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BIRD COMMUNITIES IN FIVE ATLANTIC FOREST FRAGMENTS IN SOUTHERN BRAZIL

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Resumo. – Comunidades de aves em cinco fragmentos de floresta Atlântica no sul do Brasil. – Comunidades de aves em cinco fragmentos florestais da floresta atlântica foram estudados usando contagens pontuais de distância ilimitada, de Janeiro a Dezembro de 1996, na região de Londrina (23º17'S, 51º15'W), Estado do Paraná, sul do Brasil. Em quatro destes fragmentos florestais, os quais não estão a mais de 1100 m entre si, o número de espécies diminuiu e foi altamente correlacionado com o tamanho da área (r = 0.998, df = 2, P = 0.002): 134, 129, 113 e 106 espécies em fragmentos de 656 ha (em torno de 70 ha foram somente amostrados), 56 ha, 25 ha e 11 ha, respectivamente. No quinto fragmento de 60 ha, o qual está isolado por ao menos 2 km de qualquer outra grande área de floresta, somente104 espécies foram registradas. O número médio de espécies por mês no fragmento de 656 ha (64 ± 11.3 species) foi estatisticamente similar ao de 56 ha (59.8 ± 8.1 espécies; P > 0.05) e ao de 25 ha (54.8 ± 6.1 espécies; P > 0.05) mas não ao de 11 ha (49.5 ± 7.6 espécies: P < 0.05) e ao de 60 ha (45.8 ± 7.3 espécies; P < 0.05, teste de Tukey). A estrutura da comunidade (tendo em consideração os hábitos alimentares das espécies) do fragmento de 25 ha foi smilar ao de 656 ha (r_s = 0.81), provavelmente, em função de um corredor de 100 m de largura que os conectava; os outros fragmentos, os quais eram completamente isolados, tiveram menor correlação (r_s < 0.72) em relação ao fragmento de 656 ha. Aumento da abundância relativa com a diminuição do tamanho da área dos fragmentos (densidade compensatória) foi encontrada em 18 espécies. Embora algumas tendências gerais serem apresentadas neste estudo para certos grupos de aves, os efeitos da fragmentação florestal são certamente específicos para cada espécie.

Abstract. – Bird communities in five Atlantic forest fragments were studied using point counts of unlimited distance monthly, January to December of 1996, in the Londrina region (23º17'S, 51º15'W), Paraná State, southern Brazil. In four of these forest fragments, which are no farther than 1100 m from each other, the species number decreased and was strongly correlated with area size (r = 0.998, df = 2, P = 0.002): 134, 129, 113 and 106 species in fragments of 656 ha (only about 70 ha were sampled), 56 ha, 25 ha and 11 ha, respectively. In the fifth fragment of 60 ha, which is isolated by at least 2 km from any other large forest area, only 104 species were recorded. The mean number of species per month in the 656 ha fragment (64 ± 11.3 species) was statistically similar to that in the 56 ha (59.8 ± 8.1 species; P > 0.05) and 25 ha fragments (54.8 ± 6.1 species; P > 0.05) but not to the 11 ha fragment (49.5 ± 7.6 species; P < 0.05) or the isolated fragment of 60 ha (45.8 ± 7.3 species; P < 0.05, Tukey test). The community structure (taking into account the species` feeding habits) of the 25 ha fragment was similar to the 656 ha fragment, probably, because of a 100 m wide forest corridor connecting them (r_s = 0.81); the other fragments, which were fully isolated, had lower correlation (r_s < 0.72) to the 656 ha fragment. Increase of relative abundance with decrease in area size of fragments (density compensation) was found for 18 species. Although some general tendencies are presented in this study for certain bird groups, the effects of forest fragmentation are certainly species-specific. *Accepted 20 August 2000*.

Key words: *Forest fragmentation, Paraná, Londrina, conservation, density compensation, Brazil, bird communities.*

INTRODUCTION

Atlantic forest stretches along the Atlantic coast of Brazil from Ceará state, in the north, to Rio Grande do Sul state, in the south, and has undergone such intense fragmentation as to make it the most endangered zoogeographical region in South America (Stotz *et al.* 1996). Vegetation in northern Paraná state (Fig. 1), for example, was made up of continuous forest until the 1920s. Since then there has been rapid deforestation in the region for agriculture. The continuous forest was reduced by this process of land use to small and sparse forest fragments which currently total less than 1% of the original area in the north of Paraná. The largest and the most representative forest fragment in northern Paraná is Parque Estadual Mata dos Godoy (656 ha).

In Brazil, studies on bird fauna in forest fragments have been carried out particularly in southern and southeastern regions and in Amazonia (Willis 1979; Anjos & Laroca 1989, Bierregaard & Lovejoy 1989, Bierregaard 1990, Vielliard & Silva 1990, Melo & Marini 1997, Anjos 1992, Aleixo & Vielliard 1995, Stouffer & Bierregaard 1995a, b; Bierregaard & Stouffer 1997, Aleixo 1999, Almeida *et al.* 1999, Anjos & Boçon 1999, Soares & Anjos 1999). Most of the studies have detected a decrease in number of species and modification in bird community structure (e.g., Willis 1979, Bierregaard 1990); these effects tend to be minimized in small fragments linked to larger fragments by forest corridors, or that are simply close to them (e.g., Stouffer & Bierregaard 1995b, Anjos & Boçon 1999). Some species benefit from fragmentation and increase their numbers because of an expansion of the ecological niche in the smaller forest fragments, a phenomena which has been called density compensation (MacArthur *et al.* 1972, Wright 1980).

The goal of this study was to analyze what differences in the composition of the bird community are found among five Atlantic forest fragments in the northern region of Paraná state.

