ORNITOLOGIA NEOTROPICAL 15 (Suppl.): 137–144, 2004

EFFECTS OF FRAGMENTATION ON THE BIRD GUILDS OF THE ATLANTIC FOREST IN NORTH PARANÁ, SOUTHERN BRAZIL

Luiz dos Anjos[1,3], Lorenzo Zanette[2] & Edson Varga Lopes[3]

[1]Departamento de Biologia Animal e Vegetal, Universidade Estadual de Londrina, P.O. Box 6001, 86051-970, Londrina, Paraná, Brazil. *E-mail:* llanjos@sercomtel.com.br

[2]PhD Program, Dept. Biology, University College London, Wolfson House, 4 Stephenson Way, London NW1 2HE, UK.

[3]Curso de Pós-Graduação em Ciências Biológicas, Universidade Estadual de Londrina, P.O. Box 6001, 86051-970, Londrina, Paraná, Brazil.

Resumo. – Efeitos da fragmentação sobre guildas de aves da Floresta Atlântica no norte do Paraná, sul do Brasil. – Riqueza e abundância de aves foram avaliadas em uma paisagem fragmentada de floresta Atlântica, sul do Brasil, onde a conectividade estrutural entre os fragmentos florestais é similarmente baixa, especialmente para as aves florestais, desde que o habitat matriz é formado principalmente por plantações de soja. O objetivo deste estudo foi testar se o grau de isolamento dos fragmentos tem um efeito mais significativo do que seus tamanhos para mudança na composição de guildas. Contagens pontuais foram realizadas em 14 fragmentos (11–656 ha). Quando os fragmentos foram separados pelos seus tamanhos, uma raiz marginalmente significante foi obtida em uma análise discriminante canônica (ADC) usando o número de espécies em cada guilda (χ^2_{16} = 25,59; P = 0,06). Uma raiz significante foi também obtida separando os fragmentos pelos seus respectivos graus de isolamento (ADC; χ^2_{16} = 26,38; P = 0,05). A guilda dos insetívoros de folha foi a mais importante para estes resultados em ambas as ADCs. Nenhuma raiz discriminante significativa foi encontrada quando foram comparados dados da abundância.

Abstract. – Richness and abundance of birds were evaluated in a fragmented landscape in the Atlantic forest region, southern Brazil, where the structural connectivity among the forest fragments is similarly low, especially for the forest bird species, since the habitat matrix is formed mainly by soya bean plantations. The goal of the study was to test if the degree of isolation of the fragments has a more significant effect than their sizes in changing the guild composition. Point counts were performed in 14 forest fragments (11–656 ha). When separating the fragments by their sizes, a marginally significant discriminant root was obtained in the canonical discriminant analysis (CDA) using the number of species in each guild (χ^2_{16} = 25.59; P = 0.06). A significant root was also obtained by separating fragments according to their degree of isolation (CDA; χ^2_{16} = 26.38; P = 0.05). Leaf insectivores were the most important guild for the results in both CDAs. No significant discriminant root was found when considering the abundance data. *Accepted 16 January 2004.*

Key words: Bird guilds, Brazil, Atlantic forest fragments, forest fragment isolation, forest fragment size.

INTRODUCTION

Forest fragmentation is one important force driving bird extinction in the tropics. Habitat loss, increased edge effect and isolation of populations are considered to be the direct causes of that process (Laurance *et al.* 1997). Changes in guild composition may be an

TABLE 1. Sizes (ha) and distances of each forest fragment from the nearest reference fragment (PG, FJ, or FI), except in the case of the fragment HI. Connections through forest corridors are also indicated.

Forest fragments	Size	Distance
PG	656	Reference
FM	564	800 m from FI
FJ	393	Reference
FN	387	5900 m from FI
FE	350	5000 m from PG
FG	285	2000 m from PG; connected to PG by forest corridor
FI	184	Reference
FD	87	800 m from PG
FH	72	2400 m from PG
FO	70	3300 from FI
HI	60	2000 from any other large forest
FA	56	500 m from PG
FB	25	400 m from PG; connected to PG by forest corridor
FC	11	1100 m from PG

additional effect of forest fragmentation (Renjifo 1999). Laurance *et al.* (2002) reported considerable changes in the guild composition of birds of Amazonian fragments monitored for 22 years. They observed that insectivores were especially vulnerable to fragmentation, whereas many omnivores and nectarivores remained stable or increased in fragments.

