained the greatest richness of forest, generalist and aquatic bird species. However, small forest patches might also have an important role in the regional habitat mosaic. These patches may provide resources and function as dispersal paths for birds, although they might not be sufficient to encompass the entire home range of many species. This study also suggests that eventual forest fragmentation by deforestation, now occurring in the region, will cause a considerable negative impact on the diversity of the Pantanal's bird species.
KEY WORDS: bird community, forest patches, patchy environment, Pantanal, wetland, Brazil, Neotropical.

In many tropical regions, habitats are becoming increasingly fragmented due to human activities. Such fragmentation is a major concern for conservation because the remaining wildlife populations tend to become increasingly isolated, with consequent genetic (Schonewald-cox *et al.* 1983) and demographic (Shaffer and Samson 1985) changes. The effects of fragmentation in the tropics have for the most part been studied in fragments that resulted from partial deforestation of extensive natural forests. Through this kind of habitat alteration, original environments usually become patchy and the remaining forest patches suffer an increasing edge effect, which can lead to changes in community structure and composition (Lovejoy *et al.* 1986, Laurance 1991, Laurance and Yensen 1991).

Large conservation reserves are undoubtedly essential to maintain the integrity and biodiversity of any ecosystem. However, some studies have also highlighted the importance of forest remnants for plant and animal communities. Amazonian forest remnants have been considered as important sources of organisms that may colonize secondary growth forests in abandoned agricultural lands (Nepstad *et al.* 1996). Merrill *et al.* (1998) showed that residual patches contribute to forest bird diversity in clearcuts and may enhance populations at regional scales. Further, in agricultural landscapes, even the lowest levels of tree density contribute to increase the bird diversity of farm fields (Greenberg 1996).

Information on the use of natural forest patches by birds can be relevant for regional conservation efforts, as it may help to predict the vulnerability of species to habitat destruction. In biomes dominated by open physiognomies, forest habitats strongly contribute to species diversity and

richness (Redford and Fonseca 1986, Stotz *et al.* 1996). Studies of naturally patchy forests are rare in the Neotropics. Only recently have bird communities been studied in this kind of environment (*e.g.* Anjos and Boçon 1999).

In the Pantanal wetland, the larger forest patches are currently being converted to pastures, resulting in further fragmentation of these habitats (Silva 1995), but no study has yet examined the impact on bird communities. The few studies conducted on bird species diversity in the Pantanal region primarily have resulted in annotated checklists, with some additional information on habitat, seasonal occurrence and abundance (Weinberg 1984, Brown Jr. 1986, Cintra and Yamashita 1990, Willis and Oniki 1990, Antas 1994). Additional information can be found in general references for the region (Dubs 1992, Sick 1997). No studies have been designed to investigate the response of bird communities to the natural patchiness of forested habitats in the central region of the Pantanal. This study examined how species primarily found in different landscape units (forested, aquatic and open habitats) of the habitat mosaic are distributed among the forest patches of the study area. Additionally, we assessed the similarity of bird communities among habitat patches of different sizes, as well as verified how important these patches would be for the bird diversity of the Pantanal.

STUDY AREA

The Pantanal wetland is a large floodplain (140,000 km²) located in the upper Paraguay River basin, with elevations ranging from 75 to 170 m above sea level. Seasonal inundation of the floodplain is the main ecological factor in the Pantanal ecosystem (Adámoli 1982). According to Adámoli (1982), four important South American floristic provinces converge within the Pantanal: the Cerrado (savanna of Central Brazil), Amazon Forest, Chaco, and Meridional Atlantic Forest (*"Floresta Paranaense"*). Adámoli (1982) also suggested that the Cerrado has the most influence over the Pantanal's flora.

The Pantanal vegetation consists of a mosaic of several forested and open habitats that vary in topography and flooding regime (Prance and Schaller 1982). Primary features of the Pantanal landscape are the *cordilheiras* - ancient sand dunes now covered by open savanna vegetation (cerrado *sensu stricto*), deciduous and semideciduous forests, and gallery forests (Ratter *et al.* 1988). The *cordilheiras*, which lie 1 to 2 m above the surrounding floodplain, generally are not flooded. They form narrow, elongated and often inter-connected forest corridors that are surrounded by grasslands that may or may not flood (Prance and Schaller 1982).