STUDY AREA AND METHODS

Five forest fragments were studied, including the Parque Estadual Mata dos Godoy (PG). All are close to the town of Londrina, Paraná state, southern Brazil (Fig. 1). PG (23°17'S, 51°15'W) 656 ha, is located 15 km south of Londrina. Three different sized forest fragments called A, B and C fragments are south of PG and close to it; fragment A (FA, 56 ha) is 500 m from PG; fragment B (FB, 25 ha) is 400 m from PG and linked to it by a 100 m wide forest corridor (a continuous forest with a similar vegetation structure to the fragments), and fragment C (FC, 11 ha), which is totally isolated and 1100 m from PG, 500 m from FA and 250 m from FB (Fig. 1). The space between these four forest fragments, the matrix habitat (Sisk *et al.* 1997), is used for ranching and has some bushes and scattered trees. The forest fragments are isolated for this matrix habitat for at least 40 years. PG has been a permanent preservation area since 1989; before that, hunting and cutting were not permitted by the owner of the area. Vegetation is well preserved in PG and in the other three fragments. The fifth fragment studied is the Horto Municipal de Ibiporã (HI, 60 ha), 35 km northeast of PG. This fragment also has well preserved vegetation, but it is more isolated (at least 2 km from any other large forest fragment). The matrix habitat around HI is 60% agriculture and 40% urban. The forest fragments are seasonal semi-deciduous forest. The dominant trees are: *Aspidosperma polyneuron* (Apocynaceae), *Euterpe edulis* (Areceae), *Galesia intergrifolia* (Phytolaccaceae) and *Ficus glabra* (Moraceae). The mean annual rainfall is 1,200 mm in the region, and is highest from October to March (130 to 200 mm

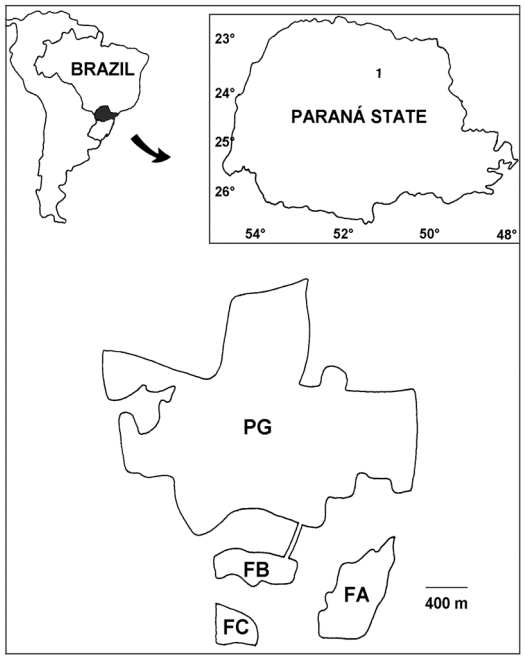


FIG. 1. Forest fragments (PG, 656 ha; FA, 56 ha; FB, 25 ha; FC, 11 ha) studied in Londrina region (1) north of Paraná State, southern Brazil. PG and FB are linked by a forest corridor. The fifth fragment studied (HI, 60 ha) is located 35 km northeast of PG.

per month). The annual temperature variation shows that the means from December to February are higher (around 23°C) and the June and July means are lower (around 17°C) (Maack 1981). PG is 650 m a.s.l.

Forest fragments were censused by monthly point counts of unlimited distance (Blondel *et al.* 1970, Vielliard & Silva 1990) from January to December 1996. A total of 45 points were used to estimate relative abundance: 15 in PG, 10 in HI, 10 in FA, 6 in FB and 4 in FC. These points covered the total areas of HI, FA, FB and FC but just part of the total area of PG (the area sampled in PG was around 70 ha). Each point was 100 m from another and at least 50 m from the edge of forest. Each month five points in each fragment were chosen by random selection for sampling; in FC the fourth point was always repeated once each month. So, 60 counts were performed in each fragment during the year. The time for sampling at each point was 20 min. The Index of Point Abundance (I.P.A.) of each species (Blondel *et al.* 1970; Vielliard & Silva 1990), considered in this work as the relative abundance of each species, was estimated by dividing the total number of species contacts by the total number of points (60) sampled in each fragment. Sampling began at dawn at the first randomly selected point and finished about 3 h later at the fifth point. Species were identified primarily by sound (99%). Each pair or flock of each species was counted once (one contact) while vocalizing. Precaution was taken not to count the same individual or group more than once (a form was used in order to locate the counted individuals), particularly for highly mobile species. Bird recordings (2,300 recordings of 470 species), deposited in the

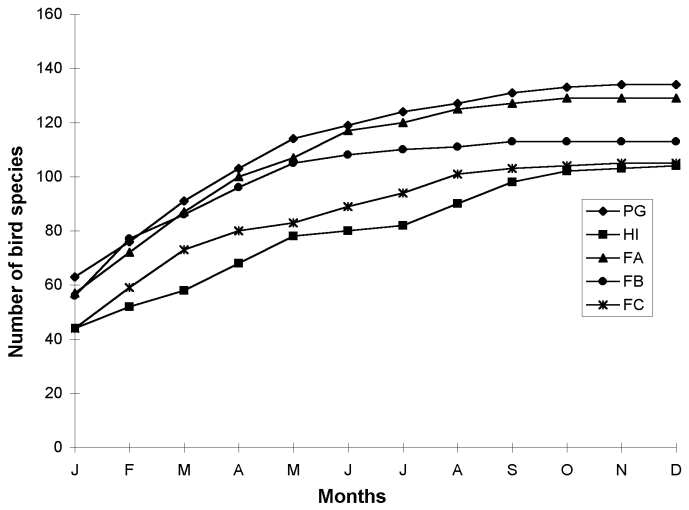


FIG. 2. Monthly accumulated number of bird species in the studied forest fragments.

