Composition of mixed-species bird flocks in forest fragments of southern Brazil

Cláudia S. Brandt [1, 3]**; Heinrich Hasenack** [1]**; Rudi R. Laps** [2] **& Sandra Maria Hartz** [1]

[1] Programa de Pós-Graduação em Ecologia, Centro de Ecologia, Universidade Federal do Rio Grande do Sul. Avenida Bento Gonçalves 9500, Caixa Postal 15007, 91501-970 Porto Alegre, Rio Grande do Sul, Brasil.
[2] Laboratório de Biologia Animal e Laboratório de Ecologia e Ornitologia, Departamento de Ciências Naturais, Universidade Regional de Blumenau. Rua Antônio da Veiga 140, Victor Konder, 89012-900 Blumenau, Santa Catarina, Brasil.
[3] Correspondig author. E-mail: claubrandt@gmail.com

ABSTRACT. The present study aimed to evaluate the composition of mixed-species bird flocks in a fragmented landscape of the Atlantic Forest in southern Brazil. We recorded 117 species in 218 mixed-species flocks. The correspondence analysis showed two distinct groups of fragments according to degree of connectivity with other fragments. The percentage of original cover surrounding a sampled fragment area up to a ratio of 2.5 and 1 km was the variable that presented highest correlation with the formation of different composition of mixed-species bird flocks, followed by altitude. Based on these results, we concluded that, in landscapes with low levels of fragmentation, the composition of mixed flocks reflects the local species pool. Thus, future studies comparing composition of mixed-specie flocks should concentrate their efforts in areas where some of these variables remain constant, as for example where fragments are at similar altitudes.

KEY WORDS. Atlantic Forest; bird community; ecological interactions; fragmentation; mixed-species flocks.

Forest fragmentation and its effects on biodiversity are issues frequently discussed in the literature. In contrast, the number of studies addressing the effects of habitat fragmentation on social systems and the behavior of participant individuals has received little attention, at least until recently (TELLERIA *et al.* 2001). As an attempt to fulfill this gap, new approaches that focus on the ecological interactions between species, which play an important role in maintaining the integrity of local communities (MALDONADO-COELHO & MARINI 2003, SRIDHAR & SANKAR 2008), have emerged.

Mixed flocks of birds are amongst the most common and complex interactions in forest environments (JULLIEN & THIOLLAY 1998). For this reason, understanding their ecology may enhance our understanding of the biology and behavior of the participant species, and help provide information to devise conservation strategies in fragmented landscapes (MALDONADO-COELHO & MARINI 2003). An example of the latter is a study conducted in the Amazon Forest (VAN HOUTAN *et al.* 2006) showing that species that participate in mixed flocks are more sensitive to habitat fragmentation, thus spending less time in fragmented landscapes when compared with solitary species.

All over the world researchers have been following mixed flocks of birds in fragmented forests (STOUFFER & BIERREGAARD 1995, TELLERIA *et al.* 2001, POMARA *et al.* 2003, LEE *et al.* 2005, VAN HOUTAN *et al.* 2006). In contrast, few studies have been conducted in the Atlantic Forest, one of most endangered and fragmented biomes in the world, now less than 10% of its original size (MALDONADO-COELHO & MARINI 2000, 2003, 2004). The few studies conducted in this biome suggest that the composition

of mixed bird flocks is relatively low in diversity and that participant species are those best adapted to small forest fragments or fragments with new (recent) or otherwise weakly developed forest cover (MALDONADO-COELHO & MARINI 2000, 2003, 2004).

In order to fully understand the effects of forest fragmentation on mixed flocks of birds in the Atlantic Forest, however, supplementary studies on other aspects of habitat degradation are needed. Among the factors that are known to affect populations and communities in fragmented landscapes are habitat loss and the territory configuration (FAHRIG 1998, GASCON *et al.* 1999, VILLARD *et al.* 1999). The importance of these factors, in turn, depends on the structural characteristics of the landscape and the biological aspects of the species involved (ANTONGIOVANNI & METZGER 2005).

Where habitat fragmentation is not too severe, the resulting fragments may not be totally isolated from the remaining forest matrix or forest patches. In such cases, species composition and biological interactions between species can be influenced by how adaptable participant species are to transition zones and to changes in the structure and microclimate of the local vegetation (HOWROT & NIEMI 1996, PIRES *et al.* 2006). The forest cover left around the fragments can also influence local communities by affecting the degree of isolation between patches and the maximum size of local populations (ANDRÉN 1994, VILLARD *et al.* 1999).

The present study aimed to study the mixed flocks of birds in a fragmented landscape in order to ascertain whether distinct fragment configurations, different percentages of surrounding forest cover and altitude impact the composition of these flocks.

MATERIAL AND METHODS

This study took place at the Itajaí River Basin, Santa Catarina, Brazil (26°38'-27°38'S, 50°13'-48°21'W). The climate is humid mesothermic without seasonal water deficiency (GAPLAN 1986). The vegetation is part of the Atlantic Forest biome, and has been classified as mainly Ombrophilous Dense Forest (GAPLAN 1986).