The main economic activity in the Pantanal has long been extensive cattle ranching, over very large areas. However, there is a recent tendency toward more intensive cattle production on cultivated pastures in upland (non-flooding) areas. The *cordilheiras* are the preferred sites for cultivated pastures, and are often deforested for this purpose.

We conducted fieldwork at the Fazenda Nhumirim Experimental Station (18°59'S, 56°39'W), which is run by the *Centro de Pesquisa Agropecuária do Pantanal* (CPAP/EMBRAPA). This 4,300 ha ranch is located in the Nhecolândia sub-region, central Pantanal (see Adámoli 1982), in the State of Mato Grosso do Sul, Brazil. The elevation is about 89 m above sea level. The rainy season occurs between November and April, with a dry season between May and October (Cadavid Garcia 1984). The study area contains vegetation that is typical of the region, including *cordilheira* forest corridors, as well as small forest patches (*capões*), near *cordilheiras*, that contain semideciduous forest and cerrado *sensu stricto* (Ratter *et al.* 1988). The main aquatic habitats are permanent and temporary fresh water (*baías*) and brackish (*salinas*) ponds.

METHODS

Bird surveys were conducted in January and February of 1991 and 1992 in five forest patches: four *capões* of different sizes (sites C1, C2, C3 and C4) and one *cordilheira* (COR site) (table 1). The smaller forest patches were about the same distance from the COR site, while the largest one (C4) was more isolated (table 1). The *capões* are scattered throughout the study area and function as "island bridges" between *cordilheiras*. This situation favors bird dispersal between forest patches and decreases the isolation effect. All study sites were exposed to cattle grazing and trampling.

Table 1. Area, approximate distance from the COR site, number of sampling periods, total number of species, and number of exclusive species for each study site at Nhumirim Ranch, Pantanal, Brazil.

Study sites	Area (m^2)	Distance to the COR site (m)	Number of samples	Total richness	Exclusive species
COR	564,600	-	240	127	58 (45%)
C4	25,000	500	160	73	11 (15%)
C3	7,450	50	144	60	1 (2%)
C2	260	50	120	38	2 (5%)
C1	25	30	96	20	-

The four smaller patches were sampled completely, while the COR site was sampled in a restricted area (about 5 ha including edges and interior). The bird surveys were conducted by walking in the forested sites (edge and interior zones), except site C1, which was too small to be entered. In this case, observations were conducted from outside, given that this patch was entirely visible. Presence / absence of each bird species detected by sight or sound over 30-min sampling periods was recorded at each study site from 06:00 to 10:30h and from 14:30 to 18:00h. Observations were not conducted at different sites in a single day and the number of observation periods conducted in each site on a given day was equal (16).

The sampling effort corresponds to the number of 30-min observation periods accumulated at each site. The relative frequency of each bird species was the ratio between the number of intervals in which it was recorded and the total number of intervals sampled at each site. Sampling at any study site terminated only if the accumulated richness remained unchanged for at least 12 consecutive hours (24 observation intervals). *Leptotila spp* in the Appendix contains records of *L. rufaxila* and *L. verreauxi*, because distinction between these two species was often difficult during the sampling periods.

Bird species were classified into four categories, according to their primary habitat, based on information from the literature (Negret 1983, Stotz *et al.* 1996, Sick 1997, Tubelis 1997). The physiognomic forms were based on Prance and Schaller (1982), Ratter *et al.* (1988) and Eiten (1993). These categories are:

- open habitat birds (O): include species that are most often found in non-flooded grasslands (*campo limpo* and *campo sujo*) and/or in open woodlands (*campo* cerrado and cerrado *sensu stricto*);
- forest birds (F): include species that primarily use gallery forests, deciduous and semideciduous forests, including the *cerradão*;
- aquatic birds (A): include species that are primarily found in ponds, rivers, marshes and flooded grasslands;
- habitat generalist birds (G): species not included in the other categories. They are often found in forested, open and/or aquatic habitats.

A Mantel test was used to verify how changes in bird community structure co-varied with changes in the patch area gradient. The relative frequency of each bird species in different patches was used in the bird matrix, and the log10 of the patch areas was used in the area matrix. The algorithm was based on Douglas and Endler (1982), and Sorensen's distance measure was utilized in the test.

