Bird Conservation International (2001) 11:13–25.

Effects of forest fragmentation on birds of the cerrado region, Brazil

MIGUEL Â. MARINI

Summary

Bird surveys were conducted through observations and mist-netting in six forest fragments in the cerrado region of central Brazil, to evaluate the effects of fragmentation on bird species richness and community composition. Smaller forest fragments had fewer species than larger fragments. The proportion of species in most foraging guilds did not change with forest size, except for that of granivores, which decreased as fragment size increased. The proportion of forest-dependent species increased significantly with increasing fragment size while that of semi-dependent species significantly decreased. Forest-dependent endemic birds, however, were not area sensitive, but appeared to be partially dependent on the flooded forests of the region. Conservation policies for the region should conserve both large and small forest fragments urgently, and flooded forests especially.

Introduction

The cerrado region, which covers 25% of Brazil, is a biome unique to the Neotropics. Its original vegetation consists of a mixture of grasslands, ''cerrado'' *sensu stricto* vegetation (a scrub-like savanna), dry-semideciduous forests, and gallery forests along watercourses. However, natural habitats of the cerrado have been rapidly converted into plantations, pasturelands and other habitats generating a mosaic of habitat fragments of variable size and degree of isolation. Today, only 6.6% of the region is in natural reserves, with the remaining area covered either by transformed (e.g. crops, urban areas) or managed (e.g. native pasture, timber exploitation) areas (Dias 1990). Willis and Oniki (1993) considered the Brazilian cerrado to be the most rapidly disappearing habitat in the world.

Habitat area is the best predictor of species number (richness) for many groups of organisms (Shafer 1990), with richness increasing with habitat patch size (Abbott 1980, Andrén 1994, Hagan *et al.* 1996). Few studies of bird communities in fragmented landscapes have been carried out in the Neotropical region (Turner 1996). Those that have are mostly from the Minimum Critical Size of Ecosystems Study (now Biological Dynamics of Forest Fragments Project) in Brazilian Amazon (e.g. Bierregaard and Lovejoy 1986, 1989, Bierregaard *et al.* 1992). The few other existing examples of species–area relationships in Neotropical forest fragments include Willis's (1979) study of three Atlantic Forest fragments, Leck's (1979) study of Ecuadorian forests, Kattan and Alvarez-López's (1996) study of Colombian Andes birds, and Christiansen and Pitter's (1997) and Anjos and Boçon's (1999) study of 3 and 12 forest fragments in south-east Brazil, respectively.

Considering the variety of habitats in the Neotropical region, and the existence of exceptions to the species-area relationship (review in Andrén 1994), patterns proposed for different biomes or regions of the world, especially temperate zones, should be evaluated for all Neotropical habitats before being widely accepted. For example, contrary to what has been shown in several regions of the world, Melo and Marini (1997) and Leite and Marini (1999) showed that predation rates on artificial nests do not increase with decreasing fragment size in south-eastern Brazilian forests.

The aim of this study was to compare bird communities between forest fragments of different sizes, by examining the relationship between forest fragment size and (1) bird species richness, (2) levels of bird forest dependence (dependent, semi-dependent and independent), and (3) foraging guilds.

Study area

The study was conducted between February 1994 and April 1996 in six forest fragments in the Triângulo Mineiro region (elevation ~ 800 m a.s.l.), near Uberlândia, Minas Gerais state, Brazil (Figure 1). Uberlândia has warm rainy summers (October–March) and cool dry winters (April–September) (Rosa *et al.* 1991), with a mean annual temperature of 22°C and mean annual rainfall of 1,550 mm.

Forest fragments ranged in size from 7.5 to 230 ha (Table 1), were surrounded in large part by pasture, and were separated from each other by a few to several hundred meters. Seventy-five percent of Uberlândia county has already been converted into pastures and crops. The dominant vegetation of the fragments was tropical dry forest. Fragments differed in the presence or absence of flooded forests, and with respect to the level of disturbance of the forest. Canopy height was usually between 15 and 20 m with some emergent trees up to 25 m. Details of the vegetation of the region can be found in Schiavini and Araújo (1989), Araújo and Haridasan (1997), Araújo *et al.* (1997), and Rodrigues and Araújo (1997).

Methods

Bird surveys were conducted mostly during the dry season (April–September), and never during periods of rain or strong wind. Observations occurred mainly in the mornings (06h00–11h00) by walking slowly (~1 km/hour), mostly on trails, along watercourses, and forest borders. Only birds heard and/or observed in the fragment or perched on a plant that was rooted in the fragment were recorded. Birds observed flying over the fragment were not included. Unidentified bird vocalizations were tape-recorded and identified subsequently.