We circumscribed our study sites according to their configuration in the following manner. First, we considered any disturbed area as a non-forest matrix (BECKER *et al.* 2007). Inside the limits of the region under study, non-forest matrices correspond to a mosaic of urban and rural areas, as well as habitats in their first phase of regeneration ("capoeira"). Taking this into consideration, we selected eleven forest fragments that were formerly part of the same, continuous forest, and classified them as follows: 1) massive fragment (immersed in a massive forest); 2) intermediate fragment (limited by a non-forest matrix but maintaining a continuous link with the forest matrix); 3) isolated fragment (totally limited by non-forest matrices). Our study sites were separated by an average of 19.36 km (2.2-45.84 km) from each other.

In addition to the configuration of the study sites, we also took into consideration the percentage of forest cover in the surrounding areas, regardless of whether they bear a direct connection with the study sites or not. Forest cover was evaluated based on an satellite image taken on November 27, 2005 by CBERS-INPA (Satélite Sino-Brasileiro de Recursos Terrestres – Instituto Nacional de Pesquisas Espaciais) and classified into two categories with the help of the computer software Idrisi v. 15.01 (Andes) from 2006 (EASTMAN 2006): 1) original vegetation present; 2) original vegetation not present. Next, using the same program, we circumscribed circular areas (buffers) around each study site and superimposed them on the image classified according to the categories defined above. Because the forest cover may vary according with the scale used, thus influencing the results, we used three different buffer sizes, 1.0 km (3.14 km²); 2.5 km (19.63 km²); and 5.0 km (78.53 km²) (Fig. 1).

Sampling was conducted between May-Aug in order to avoid the reproductive season of most local bird species. In order to minimize variables that influence the composition of mixed bands, the structure of the vegetation within fragments was standardized by including only fragments composed mainly by secondary vegetation in the middle stage of plant succession (KLEIN 1980). Because most of the vegetation in the region under study grows on slight to steep slopes, we were not able to standardize the altitude. Because this variable may influence the composition of mixed bands (KOTAGAMA & GOODALE 2004), we recorded the maximum altitude of each sampled area (Tab. I).

Each fragment area was sampled during a period of four consecutive days. Observations were conducted between 7:00-10:30 am and 2:00-5:30 pm, totaling 286 hours of effort in each area.
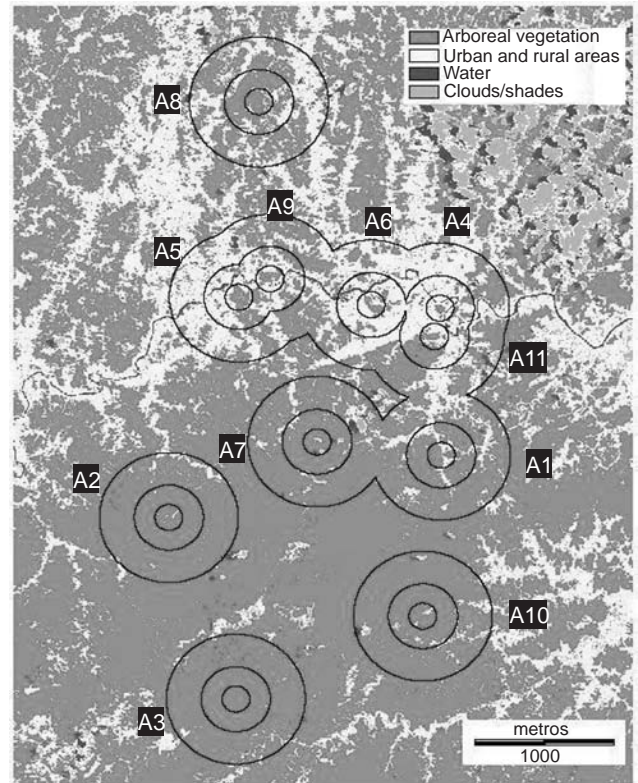

Figure 1. Atlantic Forest remnants of the hydrographic bacin of the Itajaí River, Santa Catarina, surveyed in this study. The circles indicate area buffers. The image was made available by the Instituto de Pesquisas Espaciais-INPE.

Mixed-species flocks are defined after STOTZ (1993) as associations between two or more species moving in the same direction for at least five minutes. During our surveying efforts we followed pre-existing paths, trying not to take the same path twice in order to avoid encountering a mixed flock more than once in the same fragment area. We observed each band for fifteen minutes and walked away from it in case the flock continued to remain visible after this period (MALDONADO-COELHO & MARINI 2004).