The Atlantic forest (a strip of rain forest along the mountains of the Brazilian Atlantic coast) is one of the most threatened areas in the tropics; only 5% of its original cover is remaining (Myers *et al.* 2000). Several authors have studied the effects of forest fragmentation on the communities of the Atlantic forest (e.g., Willis 1979, Aleixo & Vielliard 1995, Anjos 2001). However, these studies, except one, considered a restricted number of fragments, limiting possible generalizations of their results (Debinski & Holt 2000). The exception is the study of Marsden *et al.* (2001) which analyzed 31 forest fragments (from 10 to 150 ha in size) in a fragmented landscape close to Sooretama/Linhares reserve, state of Espírito Santo, southeastern Brazil.

The north of Paraná state, one of the three south Brazilian states, suffered a strong and fast fragmentation process, the remaining Atlantic forest representing only 1% of the original cover (100% were covered by forest by 1920s). Farming is the most common type of land use in the region. The landscape matrix is largely made of soya been plantations which form the most extensive and connected habitat in that region (Forman 1995). Such habitat matrix is not tolerated by true forest bird species. Therefore, it is possible to assume that the structural connectivity among the forest fragments is similarly low, especially for the forest species. Consequently, other factors such as the size of the fragments and their degree of isolation may have a strong influence on the composition of the bird communities (Anjos & Boçon 1999). Several fragments are still primary forest, most of them have been isolated for at least 40 years.

The goal of the present study is to test if the degree of isolation of the studied fragments has a more significant effect than their sizes in changing guild composition. To the best of our knowledge, this is only the second time that a large number of forest fragments is used to assess the effects of fragmentation on the bird populations of the Atlantic forest.

METHODS

Study sites. Fourteen Atlantic forest fragments in the north of the State of Paraná were analyzed. Sizes of the forest fragments ranged between 11 ha and 656 ha (Table 1). Although the forest fragments could not be consider perfect replicates, they could be grouped according to their size and degree of isolation from other fragments. Three forest fragments were chosen as the references in this study (PG, FH, and FI). PG was the largest one (656 ha; 23º27'S, 51º15'W), FJ (393 ha) and FI (184 ha). FJ and FI were selected because they formed together a complex totaling 577 ha in area, slightly larger than FM (564 ha). Although the three references areas were also fragments, they can be considered the best representatives of the previous continuous forest, since no other preserved forest fragment with similar size and level of habitat complexity exists in the region. Actually, PG is an important conservation unit for this region of Atlantic forest since 1989: the Godoy State Park. The remaining fragments were categorized according to their sizes: (1) large, from 184 ha to 564 ha (FG, FE, FN, and FM) and (2) small, from 11 ha to 87 ha (FB, FA, HI, FO, FH, and FD). They were also categorized according to their degree of isolation: (1) isolated, when they were 2000 m or more away from a reference fragment (HI, FN, FO, and FE) and (2) not isolated, when they were less than 800 m apart from a reference fragment or were connected to one or more by forest corridors (FD, FB, FG, FM, FH, and FA).

All the fragments represented relatively undisturbed primary forests. Hunting and selective cutting were forbidden in all sites. Although these activities may have occasionally occurred in the area, it may be assumed by our previous experience and historical knowledge of the region that they have not affected our data. The matrix habitat around the sites is mostly agricultural (soya bean); only HI has a mixed surrounding matrix (40% urban and 60% agricultural). For a more complete description of the vegetation and climatic conditions of the region, see Anjos (2001).

Field work. The field work was carried out between September and December of 1997 in PG, HI, FA, FB, and FC, and in the same period of 2000 in the other sites. The selected period of study covered four months, from September to December (part of spring and summer), and permitted to register, on average, 90% of the species recorded during previous 1-year studies in five of the same fragments (Anjos 2001). Each site was censured by monthly point counts of unlimited distance (Blondel *et al.* 1970, Bibby *et al.* 1993) during the four months. The estimated sampled area in each site was 10 ha. The songs of 12 individuals of 11 species were recorded (UHER 4400 with Sennheiser K6 microphone) and collected in forest fragments not used in this study in order to confirm identification.

According to feeding habits, each species was assigned to one of the following categories: nectarivores, carnivores, omnivores of the sub-canopy, canopy omnivores, frugivores of the sub-canopy, canopy frugivores, leaf insectivores, trunk insectivores, and general insectivores (the others insectivores that do not capture food on leaves or trunks).