Mist-netting was conducted to detect cryptic and shy species difficult to record during walks. Mist-netting was conducted mostly on permanent 500-m transects with 10–20 mist-nets (mesh size 35 mm), one at every 50 m. Nets were open mostly between 06h00 and 14h00, with total effort ranging from 316 to 824 mist-

https://doi.org/10.1017/S0959270901001034 Published online by Cambridge University Press

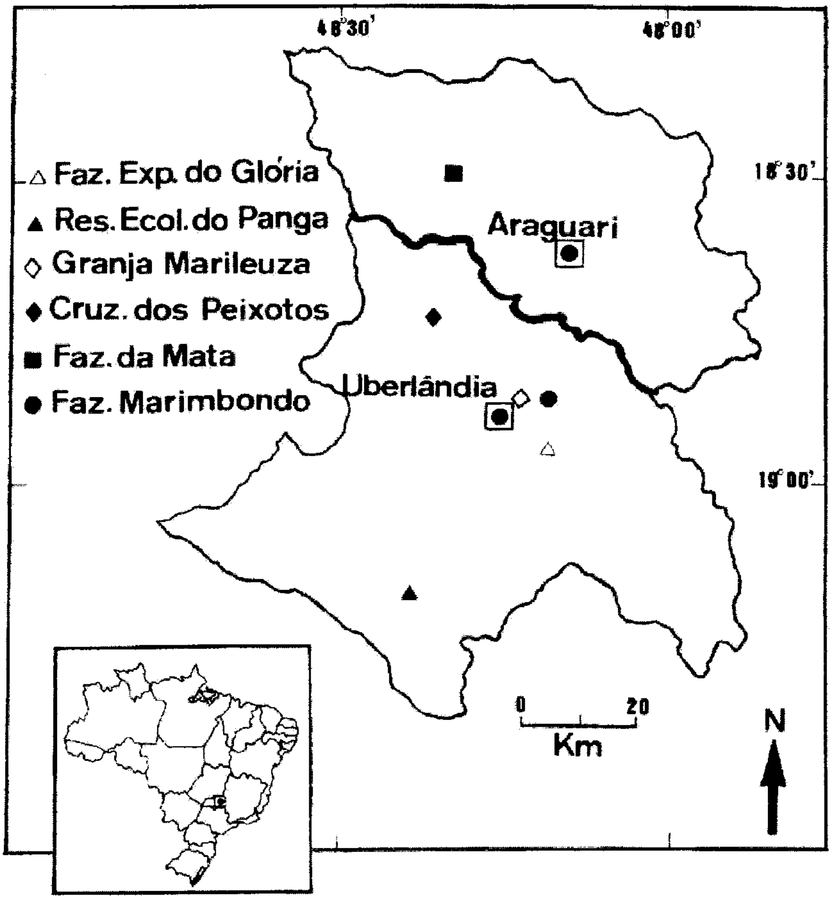

Figure 1. Map of the study area showing the five study sites at the Triângulo Mineiro region, Minas Gerais state, Brazil. The two smaller forest fragments (7.5 and 9 ha) were located at Granja Marileuza.

Table 1. Area, geographical coordinates, and total observation and mist-netting effort at six forest fragments in the Triângulo Mineiro region, Minas Gerais state, Brazil

Fragment	Area (ha)	Forest type (vegetation)	Geographical coordinates	Observation hours	Mist-net hours
Fazenda da Mata	230	Dry–humid	48°03′W; 18°30′S	51	676
Cruzeiro dos Peixotos	155	Dry	48°21′W; 18°46′S	45	611
Fazenda Experimental do Glória	54	Dry–humid	48°13′W; 18°52′S	40	824
Reserva Ecológica do Panga	24	Dry–humid	48°21′W; 19°11′S	32	549
Granja Marileuza (dry)	9	Dry	48°15′W; 18°52′S	24	339
Granja Marileuza (flooded)	7.5	Humid	48°15′W; 18°52′S	24	316
Total	479.5			216	3,315

https://doi.org/10.1017/S0959270901001034 Published online by Cambridge University Press

net hours (Table 1). One mist-net hour consisted of one 12-m net open for one hour. Captured birds received a numbered metal ring.

One of the strongest criticisms of species–area studies is that organisms are considered independently of their association with the habitat under consideration. Therefore, species were categorized by (a) their forest dependence (dependent, semi-dependent and independent), according to Silva (1995); (b) their endemism or quasi-endemism to the cerrado region or to Brazil, according to Sick (1997); and (c) their diet, following Willis (1979), Motta-Júnior (1990), Sick (1997) and personal observations.

Pearson's (r) correlation coefficients were calculated between dependent variables (log number of species, log number of genera) and forest fragment area (log ha). Analyses of changes in species composition by foraging guild and by habitat dependence were made using the percentage of species in each category, with total sampling effort as in Table 1. Pearson's (r) correlation coefficients between percentage of species in a guild category and fragment area were calculated after angular transformation (arcsine square root) of the percentage of species (Ott 1988). The same transformation was used for the percentage of species categorized by habitat dependence.

Results

Excluding aquatic (Threskiornithidae, Ardeidae and Alcedinidae), aerial (Falconiformes) and nocturnal (Tytonidae, Strigidae and Caprimulgidae) species, 145 species in 115 genera in all forest fragments were detected (Appendix 1), including 12 species of special conservation importance. Seven of these were forest-dependent species endemic or quasi-endemic to the cerrado region (Bare-faced Curassow *Crax fasciolata*, Large-billed Antwren *Herpsilochmus longirostris*, Sharp-tailed Streamcreeper *Lochmias nematura*, Russet-mantled Foliage-gleaner *Phylidor dimidiatus*, Chestnut-capped Foliage-Gleaner *Automolus rectirostris*, Helmeted Manakin *Antilophia galeata* and White-striped Warbler *Basileuterus leucophrys*) and five were species endemic or quasi-endemic to open areas of the cerrado region but also use forest fragments (Small-billed Tinamou *Crypturellus parvirostris*, Toco Toucan *Ramphastos toco*, Campo Flicker *Colaptes campestris*, Narrow-billed Woodcreeper *Lepidocolaptes angustirostris* and Curl-crested Jay *Cyanocorax cristatellus*).