We used correspondence analysis (CA) to evaluate similarities in species composition between mixed bird flocks, with the help of the statistics package MULTIV v.2.4 (PILLAR 2006). The matrix contained the presence or absence of species in each area. Bootstrap autoresampling was used to evaluate axes stability (PILLAR 1999). A given species was considered responsible for the segregation of a group of fragments when its correlation with a stable axis was ⩾ 0.5.

Once the stability of at least one axis of the CA and the formation of distinct fragments groups with respect to species composition were confirmed, the effects of the following variables were tested: configuration in the landscape, original for-

Table I. Description of the characteristics of the remnants of the Atlantic Forest of the hydrographic basin of the Itajaí River, Santa Catarina, evaluated for the composition of mixed-species bird flocks.

Locality name	Code	Configuration	Area (ha)	Forest cover buffer ratio (%)			Max. altitude (m)
				1 km	2.5 km	5 km	
RPPN Bugerkopf	A1	Intermediate	57,000	74.0	82.0	79.0	528
Encano Alto	A2	Massive	57,000	92.3	71.3	88.2	365
Lageado Alto	A3	Massive	57,000	89.2	94.7	93.4	750
Morro da Banana	A4	Intermediate	26	15.1	16.9	31.0	155
Morro Geisler	A5	Intermediate	57,000	40.5	33.0	34.7	400
Associação Desportiva Cia Hering	A6	Intermediate	80	37.5	20.4	31.6	300
Warnow Alto	A7	Massive	57,000	93.4	98.5	95.6	600
Morro Azul	A8	Intermediate	57,000	77.8	71.3	55.9	700
Mulde Baixa	A9	Intermediate	85	40.5	37.8	45.5	50
Fazenda Agrião	A10	Massive	57,000	99.9	99.2	96.1	700
PNM São Franscico de Assis	A11	Intermediate	57,000	38.6	33.2	39,4	135

est cover, and maximum altitude. The statistical software R (R Development Core Team 2007) was then used to perform a CA between these environmental variables and the scores of the stable axes for each area representing the composition of mixed bands. The results of each CA were considered significant when p was > 0.05. Whenever more than one environmental variable showed significant correlation with the composition of mixed bands, a CA was conducted between them. When more than one scale of original forest cover showed significant results, only the one with a higher p-value was considered.

RESULTS

We recorded 117 species of birds in 218 mixed-species flocks (Tab. II). The number of species in each flock ranged from 18 (A4) to 71 (A2) species, with a mean of 51.09 ± 16.66 species/area (Tab. I).

With respect to species composition, only five species were present in all fragment areas: *Dysithamnus mentalis* (Temminck, 1823) ,Thamnophilidae; *Xiphorhynchus fuscus* (Vieillot, 1818), Dendrocolaptidae; *Parula pitiayumi* (Vieillot, 1817), Parulidae; *Basileuterus culicivorus* (Deppe, 1830), Parulidae; and *Euphonia violacea* (Linnaeus, 1758), Fringillidae. Furthermore, no single species was present in all mixed species flocks sampled. The different fragment areas formed two distinct groups, as shown by the stability of the first axis (% variance = 18.10, p = 0.103) of the CA (Fig. 2). In other words, mixed flocks from the areas A1, A2, A4, A5, A6, A9 and A11 (Group 1) had a slightly different species composition with respect to areas A3, A7, A8 e A10 (Group 2.). In more general terms, however, the flocks were similar in all areas sampled.

Species composition of bird flocks correlated with environmental variables in various ways. An analysis of the posi-

tion of these variables in relation to axis 1 of the CA (Fig. 2 and Tab. III) reveals that fragment areas in Group 1 tend to have low percentage of surrounding original forest cover, low altitudes (50 to ~500m) and mainly non-forest matrix boundaries. In contrast, Group 2 is exclusively composed by fragment areas with high indexes of surrounding original forest cover, high altitudes (≥ ~500 m) and at least partial borders with the forest matrix. These tendencies are confirmed by the results of the CA, in which all environmental variables correlate positively with axis 1and, consequently, with the composition of mixed flocks (Tab. IV).
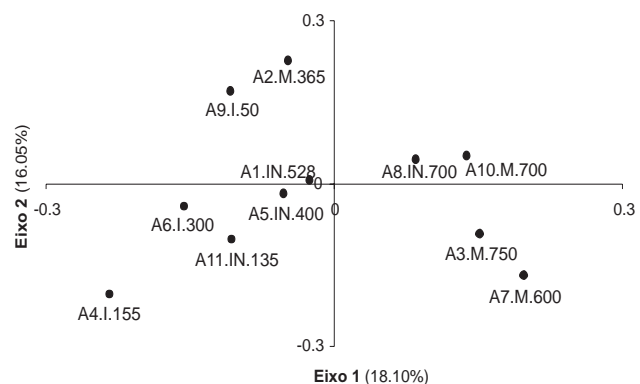
Figure 2. Correlation scores between the remnants of the Atlantic Forest of the hydrographic basin of the Itajaí River, Santa Catarina, sampled in the present study, and axis 1 of the Correspondence Analysis diagram, evaluating mixed species flock composition. The letters M, IN and I are initials for massive fragment, intermediate fragment and isolated fragment, respectively. Numbers following the letters indicate the maximum altitude of each fragment.