Bioacoustics Laboratory of the Universidade Estadual de Londrina, were used to aid identification.

Taxonomy mostly follows Meyer de Schauensee (1982) and Sick (1997). Feeding habit was determined for each species based on field observations and references (Fitzpatrick 1980, Belton 1984, 1985, Ridgely & Tudor 1989, 1994, Cabot 1992, del Hoyo 1994, Baptista *et al.* 1997, Collar 1997, Sick 1997) and was categorized as: nectarivore, frugivore (feeding especially on fruit pulp), herbivore (including pulp, seeds, buds and/or leaves), insectivore, omnivore (feeding on invertebrates and small vertebrates), carnivore (feeding especially on small vertebrates) and herbivore/omnivore (feeding on either plant or animal sources). For insectivores, the area where the insect or its larvae was most often captured was also recorded. Three classes of capture sites were defined: (1) trunk (and twigs), (2) leaves, and (3) other sites (called generalized insectivores).

The accumulated number of species was obtained monthly in each fragment based on the five point counts performed each month. Analyses of variance (one way ANOVA) and the Tukey multiple range test ($P < 0.05$) were used to evaluate the average number of species and of contacts per month in forest fragments. Similarities in the bird species composition among forest fragments were determined using the Sørenson Index (C_s; Magurran 1988): $C_s = 2j/(a + b)$, where j is the number of species found in both sites and a is the number of species in site A, and b is the number of species in site B. Correlation (r) was used to measure the relation between the species number and area size of fragment. Spearman's rank correlation (r_s) was used to measure the relation between the community structures of the fragments. Differences in number of contacts of species between the fragments were tested with χ^2 analysis at $\alpha < 0.05$.

RESULTS

Number of species and similarity. Birds in the five forest fragments totaled 184 species: 134 in PG (656 ha but only 70 ha were sampled), 104 in HI (60 ha), 129 in FA (56 ha), 113 in

TABLE 1. Number of bird species in the study forest fragments (including only the sampled area of PG) according to their feeding habits.

Feeding habits	Forest fragments/area size (ha)				
	PG/70	HI/60	FA/56	FB/25	FC/11
Nectarivores	2	4	4	5	3
Frugivores	16	8	12	11	8
Herbivores	16	11	14	15	14
Trunk insectivores	15	13	16	12	14
Leaf insectivores	26	24	23	20	20
Generalized insectivores	13	11	14	11	8
Omnivores	6	5	5	5	6
Carnivores	7	3	5	4	3
Herbivores/omnivores	33	25	36	30	30
Total Species	134	104	129	113	106

FB (25 ha) and 106 in FC (11 ha; Appendix). The accumulated number of species in the study months, show that no species was added after September in FB, October in FA and November in PG and FA. One species was added to the list in HI in December (Fig. 2).

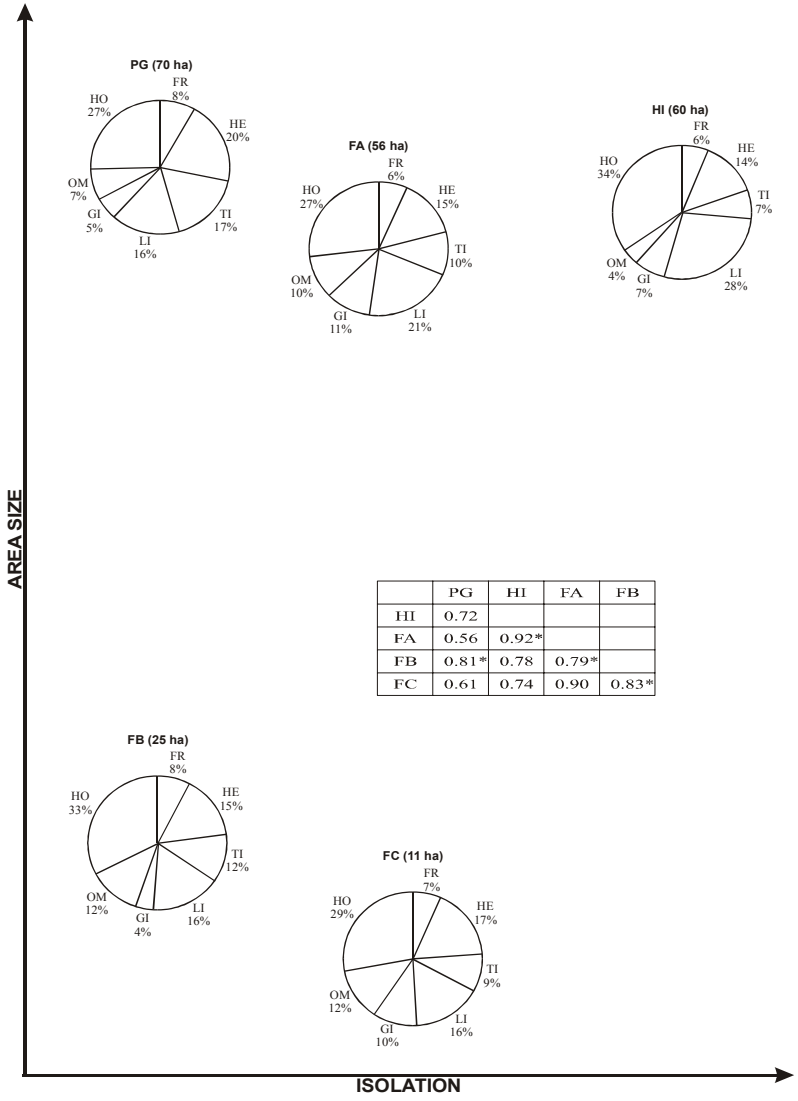
FA and FB (59.8 ± 8.1 and 54.8 ± 6.1 species respectively) had a statistically similar mean number of species per month (considering the bird lists obtained in the five samplings each month) to PG (64 species ± 11.3; Tukey test, $P > 0.05$); HI and FC (45.8 ± 7.3 and 49.5 ± 7.6 species respectively) had lower means (Tukey test, $P < 0.05$).