Species richness increased with forest fragment size when considering both total sampling effort ($r = 0.951$, $df = 5$, $P = 0.004$) and initial sampling effort (first 24 hs of observation and first 320 hours of mist netting) for each fragment ($r = 0.829$, $df = 5$, $P = 0.042$) (Figure 2, Appendix 1).

The proportion of forest dependent species increased significantly ($r = 0.956$, $df = 5$, $P = 0.003$) with increasing fragment area (Figure 3), while that of semi-dependent species decreased significantly ($r = -0.946$, $df = 5$, $P = 0.004$), and the proportion of forest independent species did not change ($r = -0.604$, $df = 5$, $P = 0.204$) (Figure 3).

Endemic species did not appear to be area sensitive. The occurrence of forest-dependent endemic or quasi-endemic cerrado species did not follow the same pattern for all species, and was unrelated to forest fragment size for both sampling efforts (Table 2). With the exception of two forest endemics (Large-billed

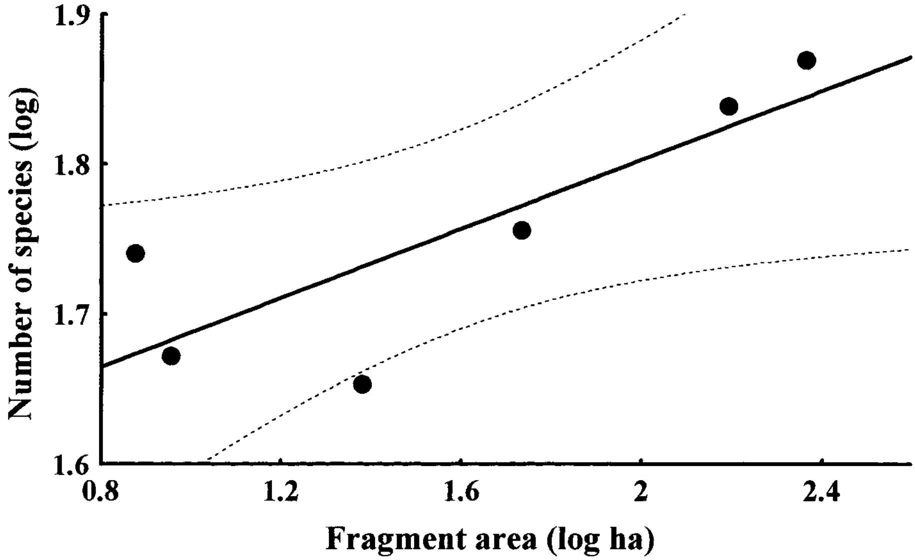

Figure 2. Correlation between log number of species and fragment size (log ha) for the six forest fragments at the Triângulo Mineiro region, Brazil. Sampling effort of 24 observation hours and of 32 mist-netting hours.

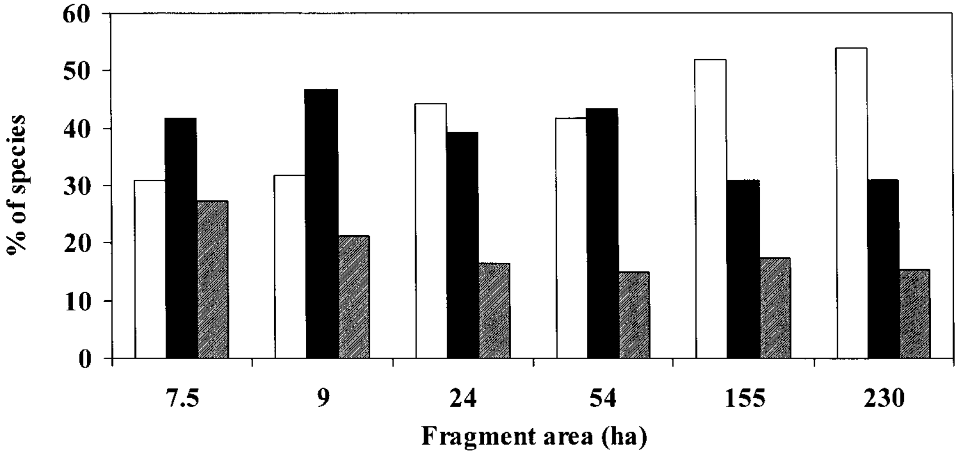

Figure 3. Percentage of forest-dependent (white bars), semi-dependent (solid bars) and independent (grey bars) species (from Silva 1995) recorded in each of six forest fragments at the Triângulo Mineiro region. Based on total sampling effort as in Table 1.

Antwren, Helmeted Manakin), the occurrence of the other five forest-dependent endemics was related to the presence of patches of flooded forest in the fragment (Tables 1 and 2).