Table II. Species participating in mixed-species bird flocks sampled from remnants of the Atlantic Forest of the Hydrographic bay of the Itajaí River, Santa Catarina, between April and August, 2007.

Scientific name	Frequency in the study areas										
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Cuculidae											
Piaya cayana (Linnaeus, 1766)	0.24	0.14		0.75		0.13				0.13	0.31
Trochilidae											
Phaethornis squalidus (Temminck, 1822)	0.08										
Phaethornis eurynome (Lesson, 1832)		0.05									
Aphantochroa cirrochloris (Vieillot,1818)								0.04			
Thalurania glaucopis (Gmelin, 1788)	0.16	0.14			0.06	0.04	0.04	0.08		0.09	
Trogonidae											
Trogon surrucura (Vieillot, 1817)	0.20	0.05		0.25		0.08	0.04	0.08	0.14	0.09	0.08
Trogon rufus (Gmelin, 1788)	0.04	0.18									
Ramphastidae											
Selenidera maculirostris (Lichtenstein, 1823)		0.05									
Picidae											
Picumnus temminckii (Lafresnaye, 1845)	0.36	0.09			0.31	0.17	0.25	0.17	0.29	0.17	0.15
Melanerpes flavifrons (Vieillot, 1818)		0.32			0.06	0.08			0.05		
Veniliornis spilogaster (Wagler, 1827)	0.28	0.09	0.06		0.13	0.17	0.07	0.25	0.14	0.17	0.08
Piculus aurulentus (Temminck,1821)			0.06		0.06		0.04	0.21		0.09	
Dryocopus lineatus (Linnaeus, 1766)						0.08					
Thamnophilidae											
Hypoedaleus guttatus (Vieillot, 1816)	0.24	0.14		0.25	0.06	0.04	0.14	0.04	0.05	0.09	0.08
Mackenziaena severa (Lichtenstein, 1823)	0.04						0.04				
Biatas nigropectus (Lafresnaye, 1850)							0.04				
Thamnophilus caerulescens (Vieillot, 1816)	0.04	0.05	0.06				0.11	0.17	0.10	0.17	
Dysithamnus stictothorax (Hellmayr, 1911)	0.08					0.13	0.07	0.13	0.43	0.22	
Dysithamnus mentalis (Temminck, 1823)	0.16	0.18	0.17	0.25	0.38	0.38	0.25	0.33	0.38	0.26	0.08
Myrmotherula gularis (Spix, 1825)	0.20	0.18	0.11				0.04			0.04	
Myrmotherula unicolor (Ménétriès, 1835)	0.20	0.14					0.07		0.05	0.09	
Herpsilochmus rufimarginatus (Temminck, 1822)	0.52				0.19	0.25	0.11				0.38
Drymophila ferruginea (Temminck, 1822)	0.08	0.05					0.07	0.13	0.33		
Drymophila rubricollis (Bertoni, 1901)							0.04				
Drymophila ochropyga (Hellmayr, 1906)							0.04	0.04			
Drymophila malura (Temminck, 1825)							0.04		0.04		
Terenura maculata (Wied, 1831)	0.36						0.11			0.04	0.08
Pyriglena leucoptera (Vieillot, 1818)	0.04	0.09						0.04	0.24	0.13	
Myrmeciza squamosa (Pelzeln,, 1868)	0.04	0.09						0.08	0.05	0.04	
Conopophagidae											
Conopophaga lineata (Wied, 1831)			0.06				0.04	0.13	0.05	0.04	
Conopophaga melanops (Vieillot, 1818)	0.20	0.05			0.13	0.08		0.04	0.14	0.04	0.08

Continue

Table II.Continued.