HI, the most isolated forest fragment, had the lowest similarity value (Sørenson) compared with PG (0.64); FA, FB and FC had similarities between 0.73 and 0.78 compared with PG. The highest similarity values were among FA, FB and FC (0.80 to 0.93).

In the four closer fragments (PG, FA, FB and FC), the species number decreased and was strongly correlated with area size ($r = 0.998$, $df = 2$, $P = 0.002$) when considering only the sampled area of PG (70 ha); it was not correlated, however, when considering the total area of PG (656 ha) ($r = 0.73$, $df = 2$, $P = 0.27$). After adding the isolated fragment HI to the sampled area of PG, the number of species remained uncorrelated with area of forest fragments ($r = 0.60$, $df = 3$, $P = 0.29$)

Of the 184 species recorded in the five forest fragments, 75 were insectivores, 42 herbivores/omnivores, 24 herbivores, 18 frugivores, 10 carnivores, 9 omnivores and 6 nectarivores. Among the insectivores, 36 were leaf insectivores, 20 were trunk insectivores, and 19 were generalized insectivores. The number of species of leaf insectivores was correlated with area (Table 1; $r = 0.96$, $df = 3$, $P = 0.011$), even considering HI in the analyses; all the other groups of species numbers showed weak correlations (not statistically significant) with fragment area ($r = –0.33$ for nectarivores; $r = 0.58$ for frugivores; $r = –0.08$ for herbivores; $r = 0.81$ for generalized insectivores; $r = 0.45$ for trunk insectivores; $r = –0.14$ for omnivores; $r = 0.63$ for carnivores; $r = 0.17$ for herbivores/omnivores; $df = 3$; $P > 0.05$). If HI is not considered in the analysis, correlation increases substantially for carnivores ($r = 0.96$; $df = 2$; $P = 0.042$) and frugivores ($r = 0.93$; $df = 2$; $P = 0.068$).

Relative abundance. The mean numbers of species contacts per month were not significantly



	PG	HI	FA	FB
HI	0.72			
FA	0.56	0.92*		
FB	0.81*	0.78	0.79*	
FC	0.61	0.74	0.90	0.83*

FIG. 3. Ratio between total relative abundance of the bird species grouped according to their feeding habits in the study forest fragments (considering only the sampled area of PG). The pie graphs were schematically placed according to the area size and isolation of the forest fragment; PG (70 ha) and FB (25 ha) forest fragments are linked by a forest corridor. Correlation (Spearman's correlation rank) among the community structures (pie graphs) are also showed (* indicates significant correlation, $P < 0.05$).

different between the fragments (PG = 149.6 ± 63; HI = 123.8 ± 26; FA = 147.6 ± 26; FB = 147.9 ± 25; FC = 133.7 ± 19; Tukey test, $P > 0.05$). But the ten most abundant species in HI correspond to 44% of the total contacts; in PG this percentage was much lower (33%). The percentage of contacts of the ten most abundant species in the fragments near to PG

TABLE 2. Total relative abundances of bird species in the study forest fragments (including only the sampled area of PG) according to their feeding habits.

Feeding habits	Forest fragments/area size (ha)				
	PG/70	HI/60	FA/56	FB/25	FC/11
Nectarivores	0.23	0.66	0.20	0.33	0.25
Frugivores	2.35	1.39	1.82	2.24	1.77
Herbivores	5.71	3.31	4.15	4.43	4.65
Trunk insectivores	4.88	1.65	2.87	3.55	2.42
Leaf insectivores	4.62	6.80	6.05	4.77	4.29
Generalized insectivores	1.50	1.68	3.03	1.28	2.75
Omnivores	2.05	0.90	2.92	3.62	3.31
Carnivores	0.73	0.05	0.27	0.24	0.16
Herbivores/omnivores	7.29	8.38	7.70	9.49	7.52

increased with decrease in area (36% in FA, 37% in FB and 39% in FC).

The sum of the relative abundance of species grouped according to feeding habits denotes the participation of each group in the community structure in each fragment (Table 2). Herbivores/omnivores were the most abundant species group accounting for 25% or more of the total relative abundance in each studied fragment; nectarivores and carnivores had the lowest participation (between 0.2% to 3%, Table 2). The community structure in FB, considering the relative abundance of the species groups (but excluding nectarivores and carnivores because their low participation in the community), had the highest correlation to PG (Spearman's rank correlation: $r_s = 0.81$, $n = 7$, $P > 0.05$); HI ($r_s = 0.72$), FA ($r_s = 0.56$) and FC ($r_s = 0.61$) had no significant correlation to PG ($P < 0.05$). The highest correlation were between HI and FA ($r_s = 0.92$, $P > 0.05$) and FA and FC ($r_s = 0.90$, $P > 0.05$; Fig 3).

Sixty-three species recorded in three, four or five forest fragments had relative abundance significantly different (χ^2, $P < 0.05$; Appendix). Of these 63 species, 18 increased relative abundance with decrease in area (density compensation) while 17 had the highest relative abundance in HI, the most isolated forest fragment (Table 3).