Larger forest fragments had significantly more species exclusive to them (i.e. species exclusive to one fragment) than smaller fragments (Table 2), both for all species and for forest-dependent species, independent of sampling effort.

https://doi.org/10.1017/S0959270901001034 Published online by Cambridge University Press

Table 2. Number of species in selected species categories for six forest fragments in the Triângulo Mineiro region, Minas Gerais. Pearson's correlation coefficients (r) between species category and fragment area for total and controlled sampling efforts are given

Species category	Sampling effort[a]	Fragment area (ha)						r	P
		7.5	9	24	54	155	230		
Exclusive species									
	Total	3	2	2	7	7	21	0.874	0.023
	Controlled	3	4	2	7	11	15	0.855	0.030
Exclusive forest-dependent species									
	Total	0	1	0	1	5	15	0.860	0.028
	Controlled	0	1	0	2	9	9	0.871	0.024
Forest-dependent cerrado endemics									
	Total	6	2	5	7	2	7	0.109	0.837
	Controlled	6	2	5	7	2	4	−0.138	0.794

[a] Total, total sampling effort as in Table 1; controlled, same sampling effort for all forest fragments (first 24 observation hours and first 320 mist-netting hours).

Most bird species in fragments were insectivores (~ 50% of the species) and omnivores (~ 30% of the species), with small proportions of frugivores, granivores and nectarivores. The proportion of species in each foraging guild changed little with fragment size, except for that of granivorous species, which decreased significantly ($r = -0.937$, $df = 5$, $P = 0.006$) as fragment size increased. Proportions of all other foraging guilds varied randomly with fragment size (Table 3, data from Appendix 1).

Discussion

The number of species and genera was much greater in larger forest fragments than in smaller ones, as would be expected from a number of previous studies (reviews in Abbott 1980, Andrén 1994, Turner 1996). Smaller fragments had fewer forest dependent species than forest independent species, a pattern found also by Christiansen and Pitter (1997), while Aleixo and Vielliard (1995) found that 62% of bird species recorded in a 251 ha forest fragment were forest dependent, a value close to but higher than that at the 230 ha forest of this study.

Since the ratio of forest interior to forest border decreases with an increase in

Table 3. Number (%) of species recorded at six forest fragments in the Triângulo Mineiro region, Minas Gerais, Brazil, for each of five dietary groups. Pearson's correlation coefficients (r) and probability values for the correlations between fragment area and diet (percentage of species of diet guild) are also shown

Diet guild	Fragment area (ha)						r	P
	7.5	9	24	54	155	230		
Insectivore	26 (47.3)	19 (40.4)	31 (50.0)	34 (50.0)	39 (48.2)	53 (51.5)	0.650	0.163
Omnivore	15 (27.3)	15 (31.9)	19 (30.7)	20 (29.4)	25 (30.9)	30 (29.1)	0.071	0.894
Frugivore	5 (9.1)	6 (12.8)	2 (3.2)	4 (5.9)	7 (8.6)	10 (9.7)	−0.091	0.864
Granivore	6 (10.9)	5 (10.6)	6 (9.7)	6 (8.8)	5 (6.2)	4 (3.9)	−0.937	0.006
Nectarivore	3 (5.5)	2 (4.3)	4 (6.5)	4 (5.9)	5 (6.2)	5 (4.9)	0.231	0.660

fragment area, smaller fragments are expected to have fewer forest-dependent species and more forest-independent species, such as granivores. In this study, only the proportion of granivores in the total bird community varied with fragment size. Leck (1979) suggested that fringillids (which are granivores) are abundant and probably increasing near the forest fragment he studied at Ecuador. In temperate forests of Chile, mutualists (pollinators and fruit-dispersers) were less affected by fragmentation than non-forest mutualists (Willson *et al.* 1994). Also, Stouffer and Bierregaard (1995a) did not detect negative fragmentation effects on hummingbirds in the Amazon. The number of species and the number of individuals of understorey insectivores in Amazonian forest fragments decreased after isolation (Stouffer and Bierregaard 1995b).

Nest predation has been claimed to be a major cause of species loss in forest fragments (Ambuel and Temple 1983, Wilcove *et al.* 1986, Robinson *et al.* 1995). It is important to stress, however, that Melo and Marini (1997) found no relationship between forest size and artificial nest predation rates in 10 fragments (including the five largest) of the region studied here. Leite and Marini (1999) also found no relationship between artificial nest predation and forest area for 19 similar-sized forest fragments in a region 500 km distant. These two studies suggest that, at least at the current level of forest fragmentation in these regions, nest predation does not seem to be affecting the loss of species.

Birds that occur outside the cerrado biome as well as within it may become locally extinct in the cerrado without becoming globally extinct. Endemic species, however, become globally extinct when extirpated from their restricted range (Pimm and Askins 1995). Of the seven forest-dependent endemic or quasi-endemic cerrado species, only the Bare-faced Curassow seems to be at a significant threat of global extinction in the wild, probably because it is a large (2.7–2.8 kg, Sick 1997) frugivore that is hunted for meat. Some of the six other species, despite their apparent safety from global extinction through forest destruction, may be affected by the lack of appropriate habitat (flooded gallery forests, which is not abundant). Thus, even though these species do not seem to be area sensitive, they may suffer from the destruction of their specific habitat. Two cerrado endemics (Large-billed Antwren, Helmeted Manakin) were locally abundant in all forest fragments, and are probably safe from any immediate risk of global extinction.

Paradoxically, 9 of the 12 species endemic or quasi-endemic to the cerrado region, were recorded in the small fragments (Appendix 1), implying that they are not area sensitive and that they may have the capacity to disperse among the fragments. This finding is contrary to what was expected and in agreement with other studies, such as paramo endemic birds of northern Andes (Vuilleumier 1970), chaparral endemic birds of North America (Soulé *et al.* 1988), and temperate rainforest endemic birds in Chile (Willson *et al.* 1994). It is also important to note that all large species that are hunted for meat (tinamous and curassows) were absent from the two smaller fragments.