Analyses. All calculations presented in this study were made taking into account the number of contacts with each species. These data for each of the bird species in the forest fragments are available as an electronic file to those who may need them.

TABLE 2. Species numbers and contact numbers of each bird guild in the forest fragments. The bird guilds are: nectarivores (NE), carnivores (CA), frugivores of the sub-canopy (FU), canopy frugivores (FC), leaf insectivores (LI), trunk insectivores (TI), generalized insectivores (GI), omnivores of the sub-canopy (OU), and canopy omnivores (OC).

	Bird guilds								
	NE	CA	FU	FC	LI	TI	GI	OU	OC
Species:									
PG	4	4	7	17	25	18	8	16	15
FJ	3	3	4	14	22	10	13	22	15
FI	4	4	8	14	26	15	12	21	18
FM	1	6	8	15	19	10	8	19	16
FG	1	4	6	13	23	15	12	18	14
FD	2	4	6	12	20	11	9	17	15
FH	2	5	6	10	16	10	8	15	15
FA	3	4	8	10	18	12	8	14	12
FB	2	3	7	9	19	13	8	13	13
FC	3	2	8	11	17	10	6	16	14
FN	2	1	5	11	20	11	10	18	15
FE	3	4	3	6	15	11	9	15	15
FO	0	5	5	8	15	4	10	16	13
HI	3	1	5	4	16	11	7	12	13
Contacts:									
PG	5	12	60	119	128	130	41	83	93
FJ	4	3	38	57	174	30	104	121	88
FI	4	7	46	105	238	78	93	159	119
FM	1	10	45	92	137	39	49	112	138
FG	3	8	39	86	259	77	105	133	120
FD	11	6	67	83	210	66	79	98	133
FH	2	9	39	84	186	48	65	89	145
FA	5	5	43	87	141	55	55	101	108
FB	2	6	43	74	145	86	48	100	112
FC	4	3	40	77	99	30	63	97	112
FN	3	2	55	34	128	58	55	93	119
FE	7	6	44	52	164	58	52	109	109
FO	0	6	36	67	151	19	68	107	118
HI	13	1	58	62	137	41	44	78	105

A canonical discriminate analysis (CDA) using the bird abundance data for each guild in each fragment was used to evaluate if the forest fragments could be grouped according to their size. Another CDA was used to test if the same fragments could be grouped according to their degree of isolation. These analyses were also performed using the species richness values for each guild in each fragment. Data were log transformed in all the CDAs.

The guild of carnivores (birds of prey) was not considered in these analyses because it has a very low abundance in the study, and because most of the species can easily move between the fragments; therefore, the spatial