Twenty species decreased significantly relative abundance with decrease in area. *Crypturellus obsoletus* ($\chi^2 = 25.2$, df = 4), *Aratinga leucophtalmus* ($\chi^2 = 42.8$, df = 3), *Pyrrhura frontalis* ($\chi^2 = 58.4$, df = 4), *Melanerpes flavifrons* ($\chi^2 = 70$, df = 4), *Sittasomus griseicapillus* ($\chi^2 = 98.7$, df = 4), *Xiphocolaptes albicollis* ($\chi^2 = 34.7$, df = 4), *Chiroxiphia caudata* ($\chi^2 = 28.4$, df = 2), *Piprites chloris* ($\chi^2 = 23.7$, df = 4), *Sirystes sibilator* ($\chi^2 = 54.9$, df = 3) and *Myiopagis caniceps* ($\chi^2 = 52.4$, df = 4) were the species which decreased more in abundance with decrease in area.

DISCUSSION

The curves of the cumulative number of species suggest that general totals were reasonably complete in the study forest fragments. The exception is PG; only a sample area was considered in this study due to its large size. A total of 288 bird species were in fact recorded during an exhaustive survey for the total PG area (Anjos *et al.* 1997). The difference in the number of species recorded in PG may be explained by the heterogeneous distribution of the bird species in a more continuous forest; small differences in plant composition and structure form mosaics of

TABLE 3. Species occurring in three, four or five forest fragments that increased significantly their relative abundance with a decrease in area (A), and species that had the highest relative abundance in HI (B). In both cases χ^2 tests ($P < 0.05$) were used.

Species	χ^2; df	Tendency
Crypturellus tataupa	37.0; 4	B
Crypturellus parvirostris	14.5; 4	B
Columba cayennensis	18.5; 4	A
Leptotila verreauxi	45.3; 4	B
Phaetornis eurynome	10.7; 4	B
Dryocopus lineatus	95.9; 3	A
Picumnus temminckii	17.0; 3	B
Synallaxis ruficapilla	73.8; 4	A
Xenops rutilans	9.00; 3	B
Mackenziaena severa	22.3; 4	A
Thamnophilus doliatus	50.8; 2	B
Thamnophilus caerulescens	40.0; 4	B
Dysithamnus mentalis	14.0; 4	A
Conopophaga lineata	62.2; 4	A
Psilorhamphus guttatus	62.8; 3	A
Scytalopus indigoticus	19.4; 3	A
Megarhynchus pitangua	32.4; 4	A
Myiodynastes maculatus	15.9; 4	A
Pitangus sulphuratus	28.7; 4	A
Empidonax euleri	82.8; 3	B
Tolmomyias sulphurescens	16.6; 4	B
Myiornis auricularis	60.7; 4	B
Leptopogon amaurocephalus	11.7; 4	B
Cyanocorax chrysops	12.7; 3	A
Turdus rufiventris	40.1; 4	A
Turdus leucomelas	29.2; 4	A
Cyclarhis gujanensis	40.7; 4	B
Conirostrum speciosum	20.1; 4	B
Euphonia chlorotica	12.0; 3	B
Thraupis sayaca	22.6; 4	B
Trichothraupis melanops	16.5; 4	A
Cissops leveriana	18.1; 4	A
Saltator similis	17.2; 4	A
Pitylus fuliginosus	11.7; 3	A
Arremon flavirostris	11.6; 2	B

environmental conditions for the birds (Tomialojc *et al.* 1984, Blondel 1986). A more heterogeneous distribution of bird species had already been detected in a study carried out in a continuous area of mixed temperate rain forest (also part of the Atlantic forest) when compared with the fragments; a fragment may contain a similar number of bird species to a similar sampled area of mixed temperate rain forest (Anjos & Boçon 1999). The same pattern is repeated in forest fragments in the Londrina region, for PG (134 species) and FA (129 species); the area of FA (56 ha) is rather similar in size to the sampled area covered by the 15 points of PG (70 ha) and which resulted in a similar number of species. The mean number of species per month, which was statistically similar between PG (64 species) and FA (59.8 species), corroborates this result.

Fewer species were recorded in HI (104 species) than in FA (129 species) although the areas are similar (60 ha and 56 ha respectively). The degree of isolation of an island (or forest fragment) has been considered an important impediment to colonization (MacArthur & Wilson 1967). In the present study HI is the most isolated forest fragment, which would explain the low number of species (and the lowest similarity index to PG, Sørenson index = 0.64). In addition, correlation between number of species and area was only seen when HI was not considered; the others fragments are much closer to each other.

Absence of competitors has been considered an important factor in density compensation (MacArthur et al. 1972, Wright 1980, Blondel 1991). It was tested using the groups of species with similar feeding habits. In the present study, leaf insectivores decreased in species number with decrease in area; the significant increase in relative abundance of the leaf insectivores *Synallaxis ruficapilla* and *Dysithamnus mentalis* with decrease in area could be related to the reduced competition in the small fragments. However, five other leaf insectivores (*Thamnophilus doliatus*, *Thamnophilus caerulescens*, *Tolmomyias sulphurescens*, *Myiornis*

auricularis, and *Leptopogon amaurocephalus*) had the highest relative abundance in HI which presented similar number of leaf insectivores to PG. Eight herbivores/omnivores also increased relative abundance with decrease in area (*Megarhynchus pitangua*, *Myiodynastes maculatus*, *Cyanocorax chrysops*, *Turdus rufiventris*, *Turdus leucomelas*, *Trichothraupis melanops*, *Saltator similis*, and *Pitylus fuliginosus*) but the species numbers of this group did not seem to decrease with area size. Ricklefs & Cox (1978) and Blondel (1991) have suggested slight habitat differences and differences in colonization, beside reduced competition, as additional reasons for density compensation which have to be considered for the results obtained in the present study.

Trunk insectivores had similar species numbers in the studied fragments but the relative abundance decreased substantially with the decrease in area in the closer fragments (PG, FA, FB, and FC), and was the lowest in the isolated fragment HI. This may suggest low populations for some species. In three other fragments of 100 ha, 86 ha, and 12 ha in the studied region, which are more isolated than HI, only five, seven, and one species of trunk insectivores were respectively recorded (Soares & Anjos 1999).