Most forest-dependent cerrado endemics seem to respond negatively to the lack of flooded forests. Forest fragments without flooded forest microhabitats (9 and 155 ha) held fewer species or relatively small populations of forest dependent species endemic to the cerrado region than the other four fragments. The presence of six of the seven forest-dependent species endemic to the cerrado region in the smaller (7.5 ha) fragment may be due to the fact that it is an entirely flooded forest. The importance of humid forest zones for conservation has already been stressed by Christiansen and Pitter (1997).

In conclusion, the forest-dependent species endemic to the cerrado region do not seem to be area sensitive but seem to be partially dependent on the flooded forests of the region. Considering that the cerrado biome has been rapidly disappearing (Dias 1990, Klink *et al.* 1993, Willis and Oniki 1993), conservation efforts in the region should preserve urgently both large and small fragments and especially flooded forests. The conservation of area-sensitive species, of large-bodied species, and of hunted species of the region can be achieved by preserving large forest fragments, whereas the conservation of small endemic passerines can be achieved by preserving flooded forests in both large and small forest fragments.

Acknowledgements

I was supported by a post-doctorate fellowship from CNPq. I am in debt to the property owners of the Triângulo Mineiro region and the administrators of ''Fazenda Experimental do Glória'' and ''Reserva Ecológica do Panga'' who allowed me to work on lands they own or manage. C. Melo, G. M. Oliveira, M. F. Pereira, and T. A. Melo-Júnior helped with fieldwork. Professor A. Ruszczyk-Neto, and I. Schiavini provided partial logistical support. F. A. S. Fernandez, R. O. Bierregaard, Jr., and anonymous reviewers improved the manuscript with their criticisms.

Appendix 1. List of species observed or captured in the six forest fragments at the Triângulo Mineiro region, Minas Gerais state.
Aquatic (Threskiornithidae, Ardeidae, Alcedinidae), aerial (Falconiformes) and nocturnal (Tytonidae, Strigidae and Caprimulgidae) species are excluded. Species sequence and taxonomy follow Sibley and Monroe (1990).

Species	Fragment area (ha)						Diet[a]	Forest[b] dependence
	230	155	54	24	9	7.5		
Tinamus solitarius	X	–	–	X	–	–	ONI	A
Crypturellus obsoletus	–	X	–	–	–	–	ONI	A
Crypturellus parvirostris	X	–	–	X	–	–	ONI	C
Penelope superciliaris	–	X	X	X	–	–	ONI	A
Crax fasciolata	X	–	X	–	–	–	ONI	A
Odontophorus capueira	X	–	–	–	–	–	ONI	A
Picumnus minutissimus	X	X	X	X	X	X	INS	B
Veniliornis passerinus	X	–	–	–	–	–	INS	B
Colaptes melanochloros	–	–	X	X	–	–	INS	B
Colaptes campestris	–	–	–	–	X	X	INS	C
Campephilus melanoleucos	X	X	X	X	–	–	INS	A
Dryocopus lineatus	X	–	–	X	X	X	INS	B
Ramphastos toco	X	X	X	–	X	X	FRU	B
Galbula ruficauda	X	–	X	X	–	X	INS	B
Nonnula rubecula	X	X	–	–	–	–	INS	A
Monasa nigrifrons	X	X	–	–	–	–	INS	A
Trogon surrucura	X	X	–	–	–	–	ONI	A
Momotus momota	X	–	–	–	–	–	INS	A
Baryphthengus ruficapillus	–	X	–	X	–	–	INS	A
Piaya cayana	X	X	X	X	X	X	INS	B
Tapera naevia	X	–	–	–	–	–	INS	C
Crotophaga ani	X	–	X	–	–	X	ONI	C
Guira guira	–	X	–	X	X	X	ONI	C
Phaethornis pretrei	X	X	X	X	X	X	NEC	B
Lophornis magnificus	–	X	–	–	–	–	NEC	B
Thalurania furcata	X	X	X	?	X	X	NEC	B
Amazilia versicolor	X	X	–	?	–	X	NEC	A
Amazilia lactea	–	X	–	–	–	–	NEC	A
Colibri serrirostris	–	–	X	–	–	–	NEC	B
Melanotrochilus fuscus	X	–	–	–	–	–	NEC	A
Anthracothorax nigricollis	X	–	?	–	–	–	NEC	B
Eupetomena macroura	–	–	–	X	–	–	NEC	C
Columba cayennensis	X	X	X	X	–	–	GRA	A
Columba picazuro	–	–	–	X	X	–	GRA	B
Columbina talpacoti	X	X	X	X	X	X	GRA	C
Scardafella squammata	–	–	–	X	X	X	GRA	C
Leptotila verreauxi	X	X	X	–	X	X	FRU	B
Leptotila rufaxilla	X	–	–	–	–	–	FRU	A
Amazona aestiva	X	–	–	–	X	X	FRU	A
Amazona amazonica	X	–	–	–	–	–	FRU	A
Aratinga aurea	X	?	–	–	X	X	FRU	C
Aratinga auricapilla	X	–	–	–	–	–	FRU	A
Brotogeris chiriri	X	X	X	–	–	–	FRU	B
Cyanocorax cristatellus	–	–	–	X	X	–	INS	C
Todirostrum cinereum	–	–	X	–	X	X	INS	B
Corythopis delalandi	–	X	–	–	–	–	INS	A
Camptostoma obsoletum	X	X	–	–	–	–	INS	C
Phaeomyias murina	X	X	–	–	–	–	INS	C
Leptopogon amaurocephalus	X	X	X	X	–	X	INS	A