Scientific name	Frequency in the study areas										
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Rhinocryptidae											
Psilorhamphus guttatus (Ménétriès, 1835)	0.04										
Scytalopus indigoticus (Wied, 1831)								0.04			
Formicaridae											
Formicarius colma (Boddaert, 1783)	0.08										
Scleruridae											
Sclerurus scansor (Menetries, 1835)	0.04	0.05	0.06		0.13	0.04	0.07	0.17			
Dendrocolaptidae											
Dendrocincla turdina (Lichtenstein, 1820)	0.16	0.09		0.25	0.06	0.25	0.04	0.04	0.10	0.04	0.62
Sittasomus griseicapillus (Vieillot, 1818)	0.36	0.55	0.28	0.5	0.13	0.04	0.32	0.25		0.52	0.38
Xiphocolaptes albicollis (Vieillot, 1818)		0.05							0.05		
Dendrocolaptes platyrostris (Spix, 1825)	0.04	0.18						0.04	0.10		
Xiphorhynchus fuscus (Vieillot, 1818)	0.32	0.23	0.28	0.5	0.25	0.38	0.29	0.33	0.43	0.30	0.77
Lepidocolaptes falcinellus (Cabanis & Heine, 1859)			0.06					0.04			
Furnariidae											
Synallaxis ruficapilla (Vieillot, 1819)	0.16	0.05	0.11		0.19	0.21	0.32	0.25	0.48	0.26	0.08
Anabacerthia amaurotis (Temminck, 1823)		0.05	0.11		0.06		0.07	0.17		0.30	
Philydor lichtensteini (Cabanis & Heine, 1859)	0.12	0.27	0.06		0.13		0.18	0.04	0.05	0.09	0.31
Philydor atricapillus (Wied, 1821)	0.4	0.27	0.17		0.25	0.21	0.25	0.17	0.14	0.39	0.54
Philydor rufum (Vieillot, 1818)	0.08	0.18	0.22				0.18	0.13		0.65	
Anabazenops fuscus (Vieillot, 1816)		0.05					0.14	0.04		0.30	
Cichlocolaptes leucophrus (Jardine & Selby, 1830)		0.09						0.17		0.17	
Automolus leucophthalmus (Wied, 1821)	0.08	0.05	0.06				0.21	0.08		0.26	
Heliobletus contaminatus (Berlepsch, 1885)										0.09	
Xenops minutus (Sparrman, 1788)	0.12	0.05				0.08	0.04				
Xenops rutilans (Temminck, 1821)	0.04	0.14	0.06			0.04	0.04	0.08		0.13	
Tyrannidae											
Mionectes rufiventris (Cabanis, 1846)	0.16	0.18	0.22	0.25		0.04	0.04				0.15
Leptopogon amaurocephalus (Tschudi, 1846)	0.24	0.41	0.06		0.13	0.21	0.29	0.08	0.14	0.39	0.31
Hemitriccus obsoletus (Miranda-Ribeiro, 1906)	0.04		0.17							0.09	
Hemitriccus orbitatus (Wied, 1831)	0.2					0.04			0.10		
Poecilotriccus plumbeiceps (Lafresnaye, 1846)		0.05				0.04	0.14	0.04	0.10	0.09	
Todirostrum poliocephalum (Wied, 1831)								0.04			
Phyllomyias virescens (Temminck, 1824)										0.04	
Camptostoma obsoletum (Temminck, 1824)						0.04			0.05		
Plylloscartes sp.										0.04	
Phylloscartes kronei (Willis & Oniki, 1992)		0.09									
Phylloscartes paulista (Ihering & Ihering, 1907)										0.04	

Continue

Table II. Continued.

Scientific name	Frequency in the study areas										
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Tyrannidae (continued)											
Phylloscartes sylviolus (Cabanis & Heine, 1859)	0.08										
Myiornis auricularis (Vieillot,1818)	0.12	0.36	0.22		0.13	0.21	0.25	0.04	0.14	0.30	
Tolmomyias sulphurescens (Spix, 1825)	0.28	0.23	0.11		0.19	0.08	0.11	0.13	0.24	0.17	0.15
Platyrinchus mystaceus (Vieillot, 1818)	0.08	0.18	0.28		0.13	0.25	0.14	0.25	0.05	0.22	
Myiophobus fasciatus (Statius Müller, 1776)							0.04				
Contopus cinereus (Spix, 1825)							0.04				
Muscipipra vetula (Lichtenstein, 1823)										0.04	
Colonia colonus (Vieillot, 1818)						0.04	0.07	0.04			
Attila rufus (Vieillot, 1819)						0.04		0.04			
Oxyruncidae											
Oxyruncus cristatus (Swainson, 1821)	0.04	0.27									0.08
Cotingidae											
Carpornis cucullata (Swainson, 1821)		0.05					0.04				
Lipaugus lanioides (Lesson, 1844)		0.05									
Pipridae											
Piprites chloris (Temminck, 1822)	0.08						0.04				
Ilicura militaris (Shaw & Nodder, 1809)	0.12	0.18	0.11		0.06	0.04		0.08		0.09	
Chiroxiphia caudata (Shaw & Nodder, 1793)	0.20	0.18		0.25	0.19		0.14	0.08		0.17	0.08
Tityridae											
Schiffornis virescens (Lafresnaye, 1838)	0.12	0.23	0.06		0.06			0.08	0.05	0.13	
Pachyramphus castaneus (Jardine & Selby, 1827)			0.11				0.07	0.08		0.30	
Vireonidae											
Cyclarhis gujanensis (Gmelin, 1789)	0.04	0.05	0.11			0.04	0.07	0.04	0.05	0.22	
Hylophilus poicilotis (Temminck, 1822)			0.22			0.25	0.07	0.25	0.29	0.17	0.31
Troglodytidae											
Troglodytes musculus (Naumann, 1823)				0.25							
Polioptilidae											
Ramphocaenus melanurus (Vieillot, 1819)	0.08				0.06	0.04		0.04	0.05		
Turdidae											
Turdus flavipes (Vieillot, 1818)	0.08	0.09		0.25	0.31	0.17		0.08			
Turdus rufiventris (Vieillot, 1818)				0.25		0.04					0.15
Turdus amaurochalinus (Cabanis, 1850)									0.05	0.04	0.08
Turdus albicollis (Vieillot, 1818)	0.24	0.23		0.25	0.06	0.46	0.04	0.13	0.29	0.09	0.38
Coerebidae											
Coereba flaveola (Linnaeus, 1758)	0.12		0.06		0.06	0.13	0.04	0.13	0.05	0.04	0.31
Thraupidae											
Orchesticus abeillei (Lesson, 1839)			0.17								
Orthogonys chloricterus (Vieillot, 1819)	0.04	0.27	0.06				0.07			0.09	
Pyrrhocoma ruficeps (Strickland, 1844)							0.07				
Trichothraupis melanops (Vieillot, 1818)	0.20	0.45	0.06			0.13	0.36	0.17	0.19	0.17	0.31