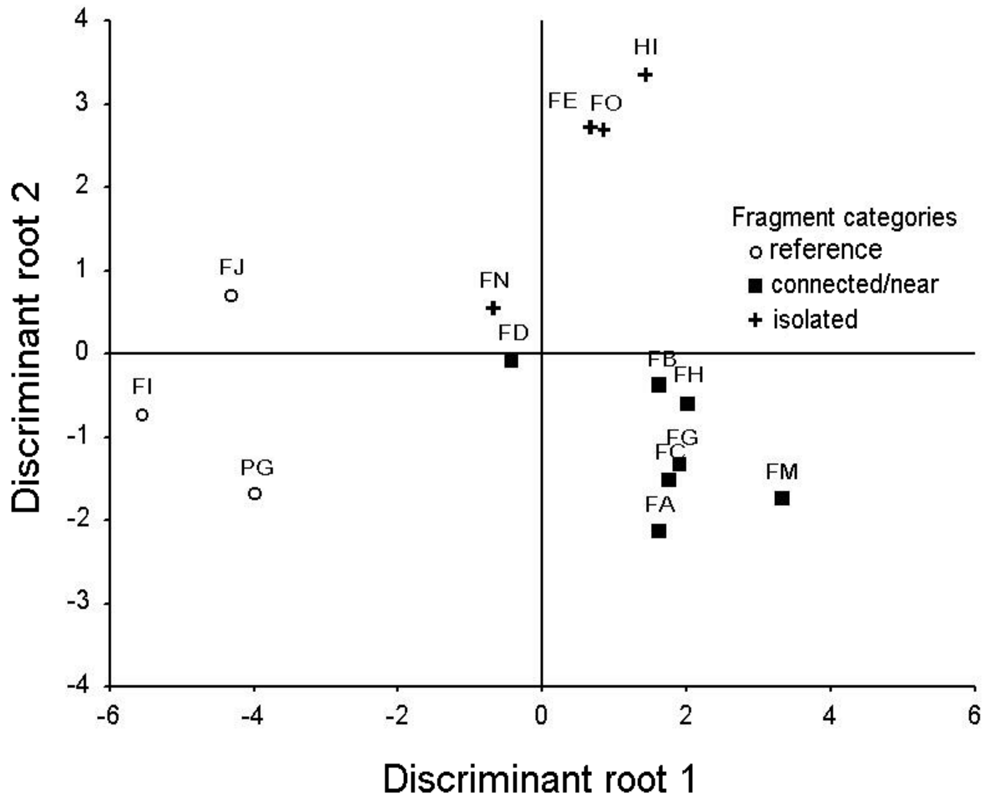

FIG. 1. Ordination plot of the studied sites using the two discriminant axes (roots) obtained with the species richness data and degree of isolation of the forest fragments (see Table 3). Explanation of symbols: CA = carnivores, FC = canopy frugivores, FU = frugivores of the sub-canopy, GI = generalized insectivores, LI = leaf insectivores, NE = nectarívoros, OC = canopy omnivores, OU = omnivores of the sub-canopy, and TI = trunk insectivores.

scale considered here might not be relevant for this bird group (Crome 1997).

RESULTS

A total of 177 bird species were recorded in the 14 forest fragments: 38 were leaf insectivores, 27 omnivores of the sub-canopy, 24 canopy frugivores, 24 canopy omnivores, 19 trunk insectivores, 16 generalized insectivores, 10 frugivores of the sub-canopy, 10 carnivores, and 9 nectarivores. Usually, the leaf insectivores were the guild with the highest number of species and the highest number of contacts in each of the forest fragments (Table 2).

When grouping the fragments by their isolation degree, the first canonical root obtained was significant when using richness data ($\chi^2_{16} = 26.38$; $P = 0.05$). In the ordination of the fragments along this root (factor), the reference fragments are clearly apart from the others (Fig. 1). The guild of the leaf insectivores (LI) was the most important variable for that root, while the canopy frugivores (FC) and the frugivores of the sub-canopy (FU)

TABLE 3. Correlation between the guilds and the first two canonical discriminant roots calculated with species richness values and considering degree of isolation of the forest fragments.

Guilds	Root 1	Root2
Frugivores of canopy	–0.234	–0.638
Leaf insectivores	–0.386	–0.456
Frugivores of sub-canopy	0.042	–0.556
Generalized insectivores	–0.288	0.002
Nectarivores	–0.246	–0.006
Omnivores of canopy	–0.214	–0.096
Omnivores of sub-canopy	–0.226	–0.169
Trunk insectivores	–0.125	–0.309

were the most important for the second root (Table 3). No significant discriminant root was found when considering the abundance data for each guild.

When separating the fragments by their sizes, a marginally significant discriminant root was obtained in the CDA using the number of species in each guild (χ^2_{16} = 25.59; *P* = 0.06). The reference fragments were again clearly separated from the others (Fig. 2). The leaf insectivores (LI) were again the guild more strongly correlated to the first root, and the omnivores of the sub-canopy (OU) was the guild more strongly correlated to the second root (Table 4). No significant discriminant root was found when considering the abundance data for each guild.

DISCUSSION

Several guilds that had decreased in species number have maintained their participation in the community because some species