Appendix 1. *continued*

Species	Fragment area (ha)						Diet[a]	Forest[b] dependence
	230	155	54	24	9	7.5		
Elaenia mesoleuca	–	X	–	–	–	–	ONI	A
Elaenia flavogaster	X	–	–	X	–	?	ONI	B
Elaenia cristata	X	–	–	–	–	–	ONI	C
Elaenia obscura	X	X	–	–	–	–	ONI	A
Tolmomyias sulphurescens	X	X	X	X	X	X	INS	A
Phyllomyias fasciatus	–	X	–	–	–	–	INS	B
Platyrinchus mystaceus	X	–	–	X	–	–	INS	A
Cnemotriccus fuscatus	X	X	X	X	X	–	INS	A
Lathrotriccus euleri	X	X	X	X	–	X	INS	A
Pyrocephalus rubinus	–	–	–	–	–	X	INS	C
Contopus cinereus	X	–	–	–	–	–	INS	A
Colonia colonus	X	–	–	–	–	–	INS	A
Casiornis rufa	X	–	–	X	–	–	INS	A
Sirystes sibilator	X	–	–	–	–	–	INS	A
Myiarchus ferox	X	–	X	X	X	?	INS	B
Myiarchus tyrannulus	X	X	–	–	–	–	INS	B
Tyrannus melancholicus	X	X	X	X	X	X	INS	C
Tyrannus albogularis	X	–	–	–	–	–	INS	C
Tyrannus savanna	–	X	–	–	–	X	INS	C
Suiriri suiriri	–	–	–	–	–	X	INS	C
Serpophaga subcristata	–	–	–	–	–	X	INS	B
Hemitriccus margaritaceiventer	–	–	X	–	–	–	INS	B
Megarhynchus pitangua	X	X	X	X	X	X	ONI	B
Myiozetetes cayanensis	X	X	–	–	–	X	ONI	A
Myiozetetes similis	–	X	X	–	–	–	INS	B
Conopias trivirgata	X	–	–	–	–	–	INS	B
Myiodynastes maculatus	–	X	X	–	–	–	ONI	A
Legatus leucophaius	X	X	–	X	X	–	ONI	B
Pitangus sulphuratus	X	X	X	X	X	X	ONI	C
Pachyramphus castaneus	X	X	–	–	–	–	INS	A
Pachyramphus polycopterus	–	–	–	X	–	–	INS	B
Tityra cayana	X	X	–	–	–	–	ONI	A
Antilophia galeata	X	X	X	X	X	X	FRU	A
Neopelma palescens	–	X	–	X	–	–	FRU	A
Pipra fasciicauda	X	–	–	–	–	–	FRU	A
Taraba major	X	X	–	–	–	–	INS	B
Thamnophilus doliatus	–	–	X	X	–	X	INS	B
Thamnophilus punctatus	X	X	X	–	–	–	INS	A
Thamnophilus caerulescens	X	X	X	X	X	–	INS	A
Dysithamnus mentalis	X	X	–	–	–	–	INS	A
Drymophila sp.	X	–	–	–	–	–	INS	A
Herpsilochmus longirostris	X	X	X	X	X	X	INS	A
Herpsilochmus pileatus	X	X	–	–	–	–	INS	B
Synallaxis frontalis	X	–	X	?	–	–	INS	A
Synallaxis candei	X	X	X	–	–	–	INS	B
Cranioleuca vulpina	–	–	X	–	–	–	INS	B
Lochmias nematura	X	–	X	X	–	X	INS	A
Philydor dimidiatus	?	–	X	–	–	X	INS	A
Philydor lichtensteini	–	–	X	–	–	–	INS	A
Phacellodomus rufifrons	–	–	–	–	X	–	INS	B
Automolus rectirostris	X	–	X	X	–	X	INS	A
Xenops rutilans	X	X	X	–	–	–	INS	A
Sittasomus griseicapillus	X	X	X	–	–	–	INS	A