To compare the bird species assemblages among the study sites, a dissimilarity coefficient (Chord Distance) was calculated, according to Ludwig and Reynolds (1988), so that two units with species abundance of approximately the same proportion, will be close in distance. The Chord Distance ranges from 0 to 1.41, and lower values indicate greater similarity between compared areas. This coefficient is a metric measurement that can use several types of data. Here, it was calculated from the relative frequency of each bird species in each study site.

RESULTS

Observations were made for a total of 120, 80, 72, 60 and 48 hours at sites COR, C4, C3, C2 and C1, respectively (table 1), although the number of species did not change after 66, 54, 48 and 23 hours of observation at sites C4, C3, C2, and C1, respectively. The species richness of site COR did not completely stabilize during the observation period, based on the shape of the richness curve. A total of 146 species was recorded in the study sites, distributed among 33 families and 121 genera (Appendix). We recorded 127 bird species in the *cordilheira* forest, including 4 species with uncertain identification, not listed in the Appendix. Fewer species were recorded in the smaller patches.

The 146 recorded bird species had different patterns of distribution among the five study sites. Seventy-two species (49% of the recorded species) were restricted to only one study site. The COR site had the higher number of exclusive species, such as *Crax fasciolata*, *Pipile pipile*, *Crypturellus undulatus*, *Celeus flavescens* and *Cnemotriccus fuscatus*, corresponding to 45% of the species observed in this site (table 1). Few or no species were exclusive to the smaller patches (table 1, Appendix). Of the 74 non-exclusive species, nine were recorded only in the larger sites (COR and C4), such as *Glaucidium brasilianum*, *Trogon curucui*, *Picumnus albosquamatus* and *Casiornis rufa* (Appendix). Fifteen species were restricted to the sites COR, C4 and C3 (Appendix). The frequency of occurrence for 10 of the 13 species recorded in all study sites, except site C1, decreased with decreasing patch size. Among them are species such as *Amazona aestiva*, *Brotogeris chiriri*, *Cyanocorax cyanomelas*, *Ortalis canicollis*, *Psarocolius decumanus* and *Ramphastos toco* (Appendix). Seventeen species were recorded in all study sites (Appendix) and appear to be less affected by the habitat patchiness. The frequency of occurrence of six species within this group was lowest in the COR site. They are *Crotophaga ani*, *Furnarius rufus*, *Gnorimopsar chopi*, *Guira guira*, *Machetornis rixosus* and *Myiopsitta monachus*.

Generalist and forest birds were dominant in the site COR's community. About 98% of forest species occurred in the COR site; less than 25% of forest species were found in smaller patches. The percentage of forest birds in each bird community decreased from COR to C1, while the percentage of open habitat and generalist birds increased from COR to C1 site (table 2). On the other hand, in the four *capões*, community composition was dominated by generalist and open habitat species, especially in C1, where forest and aquatic birds were not recorded (table 2).

Table 2. Number and percent of species in each bird category found in the study sites COR, C4, C3, C2 and C1, at Nhumirim Ranch, Pantanal, Brazil.

Species category	COR	C4	C3	C2	C1
Forested habitat	42 (34.1)	11 (15.1)	7 (11.7)	3 (7.9)	1 (0.05)
Open habitat	20 (16.3)	24 (32.9)	15 (25.0)	12 (31.6)	8 (40.0)
Aquatic habitat	13 (10.6)	6 (8.2)	7 (11.7)	3 (7.9)	0 (0.0)
Generalist	48 (39.0)	32 (43.8)	31 (51.6)	20 (52.6)	11 (0.55)
Total	123	73	60	38	20

Changes in the bird community structures co-varied significantly with variation in the area of the study sites (Mantel Statistics: $Z = 0.0371$, $t = 2.8835$, d.f. = ∞, $P = 0.004$, $r = 0.904$). The dissimilarity values suggest a positive association between bird community structure and the proportional difference in area (Log of the area ratio) of paired study sites (table 3). For example, highest similarity was found for the pairs C2-C1, COR-C4, and COR-C3, while lowest similarity occurred for the pairs COR-C1, COR-C2, and C4-C1 (table 3).

Table 3. Chord distances (above diagonal) and log of the area ratio (below diagonal) between the bird communities of five forest patches at Nhumirim Ranch, Pantanal, Brazil, January and February of 1991 and 1992.