Table II. Continued.

Scientific name	Frequency in the study areas										
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Thraupidae (continued)											
Habia rubica (Vieillot, 1817)	0.24	0.27	0.22		0.25	0.21	0.32	0.25	0.24	0.48	0.46
Tachyphonus coronatus (Vieillot, 1822)	0.16	0.50			0.31	0.67	0.07	0.13	0.43		0.23
Thraupis sayaca (Linnaeus, 1766)		0.14							0.05		0.08
Thraupis cyanoptera (Vieillot, 1817)		0.05								0.04	
Thraupis ornata (Sparrman, 1789)		0.32	0.11				0.07				
Pipraeidea melanonota (Vieillot, 1819)		0.09			0.06					0.09	
Tangara seledon (Statius Müller, 1776)	0.32	0.32	0.11		0.06	0.04	0.21	0.13		0.04	
Tangara cyanocephala (Statius Müller, 1776)	0.12	0.32	0.06			0.04	0.18	0.04		0.17	
Tangara desmaresti (Vieillot, 1819)			0.06				0.04				
Dacnis nigripes (Pelzeln, 1856)		0.05									
Dacnis cayana (Linnaeus, 1766)	0.08	0.09	0.06	0.25			0.04	0.04		0.04	
Chlorophanes spiza (Linnaeus, 1758)		0.05									
Hemithraupis ruficapilla (Vieillot, 1818)	0.28	0.41	0.06		0.06	0.08	0.14			0.04	
Emberizidae											
Sporophila frontalis (Verreaux 1869)									0.10		
Sporophila caerulescens (Vieillot 1823)									0.04		
Tiaris fuliginosus (Wied, 1830)		0.05							0.10		
Cardinalidae											
Saltator fuliginosus (Daudin, 1800)								0.08			
Saltator similis (d'Orbigny & Lafresnaye, 1837)								0.04		0.04	
Parulidae											
Parula pitiayumi (Vieillot, 1817)	0.16	0.50	0.06	0.5	0.06	0.13	0.25	0.13	0.38	0.13	0.15
Geothlypis aequinoctialis (Gmelin, 1789)		0.05				0.04					
Basileuterus culicivorus (Deppe, 1830)	0.76	0.82	0.56	0.75	0.81	0.71	0.79	0.75	0.71	0.70	0.77
Icteridae											
Cacicus chrysopterus (Vigors, 1825)			0.06				0.07				
Fringillidae											
Euphonia violacea (Linnaeus, 1758)	0.44	0.59	0.06	0.5	0.25	0.29	0.04	0.04	0.05	0.04	0.31
Euphonia pectoralis (Latham, 1801)	0.44	0.36	0.28	0.25	0.06		0.07	0.04		0.13	0.08
Number of mixed flocks	25	22	18	4	16	24	28	24	21	23	13
Number of species	66	71	45	18	37	48	66	65	45	64	37

Table III. Percent of forest cover in the surroundings of the remnants of the Atlantic Forest of the hydrographic basin of the Itajaí River, Santa Catarina, between April and August, 2007.

Forest cover (%)	Area Group 1							Area Group 2			
	A1	A2	A4	A5	A6	A9	A11	A3	A7	A8	A10
Buffer 1 km	74.0	92.3	15.1	40.5	37.5	40.5	99.9	89.2	93.4	77.8	99.9
Buffer 2.5 km	82.0	71.3	16.9	33.0	20.4	37.8	99.2	94.7	98.5	71.3	99.2
Buffer 5 km	79.0	88.2	31.0	34.7	31.6	45.5	39.4	93.4	95.6	55.9	96.1

Table IV. Results of the Correlation Analysis between landscape configuration, native cover and maximum altitude (environmental variables) and the composition of mixed-species flocks (represented by the scores of the species with axis 1 of the Correspondence Analysis) of the remnants of the Atlantic Forest of the hydrographic basin of the Itajaí River, Santa Catarina, between April and August, 2007.