Some species of frugivorous birds were not mist-netted in the small fragments of Amazonia monitored after isolation during the Minimum Critical Size of Ecosystems Project; the capture numbers of some species, however, increased in isolated fragments of 1 ha (Bierregaard & Stouffer 1997). Similar pattern was obtained in this study; frugivores decreased in species numbers with decrease in area, and were represented by few species in the isolated fragment HI. But the frugivorous *Euphonia chlorotica* and *Arremon flavirostris* had the highest relative abundance in the isolated fragment HI.

Nectarivores were not considered vulnerable to fragmentation in Amazonia because the species had equal proportion of captures or even increased them in fragments after isolation (Stouffer & Bierregaard 1995a). Nectarivores in the studied fragments in the north of Paraná tended to increase in total relative abundance with decrease in area, and presented the highest value in the isolated fragment HI (Table 2).

Although some general tendencies were presented for certain bird groups, the effects of forest fragmentation are certainly different for each species. A study in 270 forest fragments in Maryland suggested that the impacts of forest fragmentation on bird communities are complex, species specific and not related only to fragment area or fragment isolation (Lynch & Whigham 1984).

FB was the forest fragment most similar to PG when the total relative abundance of the species grouped according to their feeding habits was considered. FA had a lower similarity in relation to the community structure of PG in spite of its larger size and greater species number. The forest corridor between PG and FB may have enabled a greater similarity in the community structure and isolation seems to have importance for the low similarity of FA. However, the importance of forest corridors for movement of organisms is yet controversial because of the weakness of available data (Simberloff *et al.* 1992). Crome (1997) comparing several forest fragmentation studies suggested that each landscape appears unique in its pattern of fragmentation. So, it is too early for broad generalizations of the data presented in this study.

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APPENDIX. Relative abundance of bird species recorded in the studied forest fragments (considering only the sampled area of PG); (*) indicates the 10 species with greatest relative abundance values in each forest fragment and (s) indicates significant difference (χ^2, $P < 0.05$) between number of contacts when species is registered in 3, 4 or 5 forest fragments. Feeding habits are shown for each species: NE, nectarivore; FR, frugivore; HE, herbivore; TI, trunk insectivore; LI, leaf insectivore; GI, generalized insectivore; OM, omnivore; CA, carnivore; HO, herbivore/omnivore.

Families and species	Forest fragments-ha					Feeding habits
	PG-70	HI-60	FA-56	FB-25	FC-11	
TINAMIDAE						
Tinamus solitarius	0.22					HO
Crypturellus obsoletus (s)	0.62 *	0.1	0.4	0.4	0.26	HO
Crypturellus undulatus	0.05					HO
Crypturellus parvirostris (s)	0.05	0.27	0.17	0.05	0.16	HO
Crypturellus tataupa (s)	0.07	0.7 *	0.48	0.32	0.68	HO
ACCIPITRIDAE						
Harpagus diodon		0.02				OM
Ictinia plumbea			0.02			GI
Buteo magnirostris		0.07		0.09	0.05	OM
Buteo leucorrhous			0.02			CA
Buteo nitidus			0.02			CA
FALCONIDAE						
Herpetotheres cachinnans (s)	0.25	0.02	0.08	0.07	0.11	CA
Micrastur semitorquatus	0.15					CA
Micrastur ruficollis	0.1	0.02	0.05	0.02	0.02	CA
CRACIDAE						
Penelope superciliaris	0.07	0.17	0.08	0.21	0.25	FR
Pipile jacutinga	0.02					FR
Crax fasciolata	0.02					HE
PHASIANIDAE						
Odontophorus capueira			0.02	0.02	0.02	HE
RALLIDAE						
Aramides cajanea			0.05			HO
Aramides saracura		0.10	0.03	0.05	0.18	HO
COLUMBIDAE						
Columba speciosa		0.02	0.07			FR
Columba picazuro	1.7 *	1.7 *	1.93 *	1.91 *	2.07 *	HE
Columba maculosa			0.02		0.05	HE
Columba cayennensis (s)	0.27	0.75 *	0.73 *	0.54	0.81*	FR
Columba plumbea	0.02		0.02			FR
Zenaida auriculata		0.14		0.02		HE
Columbina minuta		0.02				HE
Columbina talpacoti		0.22		0.04		HE
Columbina picui		0.09				HE
Claravis pretiosa		0.03				HE
Scardafella squammata				0.02		HE
Leptotila verreauxi (s)	0.47	1.15 *	0.4	0.53	0.33	HO
Leptotila rufaxilla	0.32	0.44	0.37	0.37	0.37	HO

APPENDIX. Continuation.