Appendix 1. *continued*

Species	Fragment area (ha)						Diet[a]	Forest[b] dependence
	230	155	54	24	9	7.5		
Lepidocolaptes angustirostris	X	X	–	X	–	–	INS	C
Conopophaga lineata	X	X	–	X	–	–	INS	A
Cyclarhis gujanensis	X	X	X	X	X	X	INS	B
Vireo olivaceus	–	X	X	–	–	–	INS	A
Turdus leucomelas	X	X	X	X	X	X	ONI	B
Turdus amaurochalinus	X	X	X	X	X	–	ONI	B
Turdus rufiventris	–	–	X	–	–	–	ONI	C
Turdus nigriceps	–	–	–	–	X	–	ONI	A
Thryothorus leucotis	X	X	X	X	X	X	INS	A
Troglodytes aedon	X	X	–	–	–	–	INS	C
Polioptila dumicola	X	–	X	X	X	X	INS	B
Arremon flavirostris	X	–	X	X	–	–	ONI	A
Parula pitiayumi	–	X	–	–	–	–	INS	A
Basileuterus hypoleucus	X	X	X	X	X	X	INS	A
Basileuterus flaveolus	X	X	X	X	X	–	INS	A
Basileuterus leucophrys	X	–	X	X	–	X	INS	A
Coereba flaveola	–	X	X	–	X	X	ONI	B
Conirostrum speciosum	X	–	–	–	–	–	INS	A
Cissopis leveriana	X	–	–	–	–	–	FRU	A
Hemithraupis guira	X	X	–	–	–	–	INS	A
Nemosia pileata	X	X	–	–	X	X	INS	A
Eucometis penicillata	X	X	X	X	X	X	ONI	A
Thraupis palmarum	X	X	X	X	–	–	ONI	B
Thraupis sayaca	X	X	X	X	–	X	ONI	B
Ramphocelus carbo	–	–	X	X	–	–	ONI	B
Tachyphonus rufus	X	–	–	–	–	–	ONI	A
Trichothraupis melanops	X	–	–	–	–	–	ONI	A
Euphonia chlorotica	X	X	X	X	X	X	ONI	B
Euphonia cyanocephala (= musica)	–	X	–	–	X	–	FRU	A
Tangara cayana	X	X	X	X	X	X	ONI	C
Dacnis cayana	X	X	X	–	X	X	ONI	B
Tersina viridis	X	X	–	X	X	–	ONI	A
Molothrus bonariensis	–	–	X	–	–	–	GRA	C
Coryphospingus cucullatus	X	X	–	X	X	X	GRA	B
Volatinia jacarina	–	X	X	X	–	X	GRA	C
Sporophila nigricollis	X	–	X	–	–	X	GRA	C
Sporophila caerulescens	–	X	–	–	?	X	GRA	C
Sporophila lineola	–	–	X	–	–	–	GRA	C
Saltator similis	X	X	X	X	X	X	ONI	B
Saltator maximus	X	X	X	–	X	X	ONI	A
Cacicus haemorhous	X	–	–	–	–	–	ONI	B
Icterus cayanensis	X	–	–	–	–	–	ONI	B
Icteridae sp.	X	X	–	–	–	–	ONI	C
Number of genera	89	70	57	56	42	51	115	
Number of species	104	81	68	62	47	55	145	

[a] Diet: INS, insectivore; ONI, omnivore; FRU, frugivore; GRA, granivore; NEC, nectarivore. Following Willis (1979), Motta–Júnior (1990), Sick (1997) and personal observations.
[b] Habitat: A, forest dependent species; B, forest semi–dependent species; C, forest-independent species. Following Silva (1995) classification.

https://doi.org/10.1017/S0959270901001034 Published online by Cambridge University Press

References

Abbott, I. (1980) Theories dealing with the ecology of landbirds on islands. *Adv. Ecol. Res.* 11: 329–371.

Aleixo, A. and Vielliard, J. M. E. (1995) Composição e dinâmica da avifauna da mata de Santa Genebra, Campinas, São Paulo, Brasil. *Rev. Brasil. Zool.* 12: 493–511.

Ambuel, B. and Temple, S. A. (1983) Area dependent changes in the bird communities and vegetation of southern Wisconsin forest. *Ecology* 64: 1057–1068.

Andrén, H. (1994) Effects of habitat fragmentation on birds and mammals in landscapes with different proportions of suitable habitat: a review. *Oikos* 71: 355–366.

Anjos, L. and Boçon, R. (1999) Bird communities in natural forest patches in Southeastern Brazil. *Wilson Bull.* 111: 397–414.

Araújo, G. M. and Haridasan, M. (1997) Estrutura fitossociológica de duas matas mesófilas semidecíduas, em Uberlândia, Triângulo Mineiro. *Naturalia, São Paulo* 22: 115–129.

Araújo, G. M., Rodrigues, L. A. and Ivizi, L. (1997) Estrutura fitossociológica e fenologia de espécies lenhosas de mata decídua em Uberlândia, MG. Pp. 22–28 in L. L. Leite and C. H. Sato, eds. *Contribuição ao conhecimento ecológico do cerrado*. Brasília: Universidade de Brasília.

Bierregaard, R. O., Jr. and Lovejoy, T. E. (1986) Birds of Amazonian forest fragments: effects of insularization. *Proc. XIX Internatn. Orn. Congr.* 19: 1564–1579.

Bierregaard, R. O., Jr. and Lovejoy, T. E. (1989) Effects of forest fragmentation on Amazonian understory bird communities. *Acta Amaz.* 19: 215–241.

Bierregaard, R. O., Jr., Lovejoy, T. E., Kapos, V., Santos, A. A. and Hutchings, R. W. (1992) The biological dynamics of tropical forest fragments. *Bioscience* 42: 859–866.

Christiansen, M. B. and Pitter, E. (1997) Species loss in a forest bird community near Lagoa Santa in southeastern Brazil. *Biol. Conserv.* 80: 23–32.

Dias, B. F. S. (1990) Conservação da natureza no cerrado brasileiro. Pp. 583–640 in M. N. Pinto, ed. *Cerrado: caracterização, ocupação e perspectivas*. Brasília: Editora Universidade de Brasília.