Environmental variables	d.f.	r^2	p
Landscape configuration	9	0.67	0.001000
Percentage native cover within 1 km ratio	9	0.77	0.000300
Percentage native cover within 2,5 km ratio	9	0.84	0.000006
Percentage native cover within 5 km ratio	9	0.67	0.002000
Maximum altitude	9	0.75	0.000400
Configuration X percentage native cover within 2,5km ratio	9	0.70	0.000700
Maximum altitude X percentage native cover within 2,5km ratio	9	0.66	0.001000
Configuration X Maximum altitude	9	0.46	0

The percentage of original cover surrounding a sampled fragment area up to a ratio of 2.5 and 1 km was the variable that presented highest correlation with the formation of Groups 1 and 2, followed by altitude. Next, configuration of the fragment area itself and the percentage of original forest cover over a ratio of approximately 5 km were also positively correlated with these groups. Environmental variables also correlated with one another: areas with higher altitude were surrounded and limited by more extensive original cover.

Of the 117 species in mixed-species flocks, 29 were associated with one of the two groups, i.e., showed a positive correlation (≥ 0.5) with axis 1 of CA (Tab. V). With regards to species composition, Group 1 was composed exclusively of species that do not seem to be very sensitive to environmental changes in the region and are found anywhere in the Atlantic Forest, in addition to species that occur preferencially in forest borders, such as *Turdus rufiventris* (Vieillot, 1818), Turdidae; *Troglodytes musculus* (Naumann, 1823), Troglodytidae; and *Melanerpes flavifrons* (Vieillot, 1818), Picidae. In contrast, Group 2 contained species common to higher altitudes, as for example *Drymophila malura* (Temminck, 1825), Thamnophilidae and *D. ochropyga* (Hellmayr, 1906) , Thamnophilidae (found only in Group 2) and *Piculus aurulentus* (Temminck, 1821), Picidae; *Conopophaga lineata* (Wied, 1831), Conopophagidae; *Philydor rufum* (Vieillot, 1818), Furnariidae; and *Orthogonys chloricterus* (Vieillot, 1819), Thraupidae. Species that seem to be dependent on a specific micro-habitat, such as *Automolus leucophthalmus* (Wied, 1821), Furnariidae; *Anabazenops fuscus* (Vieillot, 1816), Furnariidae; and *Myrmotherula gularis* (Ménétriès, 1835), Thamnophilidae, were also found in Group 2.

DISCUSSION

Our results are in agreement with the expectation that the amount of original forest cover in the surroundings of forest fragment areas is important in the maintenance of several species, especially when the total coverage exceeds the 20% area (ANDRÉN 1994, FAHRIG 1998). Indeed, this variable was strongly correlated with the observed differences in species composition

Tabela V. Correlation scores between the bird species participating in mixed flocks and axis 1 of the Correspondence Analysis diagram. Only species with correlation values in relation to axis 1 ≥ 0.5 are represented.

Groups	Species correlated with axix 1	Correlation score
Group 1	*Dendrocincla turdina*	-0.778
	Turdus albicollis	-0.778
	Hypoedaleus guttatus	-0.778
	Turdus rufiventris	-0.726
	Piaya cayana	-0.678
	Turdus flavipes	-0.659
	Dysithamnus mentalis	-0.655
	Xiphorhynchus fuscus	-0.655
	Parula pitiayumi	-0.655
	Basileuterus culicivorus	-0.655
	Euphonia violacea	-0.655
	Trogon surrucura	-0.647
	Troglodytes musculus	-0.530
	Melanerpes flavifrons	-0.512
	Conopophaga melanops	-0.509
Group 2	*Pachyramphus castaneus*	0.841
	Philydor rufum	0.797
	Automolus leucophthalmus	0.797
	Piculus aurulentus	0.661
	Anabacerthia amaurotis	0.634
	Myrmotherula gularis	0.630
	Orthogonys chloricterus	0.630
	Conopophaga lineata	0.610
	Cacicus chrysopterus	0.609
	Drymophila malura	0.607
	Thamnophilus caerulescens	0.603
	Anabazenops fuscus	0.578
	Xenops rutilans	0.539
	Drymophila ochropyga	0.511

of mixed flocks. This result is in agreement with Villard *et al.* (1999), who found that the percentage of forest cover and landscape configuration are important predictors of what species will be found in an area, suggesting that these two variables are correlated. An overall decrease in forest cover also determines lower connectivity between fragments, consequently decreasing the likelihood that a species that depends on the original vegetation will be found. When fragmentation happens, the original landscape and the characteristics of each species will determine how connected the various fragments will remain. For example, a study conducted in the Amazon Forest found that a distance of 30 m between fragments was a barrier to flock birds (Develey & Stouffer 2001). In contrast, mixed bird flocks in the Atlantic Forest were found migrating over distances of 100 m from the forest edge (Maldonado-Coelho & Marini 2004). In any case, the surrounding matrix plays a fundamental role, as it determines permeability and consequently the ability of species and mixed bird flocks to migrate (Stouffer & Bierregaard 1995, Maldonado-Coelho & Marini 2000).