Sites	COR	C4	C3	C2	C1
COR	-	0.614	0.615	0.961	1.157
C4	1.35	-	0.656	0.688	0.934
C3	1.88	0.53	-	0.782	0.949
C2	3.34	1.98	1.46	-	0.510
C1	4.35	3.00	2.47	1.02	-

DISCUSSION

Tropical bird species respond differently to forest fragmentation (Willis 1979, Bierregaard and Lovejoy 1989, Harper 1989, Newmark 1991). Despite the difference in scale, the results of our study could be considered similar to those of Willis (1979), in which certain groups of species were especially prone to extirpation in small woodlots. Among these species, Willis (1979) included large frugivorous species of the canopy (parrots and cotingids), large birds eating large insects, understory species, large hawks, insectivorous birds of bamboo thickets and other vegetational tangles, among others. In our study, the smaller study sites appear to be too small to support raptors and frugivorous birds. For example, *Herpetotheres cachinnans* and *Pipile pipile* were observed only in the COR site (Appendix). The tendency of most species to occur only in larger sites (COR and C4) indicates that smaller patches are inadequate for these species. These results suggest that the exclusive bird species of the *cordilheira* could be most affected by the fragmentation of this forested habitat.

In addition, our results were similar to those of Anjos and Boçon (1999) from natural forest patches of southern Brazil. They also recorded a diminishing proportion of forest bird species with decreasing patch size. This pattern may reflect differences in edge-to-interior ratio, such as has been found in fragmented forests (Laurance and Yensen 1991). Further, the increase in the proportion of edge-inhabiting bird species in relation to the reduction in patch size, as reported by Anjos and Boçon (1999), is similar to the results for generalist species in our study. It is important to consider that the classification of bird species into habitat categories, in both studies, is partially subjective and seems to be largely based on the habitat matrix in each study area. For example, *Polyborus plancus* and *Tyrannus melancholicus* were considered edge species by Anjos and Boçon (1999), but in our study area they were typically observed in forest edges, as well as in open woodlands and grasslands. These differences could be explained by the relatively simple habitat matrix in southern Brazil (forest and open habitats), while in the Pantanal a more complex habitat matrix is available for birds.

Most species with lower frequency in the COR site occurred in its edge and are birds of grasslands and open woodlands (Cintra and Yamashita 1990, Sick 1997, Tubelis 1997), such as *Furnarius rufus*, *Guira guira* and *Myiopsitta monachus*. Other open habitat bird species were present in several *capões* but not in the COR site, such as *Colaptes campestris*, *Leuconerpes candidus*, *Mimus saturninus* and *Pseudoseisura cristata*. These species may be avoiding the COR site, although its edge presents shrubs and tree species commonly found in open woodlands.

The strong association between the similarity of bird communities and the similarity in size among the study sites suggests that patch size appears to strongly determine bird community structures. Area is usually associated with bird distribution and abundance in forest fragments (Forman *et al.* 1976, Askins *et al.* 1987), as well as other factors, such as isolation (Harper 1989, Haas 1995), edge effects (Brittingham and Temple 1983, Kroodsma 1984, Lovejoy *et al.* 1986) and landscape effects (see Wiens 1997). Vegetation structure and composition also influence the structure of bird communities (Rotenberry and Wiens 1980, Bibby *et al.* 1985, Tubelis 1997). In our study, the smaller forest patches appear to be dominated by plants adapted to higher light conditions, thus differentiating them from the larger areas. Such plants are typical of the cerrado *sensu stricto*, but also occur along the borders of the *cordilheiras*. These factors may be determining the bird community compositon and structure in the studied patches at the Nhumirim ranch.

Other factors, such as vegetation types of adjacent ponds, distance from ponds, and the existence of important temporary resources (*e.g.*, carcasses, fruiting trees, dead trees and swarms of insects) within the patches may attract unusual birds, thereby contributing to increase species richness on patches. The cumulative effects of cattle grazing and trampling on the understory should not be neglected, because of their potential of strongly modifying the microhabitat structure (Johnson *et al.* 1997), with consequent effects on bird species distribution and abundance.