Hagan, J. M., Matthew van der Haegen, W. and McKinley, P. S. (1996) The early development of forest fragmentation effects on birds. *Conserv. Biol.* 10: 188–202.

Kattan, G. H. and Alvarez-López, H. (1996) Preservation and management of biodiversity in fragmented landscapes in the Colombian Andes. Pp. 3–18 in J. Schelhas and R. Greenberg, eds. *Forest patches in tropical landscapes*. Washington, D.C: Island Press.

Klink, C. A., Moreira, A. G. and Solbrig, O. T. (1993) Ecological impact of agricultural development in the Brazilian cerrados. Pp. 259–282 in M. D. Young and O. T. Solbrig, eds. *The world's savannas. Economic driving forces, ecological constraints and policy options for sustainable land use*, 12. Paris: UNESCO; New York: Parthenon Publishers (Man and Biosphere Series).

Leck, C. F. (1979) Avian extinctions in an isolated tropical wet-forest preserve, Ecuador. *Auk* 96: 343–352.

Leite, L. O. and Marini, M. Â. (1999) The effects of forest fragmentation on predation rates of artificial bird nests in Minas Gerais. *Ciência Cult.* 51: 34–37.

Melo, C. and Marini, M. Â. (1997) Predação de ninhos artificiais em fragmentos de matas do Brasil central. *Orn. Neotrop.* 8: 7–14.

Motta-Júnior, J. C. (1990) Estrutura trófica e composição das avifaunas de três hábitats terrestres na região central do estado de São Paulo. *Ararajuba* 1: 65–71.

Ott, L. (1988) *An introduction to statistical methods and data analysis*. Boston: PWS-Kent.

Pimm, S. L. and Askins, R. A. (1995) Forest losses predict bird extinction in eastern North America. *Proc. Natl. Acad. Sci. USA* 92: 9343–9347.

Robinson, S. K., Thompson, F. R., III, Donovan, T. M., Whitehead, D. R. and Faaborg, J. (1995) Regional forest fragmentation and the nesting success of migratory birds. *Science* 267: 1987–1990.

Rodrigues, L. A. and Araújo, G. M. (1997) Levantamento florístico de uma mata decídua em Uberlândia, Minas Gerais, Brasil. *Acta Bot. Brasíl.* 11: 229–236.
Rosa, R., Lima, S. C. and Assunção, W. L. (1991) Abordagem prelimilar das condições climáticas de Uberlândia (MG). *Soc. e Nat., Uberlândia* 3: 91–108.
Schiavini, I. and Araújo, G. M. (1989) Considerações sobre a vegetação da Reserva Ecológica do Panga (Uberlândia). *Soc. e Nat., Uberlândia* 1: 61–66.
Shafer, C. L. (1990) *Nature reserves. Island theory and conservation practice*. Washington, D.C.: Smithsonian Institution Press.
Sibley, C. G. and Monroe, B. L., Jr. (1990) *Distribution and taxonomy of birds of the World*. New Haven: Yale University Press.
Sick, H. (1997) *Ornitologia Brasileira*. Rio de Janeiro: Editora Nova Fronteira.
Silva, J. M. C. (1995) Birds of the Cerrado region, South America. *Steenstrupia* 21: 69–92.
Soulé, M. E., Bolger, D. T., Alberts, A. C., Wright, J., Sorice, M. and Hill, S. (1988) Reconstructed dynamics of rapid extinctions of chaparral-requiring birds in urban habitat islands. *Conserv. Biol.* 2: 75–92.
Stouffer, P. C. and Bierregaard, R. O., Jr. (1995a) Effects of forest fragmentation on understory hummingbirds in Amazonian Brazil. *Conserv. Biol.* 9: 1085–1094.
Stouffer, P. C. and Bierregaard, R. O., Jr. (1995b) Use of Amazonian forest fragments by understory insectivorous birds. *Ecology* 76: 2429–2445.
Turner, I. M. (1996) Species loss in fragments of tropical rain forest: a review of the evidence. *J. Appl. Ecol.* 33: 200–209.
Vuilleumier, F. (1970) Insular biogeography in continental regions. I. The northern Andes of South America. *Am. Nat.* 104: 373–388.
Wilcove, D. S., McLellan, C. H. and Dobson, A. P. (1986) Habitat fragmentation in the temperate zone. Pp. 237–256 in M. E. Soulé, ed. *Conservation biology. The science of scarcity and diversity*. Sunderland, MA: Sinauer.
Willis, E. O. (1979) The composition of avian communities in remanescent woodlots in southern Brazil. *Pap. Avulsos Zool., São Paulo* 33: 1–25.
Willis, E. O. and Oniki, Y. (1993) New and reconfirmed birds from the state of São Paulo, Brazil, with notes on disappearing species. *Bull. Brit. Orn. Club* 113: 23–34.
Willson, M. F., Santo, T. L., Sabag, C., and Armesto, J. J. (1994) Avian communities of fragmented south-temperate rainforests in Chile. *Conserv. Biol.* 8: 508–520.

MIGUEL Â MARINI
Departamento de Biociências, Universidade Federal de Uberlândia, Uberlândia, MG 38405-382 Brazil.
Present address: *Departamento de Biologia Geral, C.P. 486, ICB, Universidade Federal de Minas Gerais, Belo Horizonte, MG 30161-970 Brazil*. E-mail: marini@mono.icb.ufmg.br.