Territory configuration of sampled fragments was also strongly correlated with the composition of bird flocks. Forest fragments bordered by non-forest matrix (isolated or intermediate fragments) differed from areas totally immersed in a forest matrix (massive fragment). As territory configuration also showed a positive correlation with original cover around the sampled areas, it is safe to assume that these two variables had a simultaneous effect over the composition of mixed flocks. This can be attributed, at least in part, to the fact that the forest matrix can influence border effects, which are in turn correlated with the configuration of the sampled area (Gascon *et al.* 1999). Consequently, species that do not tolerate the matrix may also not tolerate the border, being the first ones to disappear (Sekercioglu *et al.* 2002). This relationship can be of particular importance for individuals that participate in mixed bands as verified by Telleria *et al.* (2001). Moreover, according to Stouffer & Bierregaard (1995), species that follow mixed flocks migrate longer distances with respect to solitary birds, being more likely to encounter forest borders. As a consequence, borderline environments may cause sensitive species to disassociate from bird flock interactions and assume a solitary behavior as a strategy to survive the new circumstances. (Stouffer & Bierregaard 1995, Van Houtan *et al.* 2006). This may have been responsible for the fact that species restricted to certain habitats, as for example *Anabazenops fuscus, Drymophila malura e D. ochropyga*, foragers in patches of bamboos (Rodrigues *et al.* 1994, Rajão & Cerqueira 2006), and *Myrmotherula gularis*, dependent on humid microclimates (Sick 1997), were only found in areas that clustered with Group 2. Species that tolerate or benefit from borderline environments, as for example *Turdus rufiventris, Troglodytes musculus* and *Melanerpes flavifrons* we incorporated in mixed bands that clustered with Group 1.

Another variable that seemed to influence the composition of mixed species flocks in this study was altitude. The few

previous publications on the subject found conflicting results. For example, Kotagama & Goodale (2004) found that the composition of mixed species flocks differed with altitude in Sri Lanka, in spite of the fact that species composition was homogenous in the areas surveyed. In contrast, Sridhar & Sankar (2008) found that the composition of mixed bands did not vary with altitude in areas with homogenous species composition. Furthermore, a study conducted by Lee *et al.* (2005) in Asia revealed that species that are more sensitive to altitude are less likely to participate in mixed flocks than their counterparts. Even though the distribution of birds along the altitudinal gradient of the Atlantic Forest is not completely understood (Stotz *et al.* 1996, Buzzetti 2000), some studies have found a correlation between altitude and the occurrence and abundance of some species sampled in the present research. Among these are *Anabacerthia amaurotis* (Temminck, 1823), Furnariidae and *Cacicus chrysopterus* (Vigors, 1825), Icteridae (Buzzetti 2000); *P. aurulentus, D. ochropyga, O. chloricterus, M. gularis, C. lineata, A. fuscus* and *Xenops rutilans* (Temminck, 1821), Furnariidae (Stotz *et al.* 1996); *D. malura* (Rajão & Cerqueira 2006) and *Philydor rufum* (Aleixo 1999), all previously shown to favor high altitudes. However, because this study did not include a survey of the bird species composition and their abundance in the sampled areas, we are not able to further confirm the relationship between altitude and mixed flock composition.

Our results suggest that all variables tested correlate with mixed-species flock composition and with each other in a complex way. In order to evaluate the effects of each of these variables in isolation, future studies should concentrate their efforts in areas where some of these variables remain constant, as for example areas with fragments at similar altitudes.

The moderate fragmentation of the study area itself may be responsible for the presence of species that are sensitive to habitat degradation, independent of native cover and landscape configuration of the surroundings. In disturbed and more fragmented landscapes, mixed flocks may behave differently. For example, Maldonado-Coelho & Marini (2004) showed that flocks in different fragments vary in complex ways, showing independent dynamics. It is also possible that the similarity in the structure of the vegetation within fragments has resulted in similar microhabitats, which can be as important to the dynamics of mixed flocks as fragmentation itself (Maldonado-Coelho & Marini 2003, Lee *et al.* 2005, Sridhar & Sankar 2008).

Our results suggest that local mixed-species flocks are a reflection of the local bird diversity and species abundance, as advocated by previous authors (Hutto 1994, Aleixo 1997, Maldonado-Coelho & Marini 2003, Lee *et al.* 2005, Ghizoni-Jr & Azevedo 2006, Sridhar & Sankar 2008). However, future studies on landscapes with different degrees of fragmentation are needed to help us understand how the different environmental variables influence the ecology of mixed flocks in the Atlantic Forest.

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