Families and species	Forest fragments-ha					Feeding habits
	PG-70	HI-60	FA-56	FB-25	FC-11	
Geotrygon montana	0.3	0.22	0.37	0.25	0.28	HO
PSITTACIDAE						
Aratinga leucophthalmus (s)	0.53		0.12	0.11	0.07	HE
Aratinga solstitialis	0.17					HE
Pyrrhura frontalis (s)	0.87 *	0.02	0.3	0.42	0.37	HE
Forpus xanthopterygius	0.03	0.03	0.05	0.04	0.04	HE
Brotogeris tirica (s)	0.25		0.03	0.09	0.05	HE
Pionopsitta pileata	0.13		0.03	0.12	0.11	HE
Pionus maximiliani	0.78 *		0.53	0.84 *	0.67	HE
Amazona aestiva	0.05		0.05	0.05	0.09	HE
Triclaria malachitacea (s)	0.17		0.02		0.02	HE
CUCULIDAE						
Piaya cayana	0.5	0.53	0.6	0.74	0.70	GI
Crotophaga ani			0.02			HO
STRIGIDAE						
Pulsatrix perspicillata	0.02			0.02		CA
Pulsatrix koeniswaldiana	0.02					CA
Glaucidium brasilianum	0.18		0.1	0.14	0.04	CA
Ciccaba virgata		0.02				CA
Strix hylophila	0.02					CA
NYCTIBIIDAE						
Nyctibius griseus		0.02	0.02			GI
CAPRIMULGIDAE						
Lurocalis semitorquatus	0.1	0.03	0.12	0.11	0.09	GI
TROCHILIDAE						
Phaethornis eurynome (s)	0.2	0.39	0.15	0.19	0.16	NE
Anthracothorax nigricollis	0.03	0.15		0.04	0.07	NE
Chlorostilbon aureoventris		0.10	0.02	0.05	0.02	NE
Leucochloris albicollis		0.02	0.02	0.04		NE
Amazilia fimbriata			0.02			NE
TROGONIDAE						
Trogon viridis (s)	0.3		0.15	0.09	0.07	HO
Trogon surrucura (s)	0.62	0.02	0.58	0.6	0.3	HO
MOMOTIDAE						
Baryphthengus ruficapillus	0.6		0.4	0.81 *	0.6	HO
BUCCONIDAE						
Notharcus macrorhynchus	0.02					HO
RAMPHASTIDAE						
Pteroglossus aracari	0.07			0.07		FR
Selenidera maculirostris (s)	0.7 *	0.02	0.37	0.68	0.28	FR
Baillonius bailloni	0.05					FR
Ramphastos dicolorus	0.12		0.03	0.07	0.02	FR
PICIDAE						
Picumnus temminckii (s)	0.15	0.54	0.5	0.28		TI

APPENDIX. Continuation.

Families and species	Forest fragments-ha					Feeding habits
	PG-70	HI-60	FA-56	FB-25	FC-11	
Picumnus cirratus			0.03			TI
Picumnus albosquamatus					0.02	TI
Chrysoptilus melanochloros (s)	0.22	0.17	0.08	0.3	0.05	TI
Piculus aurulentus		0.05	0.03		0.05	TI
Celeus flavescens (s)	0.15	0.07	0.02	0.18	0.18	TI
Dryocopus lineatus (s)	0.07	0.03	0.03		0.75 *	TI
Melanerpes flavifrons (s)	0.55	0.02	0.08	0.16	0.04	TI
Leuconerpes candidus					0.02	TI
Veniliornis spilogaster	0.3	0.14	0.18	0.16	0.14	TI
Phloeoceastes melanoleucos	0.03					TI
DENDROCOLAPTIDAE						
Dendrocincla turdina	0.1		0.03	0.07		TI
Sittasomus griseicapillus (s)	1.28 *	0.09	0.48	0.75	0.21	TI
Xiphocolaptes albicollis (s)	0.43	0.03	0.27	0.25	0.04	TI
Dendrocolaptes platyrostris (s)	0.85 *	0.19	0.62	1 *	0.51	TI
Lepidocolaptes angustirostris			0.02	0.09	0.07	TI
Lepidocolaptes fuscus (s)	0.4	0.02	0.27		0.25	TI
FURNARIIDAE						
Clibanornis dendrocolaptoides	0.02					GI
Furnarius rufus		0.03				GI
Synallaxis ruficapilla (s)	0.2	0.05	1.03 *	0.65	0.79 *	LI
Synallaxis frontalis	0.05	0.02			0.04	LI
Synallaxis spixi	0.02		0.02		0.02	LI
Synallaxis cinerascens	0.02	0.02	0.02	0.02		LI
Cranioleuca obsoleta	0.05					TI
Syndactyla rufosuperciliata	0.08				0.02	LI
Anabacerthia amaurotis			0.02			LI
Philydor lichtensteini	0.03		0.03			LI
Philydor rufus (s)	0.07	0.02	0.17	0.04		LI
Automolus leucophthalmus	0.05	0.03				LI
Heliobletus contaminatus	0.18	0.1	0.2	0.19	0.11	TI
Xenops rutilans (s)	0.12	0.2	0.02	0.12		TI
Sclerurus scansor	0.03		0.02			OM
FORMICARIIDAE						
Hypoedaleus guttatus	0.93 *		0.98 *	1.32 *	1.14 *	OM
Mackenziaena leachii		0.03			0.02	OM
Mackenziaena severa (s)	0.18	0.41	0.7 *	0.65	0.7	OM
Thamnophilus doliatus (s)		0.64		0.04	0.11	LI
Thamnophilus caerulescens (s)	0.15	0.88 *	0.68	0.32	0.51	LI
Thamnophilus ruficapillus		0.10		0.02		LI
Dysithamnus mentalis (s)	0.55	0.42	0.77 *	0.98 *	0.75 *	LI
Herpsilochmus rufimarginatus	0.08	0.14	0.05		0.02	LI
Drymophila malura	0.02					GI
Pyriglena leucoptera	0.52		0.82 *	0.9 *	0.82 *	OM

APPENDIX. Continuation.