Because most *cordilheiras* are corridor-shaped, usually ranging from 50 to 200 m in width, the edge-to-area ratio tends to be large, and the presence of habitat-specialist species is likely to be restricted by the type and condition of the forest existing in these landscape units. Despite the greater number of species recorded in the *cordilheira* forest, the importance of *capões* must be considered. These natural patches might be important for species dispersal between

cordilheiras by attenuating the effect of isolation by distance. Our results suggest that these small patches might also provide important habitat features for several open habitat species, such as *Myiopsitta monachus*, *Nystalus maculatus* and *Colaptes campestris*. Finally, *capões* also provide roosting and nesting sites for wetland species usually present in the adjacent ponds, such as *Dendrocygna autumnalis*, *Chauna torquata*, *Rosthramus sociabilis*, *Busarellus nigricollis*, *Chloroceryle americana* and several colonial waterbirds.

The avifauna of the Nhumirim ranch does not represent the species richness of the floodplain, as bird species are not evenly distributed throughout the Pantanal. For example, species such as *Eurypyga helias*, *Monasa nigrifrons*, *Cacicus cela* and *Penelope ochrogaster* are regularly found in the northern Pantanal (Cintra and Yamashita 1990, Willis and Oniki 1990, Dubs 1992), but not in the central area. Also, species that seem to occur at very low densities in the Pantanal were not detected in this survey (e.g., *Sarcorhamphus papa* and *Harpyhaliaetus coronatus*). As 450 species were recorded until now in the wetland (Tubelis and Tomas *in press*), the 146 species recorded in this study represent 32.4% of the Pantanal's bird species richness.

CONCLUSIONS

This study has shown that in the naturally patchy forest environment of the Nhecolândia region of the Pantanal, bird communities are associated with the size of the forest patches. Although smaller forest patches presented less species richness, they also have an important role in the landscape because they may serve as foraging, resting and nesting sites for many bird species. The use of forest patches by birds from open and aquatic habitats suggests that maintenance of the habitat matrix integrity will be essential for conservation of bird diversity in the central Pantanal.

This study indicates that the eventual fragmentation of *cordilheira* forests will cause a considerable loss of bird species, not only those species exclusive to this habitat type, but also more demanding forest species, such as raptors and some frugivorous birds. Species of open habitats will likely increase in *cordilheira* fragments, depending on the degree of habitat disturbance, but bird diversity will decrease. The role of *cordilheiras* as dispersal corridors should not be ignored, especially for species dependent on forest habitats. Studies on habitat structure and dynamics, community structure, and biology and demography of some indicator species, including birds, are urgently needed in the region. Evaluation of the effects of habitat fragmentation is essential to develop sustainable management alternatives for *cordilheiras*, at ranch and regional levels, in order to conserve the faunal diversity in the Pantanal wetland.

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Appendix. Relative frequency (%) of bird species recorded in the forest patches at Nhumirim Ranch, Pantanal, Brazil. COR, C4, C3, C2 and C1 are the study sites (table 1) and PH indicates the categories of habitat utilization in the Pantanal and in its border areas: F = forest species, A = aquatic species, O = open habitat species and G = habitat generalist species.