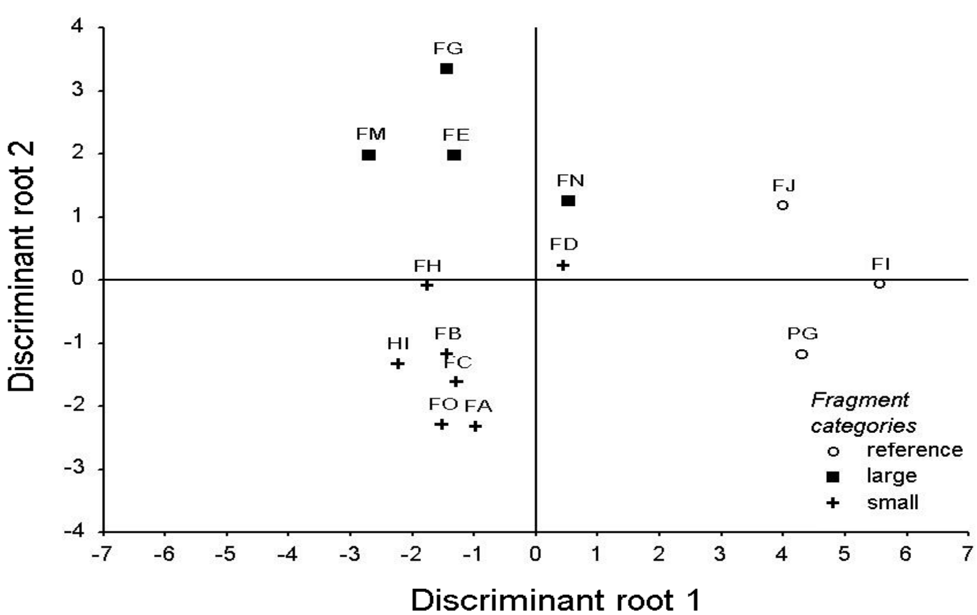

FIG. 2. Ordination plot of the studied sites using the two discriminant axes (roots) obtained with the species richness data and classes of size of the forest fragments (see Table 4). Explanation of symbols: CA = carnivores, FC = canopy frugivores, FU = frugivores of the sub-canopy, GI = generalized insectivores, LI = leaf insectivores, NE = nectarívoros, OC = canopy omnivores, OU = omnivores of the sub-canopy, and TI = trunk insectivores.

TABLE 4. Correlation between the guilds and the first two canonical discriminant roots calculated with species richness values and considering the size of the forest fragments.

Guilds	Root 1	Root2
Frugivores of canopy	0.237	0.158
Leaf insectivores	0.417	0.233
Frugivores of sub-canopy	0.017	–0.194
Generalized insectivores	0.328	0.359
Nectarivores	0.263	–0.232
Omnivores of canopy	0.267	0.369
Omnivores of sub-canopy	0.294	0.399
Trunk insectivores	0.155	0.166

increased in abundance; those species, supposedly, benefited from the forest fragmentation. The increase in the abundance of certain species may explain why no significant discriminant root was found when considering abundance data. The best example is that of the leaf insectivores, which presented 25 species and 128 contacts in PG, and 16 species and 137 contacts in HI; so, the contact numbers could be maintained for that guild.

In contrast to the abundance data, significant discriminant roots were obtained when the number of species in each guild was considered. The great importance of leaf insectivores in these roots indicates that this guild is highly sensitive to the fragmentation process, especially when considering the size of fragments and their degree of isolation. This result is consistent with several other studies which showed the insectivores as highly sensitive to fragmentation (Willis 1974, Stouffer & Bierregaard 1995, Sieving *et al.* 1996, Renjifo 2001). Several leaf insectivores seem highly dependent on specific microhabitats found within large fragments, such as bamboo and vine-tangle species (*Synallaxis ruficapilla*, *Scytalopus indigoticus*, *Hemitriccus diops*, and *Hylopezus nattereri*).

Renjifo (2001) indicated that the habitat matrix was a major factor influencing the bird communities of the forest fragments in the Colombian Andes. Other studies showed the high influence of habitat matrices on the bird communities of forest fragments (Debinski & Holt 2000). Considering that the connectivity between the fragments increases with the increasing similarity of habitat structures or floristic composition between fragments and matrices (Taylor *et al.* 1993), one possible explanation for the observed relation between the bird species richness and the size and degree of isolation of the fragments in the north of Paraná may be that the great homogeneity of the habitat matrix is not tolerated by true forest species.

Marsden *et al.* (2001) did not find significant relationships between the bird species richness and the size and degree of isolation of forest fragments of the fragmented landscape close to the Sooretama/Linhares reserve in southeastern Brazil. The lack of relationship was considered as the result of different histories of disturbance in the fragments. However, the low range of the fragment sizes analyzed by Marsden *et al.* (2001), from 10 to 150 ha, compared to the range (11 to 387 ha) in the present study, excluding the reference fragments, may be another reason for the observed results.

In the CDAs using the number of species in each guild, the degree of isolation of the sites was a factor slightly more significant than their size when grouping the forest fragments. This result suggests that the conservation of all the fragments close to the reference fragment should be a priority over the isolated ones in the studied landscape.