Families and species	Forest fragments-ha					Feeding habits
	PG-70	HI-60	FA-56	FB-25	FC-11	
Chamaeza campanisona	0.42		0.02			HO
Grallaria varia	0.32					OM
Conopophaga lineata (s)	0.05	0.10	0.65	0.12	0.51	GI
RHINOCRYPTIDAE						
Psilorhamphus guttatus (s)	0.08		0.47	0.02	0.75 *	GI
Scytalopus indigoticus (s)	0.03		0.25	0.02	0.19	GI
COTINGIDAE						
Pachyramphus viridis	0.02					HO
Pachyramphus castaneus	0.03	0.02	0.07	0.05	0.05	HO
Pachyramphus polychopterus		0.36	0.05			HO
Pachyramphus validus	0.08	0.07	0.23	0.16	0.16	HO
Tityra cayana (s)	0.37		0.1	0.16	0.07	HO
Tityra inquisitor	0.03	0.02		0.02		HO
PIPRIDAE						
Manacus manacus	0.05					OM
Chiroxiphia caudata (s)	0.42		0.02	0.12		FR
Piprites chloris (s)	0.43	0.05	0.22	0.21	0.14	FR
Schiffornis virescens	0.02	0.02				HO
TYRANNIDAE						
Colonia colonus	0.08		0.05			GI
Sirystes sibilator (s)	0.45	0.02	0.02	0.09		GI
Tyrannus melancholicus	0.02	0.03	0.02	0.05		GI
Empidonomus varius			0.03	0.04		GI
Megarhynchus pitangua (s)	0.38	0.37	0.32	1 *	0.47	HO
Myiodynastes maculatus (s)	0.07	0.29	0.25	0.26	0.46	HO
Myiozetetes similis	0.02		0.02	0.02	0.02	HO
Pitangus sulphuratus (s)	0.07	0.37	0.4	0.67	0.58	OM
Myiarchus swainsoni		0.05			0.16	GI
Empidonax euleri (s)	0.05	0.8 *	0.18	0.05		GI
Cnemotriccus fuscatus		0.03				GI
Myiophobus fasciatus	0.02	0.03	0.08	0.02	0.02	GI
Platyrinchus mystaceus			0.02	0.02		LI
Tolmomyias sulphurescens (s)	0.07	0.25	0.22	0.02	0.16	LI
Todirostrum cinereum		0.05	0.05		0.12	LI
Todirostrum plumbeiceps	0.03		0.25			LI
Idioptilon nidipendulum	0.1					LI
Myiornis auricularis (s)	0.23	0.83 *	0.23	0.33	0.05	LI
Hemitriccus obsoletus (s)		0.02	0.23	0.02	0.02	LI
Phylloscartes eximius	0.02					LI
Phylloscartes ventralis	0.15	0.14	0.17	0.18	0.04	LI
Capsiempis flaveola (s)	0.05	0.02	0.23	0.11	0.02	LI
Serpophaga subcristata					0.02	LI
Elaenia flavogaster			0.02		0.02	HO
Elaenia mesoleuca	0.02					HO

APPENDIX. Continuation.

Families and species	Forest fragments-ha					Feeding habits
	PG-70	HI-60	FA-56	FB-25	FC-11	
Myiopagis caniceps (s)	0.7 *	0.29	0.13	0.12	0.16	LI
Myiopagis viridicata	0.02					LI
Camptostoma obsoletum	0.07	0.10	0.08	0.16	0.04	LI
Leptopogon amaurocephalus (s)	0.18	0.46	0.25	0.26	0.18	LI
Pipromorpha rufiventris (s)	0.3		0.08	0.02		LI
Corythopis delalandi		0.7				LI
OXYRUNCIDAE						
Oxyruncus cristatus	0.05		0.02			FR
CORVIDAE						
Cyanocorax chrysops (s)	0.15		0.4	0.54	0.32	HO
TROGLODYTIDAE						
Troglodytes aedon		0.02		0.02		LI
TURDIDAE						
Turdus nigriceps			0.03	0.03	0.04	HO
Turdus rufiventris (s)	0.05	0.24	0.25	0.67	0.23	HO
Turdus leucomelas (s)	0.13	0.59	0.12	0.44	0.42	HO
Turdus amaurochalinus	0.03	0.10	0.1	0.21	0.11	HO
Turdus albicollis (s)	0.12	0.03	0.02	0.02		HO
SYLVIIDAE						
Polioptila lactea	0.02					LI
VIREONIDAE						
Cyclarhis gujanensis (s)	0.55	1.78 *	1.4 *	1.05 *	1.33 *	HO
Vireo olivaceus		0.03				LI
Hylophilus poicilotis		0.83 *	0.02			HO
ICTERIDAE						
Cacicus haemorrhous (s)	0.22	0.02	0.03	0.18	0.07	HO
PARULIDAE						
Parula pitiayumi (s)	0.27	0.17	0.07	0.07	0.04	LI
Basileuterus culicivorus (s)	1.12 *	1.41 *	1.25 *	1.4 *	1.23 *	LI
Basileuterus leucoblepharus	0.08		0.53	0.04	0.33	GI
COEREBIDAE						
Coereba flaveola				0.02		NE
Conirostrum speciosum (s)	0.35	0.41	0.15	0.11	0.14	HO
THRAUPIDAE						
Euphonia musica	0.02					FR
Euphonia chlorotica (s)	0.05	0.2	0.03	0.07		FR
Euphonia violacea	0.02		0.03	0.09	0.02	FR
Tangara cayana					0.02	HO
Thraupis sayaca (s)	0.03	0.25	0.02	0.19	0.07	HO
Habia rubica (s)	0.38	0.10	0.12	0.25	0.18	HO
Tachyphonus coronatus	0.2		0.13	0.07	0.16	HO
Trichothraupis melanops (s)	0.35	0.09	0.38	0.51	0.44	HO
Hemithraupis guira (s)	0.48	0.51	0.33	0.21	0.3	HO
Orchesticus abeillei			0.02			HO

APPENDIX. Continuation.

Families and species	Forest fragments-ha					Feeding habits
	PG-70	HI-60	FA-56	FB-25	FC-11	
Cissopis leveriana (s)	0.02	0.03	0.2	0.16	0.25	OM
FRINGILLIDAE						
Saltator similis (s)	0.07	0.36	0.38	0.39	0.19	HO
Pitylus fuliginosus (s)	0.1		0.37	0.28	0.16	HO
Arremon flavirostris (s)		0.15		0.02	0.02	FR