Species	COR	C4	C3	C2	C1	PH
Crypturellus undulatus	4.2	-	-	-	-	F
Crypturellus parvirostris	1.2	-	-	-	-	O
Butorides striatus	-	1.8	-	-	-	A
Syrigma sibilatrix	3.7	3.1	-	-	-	O
Tigrisoma lineatum	3.7	3.1	2.1	2.3	-	A
Theristicus caerulescens	0.4	-	-	-	-	A
Coragyps atratus	0.8	-	-	-	-	G
Cathartes aura	0.8	-	-	-	-	G
Cathartes burrovianus	-	1.9	-	-	-	G
Dendrocygna autumnalis	2.1	0.6	2.8	-	-	A
Cairina moschata	1.2	-	-	-	-	A
Chauna torquata	0.4	-	-	-	-	A
Rostrhamus sociabilis	0.8	0.6	-	-	-	A
Rupornis magnirostris	18.0	3.1	4.1	-	-	G
Busarellus nigricollis	2.0	3.1	2.1	-	-	A
Buteogallus meridionalis	2.9	-	-	0.8	-	O
Buteogallus urubitinga	0.8	-	-	-	-	O
Geranospiza caerulescens	0.8	0.6	-	-	-	G
Herpetotheres cachinnans	0.8	-	-	-	-	F
Milvago chimachima	1.2	0.6	0.7	-	-	O
Polyborus plancus	2.1	1.9	1.4	-	-	G
Falco rufigularis	0.4	-	-	-	-	F
Falco sparverius	-	1.9	-	-	-	O
Ortalis canicollis	64.1	61.9	55.0	4.0	-	F
Pipile pipile	10.0	-	-	-	-	F
Crax fasciolata	4.2	-	-	-	-	F
Aramus guarauna	1.7	-	-	-	-	A
Aramides cajanea	3.3	-	2.0	-	-	A
Columba picazuro	0.8	-	-	-	-	G
Zenaida auriculata	-	1.2	-	-	-	O
Columbina talpacoti	4.2	4.4	3.5	2.3	-	O
Claravis pretiosa	0.4	-	-	-	-	G
Scardafella squammata	10.0	3.1	13.9	1.5	8.3	O
Leptotila spp	53.0	60.0	43.7	31.2	10.4	F
Ara ararauna	2.5	-	0.7	-	-	G
Ara chloroptera	-	1.2	-	-	-	G
Propyrrhura auricollis	1.2	-	-	-	-	F
Diopsittaca nobilis	1.6	-	2.0	-	-	G
Aratinga acuticaudata	4.5	2.5	3.5	-	-	G
Aratinga leucophthalmus	1.7	-	-	-	-	F
Aratinga aurea	10.1	12.0	8.3	4.7	-	O
Nandayus nenday	20.4	36.2	16.7	15.6	2.1	G
Myiopsitta monachus	3.7	30.6	20.8	11.7	5.2	O
Brotogeris chiriri	6.0	3.7	2.8	1.5	-	G
Amazona aestiva	6.6	4.0	3.5	2.5	-	G
Coccyzus melacoryphus	2.1	1.2	1.4	-	2.1	G

Appendix (cont.)

Species	COR	C4	C3	C2	C1	PH
Coccyzus americanus	0.8	3.7	0.7	3.1	4.1	G
Piaya cayana	13.0	-	-	-	-	F
Crotophaga ani	2.9	16.2	6.9	5.5	5.2	G
Crotophaga major	8.7	0.6	25.7	-	-	G
Guira guira	12.8	40.6	25.7	43.7	29.2	O
Dromococcyx phasianellus	0.8	-	-	-	-	F
Glaucidium brasilianum	1.7	0.6	-	-	-	F
Nyctidromus albicollis	0.8	-	-	-	-	G
Caprimulgus rufus	-	3.1	-	-	-	F
Caprimulgus parvulus	-	-	1.4	-	-	O
Hylocharis sapphirina	1.7	-	-	-	-	F
Hylocharis chrysura	5.0	5.0	4.2	-	-	G
Polytmus guainumbi	-	0.6	-	-	-	O
Trogon surrucura	8.0	11.9	-	-	-	F
Trogon curucui	6.2	9.3	-	-	-	F
Ceryle torquata	-	-	9.0	0.8	-	A
Galbula ruficauda	0.8	-	-	-	-	F
Nystalus maculatus	10.8	41.0	17.3	19.5	9.4	G
Pteroglossus castanotis	0.4	-	-	-	-	F
Ramphastos toco	13.7	1.9	4.8	7.0	-	G
Picumnus albosquamatus	13.3	1.9	-	-	-	F
Colaptes campestris	-	2.5	0.7	-	3.1	O
Colaptes melanochloros	4.6	3.1	9.0	7.8	-	G
Piculus chrysochloros	0.4	-	-	-	-	G
Celeus flavescens	6.7	-	-	-	-	F
Dryocopus lineatus	2.9	-	-	-	-	G
Melanerpes candidus	-	1.2	0.7	-	-	O
Veniliornis passerinus	21.7	41.2	7.6	7.0	3.1	G
Campephilus melanoleucos	3.3	-	-	-	-	G
Campephilus leucopogon	3.7	2.5	-	1.5	-	O
Taraba major	17.9	15.0	25.7	-	-	F
Thamnophilus doliatus	0.4	-	-	-	-	G
Thamnophilus punctatus	0.4	-	-	-	-	F
Formicivora rufa	7.1	-	-	-	-	O
Furnarius rufus	2.5	39.4	6.9	32.8	29.2	O
Synallaxis albilora	0.8	-	-	-	-	F
Poecilurus scutatus	0.8	-	-	-	-	F
Pseudoseisura cristata	-	31.8	1.4	-	-	O
Xiphocolaptes major	1.7	-	1.4	-	-	G
Dendrocolaptes platyrostris	0.8	-	-	-	-	F
Xiphorhynchus guttatus	1.2	-	0.7	-	-	F
Lepidocolaptes angustirostris	9.2	6.2	4.2	-	-	O
Campylorhamphus trochilirostris	18.3	17.5	7.6	4.0	13.5	G
Camptostoma obsoletum	0.8	-	-	-	-	G
Sublegatus modestus	0.8	-	-	-	-	F
Elaenia flavogaster	1.2	-	-	-	-	G
Serpophaga subcristata	0.4	-	-	-	-	F
Euscarthmus meloryphus	0.8	-	-	-	-	F
Hemitriccus margaritaceiventer	23.3	-	25.0	-	-	G
Todirostrum latirostre	1.2	-	-	-	-	F
Contopus cinereus	0.4	-	-	-	-	F
Lathrotriccus euleri	1.2	-	-	-	-	F
Cnemotriccus fuscatus	1.7	-	-	-	-	F
Xolmis velata	-	1.2	-	-	-	O