ACKNOWLEDGMENTS

A. Townsend Peterson made important suggestions that improved the final version of this manuscript. This study was funded, through the Mata Atlantica Program, by MCT-CNPq (Minister of Science and Technology-National Research Council, Brasília), section International Cooperation. We also acknowledge the CNPq for a research grant (350054/95-9) awarded to LdA, and a student grant to EVL. Permissions (1) to conduct research in the Godoy State Park was obtained from IAP (Enviromental Institute of Paraná State), and (2) to collect bird specimens in the north of Paraná was obtained from IBAMA (Brazillian Insitute of Enviroment, process number 2641/99).

REFERENCES

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

Anjos, L. dos. 2001. Bird communities in five Atlantic forest fragments in southern Brazil. Ornitol. Neotrop. 12: 11–27.

Anjos, L. dos, & R. Boçon. 1999. Bird communities in natural forest patches in southern Brazil. Wilson Bull. 111: 397–414.

Bibby, C. J., N. D. Burgers, & D. A. Hill. 1993. Bird census techniques. Academic Press, San Diego, California.

Blondel, J., C. Ferry, & B. Frochot. 1970. La méthode des indices ponctuels d'abondance (I.P.A.) ou des relevés d'avifaune par "stations d'écoute". Alauda 38: 55–71.

Crome, F. H. J. 1997. Researching tropical forest fragmentation: shall we keep on doing what we`re doing? Pp. 485–501 *in* Laurance, W. F., & R. O. Bierregaard, Jr. (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Univ. of Chicago Press, Chicago, Illinois.

Debinski, D. M., & R. D. Holt. 2000. A survey and overview of habitat fragmentation experiments. Conserv. Biol. 14: 342–355.

Forman, R. T. T. 1995. Land mosaics: the ecology of landscape and regions. Cambridge Univ. Press, Cambridge, UK.

Laurance W. F., R. O. Bierregaard, Jr., C. Gascon, R. K. Didham, A. P. Smith, A. J. Lynam, V. M. Viana, T. E. Lovejoy, K. E. Sieving, J. W. Sites, Jr., M. Andersen, M. D. Tocher, E. A. Kramer, C. Restrepo, & C. Moritz. 1997. Tropical forest fragmentation: synthesis of a diverse and dynamic discipline. Pp 502–514 *in* Laurance, W. F., & R. O. Bierregaard (eds.). Tropical forest remnants: ecology, management, and conservation of fragmented communities. Univ. of Chicago Press. Chicago, Illinois.

Laurance, W., T. E. Lovejoy, H. L. Vasconcelos, E. M. Bruna, R. K. Didham, P. C. Stouffer, C. Gascon, R. O. Bierregaard, S. G. Laurance, & E. Sampaio. 2002. Ecosystem decay of Amazonian fragments: a 22-year investigation. Conserv. Biol. 16: 605–618.

Marsden, S. J., M. Whiffin, & M. Galetti. 2001. Bird diversity and abundance in forest fragments and Eucalyptus plantations around an Atlantic forest reserve, Brazil. Biodivers Conserv. 10: 737–751.

Myers, N., R. A. Mittermeier, C. Mittermeier, G. A. B. Fonseca, & J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

Renjifo, L. M. 1999. Composition changes in a subandean avifauna after long-term forest fragmentation. Conserv. Biol. 13: 1124–1139.

Renjifo L. M. 2001. Effect of natural and anthropogenic landscape matrices on the abundance of subandean bird species. Ecol. Appl. 11: 14–31.

Sieving, K. E., M. F. Willson, & T. de Santo. 1996. Habitat barriers to movements of understory birds in fragmented south-temperate rainforest. Auk 113: 944–949.

Stouffer, P. C., & R. O. Bierregaard, Jr. 1995. Use of Amazonian forest fragments by understory insectivorous birds. Ecology 76: 2429–2445.

Taylor, P. D., L. Fahrig, K. Henein, & G. Merriam. 1993. Connectivity is a vital element of landscape structure. Oikos 68: 571–573.

Willis, E. O. 1974. Populations and local extinctions of birds on Barro Colorado Island, Panama. Ecol. Monog. 44: 153–169.

Willis, E. O. 1979. The compositon of avian communities in remanescent woodlots in southern Brazil. Pap. Avulsos Zool. 33: 1–25.