Appendix (cont.)

Species	COR	C4	C3	C2	C1	PH
Satrapa icterophrys	-	-	-	0.8	-	O
Machetornis rixosus	1.7	8.1	59.7	19.5	19.8	O
Casiornis rufa	15.0	1.9	-	-	-	F
Myiarchus ferox	13.3	4.4	-	-	-	G
Myiarchus tyrannulus	22.5	13.1	8.3	-	-	G
Pitangus sulphuratus	62.1	74.3	63.2	53.1	29.2	G
Megarhynchus pitangua	4.2	10.6	-	0.8	-	G
Myiodynastes maculatus	2.5	3.7	4.2	-	-	G
Legatus leucophaius	0.4	-	-	-	-	F
Tyrannus savana	0.4	-	-	-	-	O
Tyrannus melancholicus	-	-	-	2.3	-	G
Pachyramphus polychopterus	0.8	-	-	-	-	F
Cyanocorax cyanomelas	45.0	35.0	35.4	4.7	-	G
Cyanocorax chrysops	23.7	14.4	17.4	3.9	5.2	G
Campylorhynchus turdinus	32.5	35.0	21.0	2.3	-	G
Donacobius atricapillus	1.2	-	-	-	-	A
Polioptila dumicola	0.8	-	-	-	-	G
Turdus rufiventris	9.6	23.1	5.5	-	-	F
Turdus amaurochalinus	0.8	-	-	-	-	G
Mimus saturninus	-	3.7	-	3.9	11.5	O
Cyclarhis gujanensis	0.4	8.1	-	-	-	G
Nemosia pileata	0.8	-	-	-	-	F
Eucometis penicillata	0.8	-	-	-	-	F
Ramphocelus carbo	30.0	4.4	9.0	-	-	O
Thraupis sayaca	1.2	10.0	2.1	5.5	-	G
Thraupis palmarum	11.2	5.6	14.6	2.3	-	G
Euphonia chlorotica	1.7	-	-	-	-	F
Conirostrum speciosum	0.4	-	-	-	-	F
Volatinia jacarina	0.4	-	-	-	-	O
Sporophila collaris	10.4	3.1	7.8	-	-	A
Coryphospingus cuculatus	15.8	-	-	-	-	O
Paroaria capitata	-	3.1	-	-	-	O
Saltator similis	6.7	-	16.7	-	-	G
Saltator atricollis	-	0.6	-	-	-	O
Psarocolius decumanus	22.1	9.4	8.3	3.1	-	F
Cacicus solitarius	1.2	-	1.4	-	-	F
Icterus cayanensis	14.2	8.7	18.7	4.7	1.0	G
Icterus jamacaii	9.6	3.7	6.9	0.8	1.0	G
Agelaius cyanopus	0.4	-	2.0	2.1	-	A
Amblyrhamphus holosericeus	0.8	-	-	-	-	A
Gnorimopsar chopi	3.7	6.9	13.9	28.1	26.0	O
Scaphidura oryzivora	-	0.6	-	-	-	O

Nomenclature and sequence of bird species follow Sick (1997).