The importance of riparian forest for the maintenance of bird species richness in an Atlantic Forest remnant, southern Brazil

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ABSTRACT. We compared the composition and guild structure of bird communities of riparian and upland forest in an Atlantic forest reserve, the Godoy State Park (GP), in northern Paraná State, southern Brazil. Unlimited distance point counts were sampled monthly from September-December 2001, along four trails. Two trails in upland forest (TA and TB) were parallel to each other and about 300 m apart. Two trails in riparian forest (TC and TD) were along the Apertados River, about 100 m away from the river. A total of 145 species were recorded: 81 species were recorded in both upland and riparian forests, 19 species were recorded only in upland forest and 45 species were recorded exclusively in riparian forest. Among the 81 species occurring in both forest types, 18 species had significantly higher numbers of contacts in the riparian forest while only 8 species had significantly higher numbers of contacts in the upland forest. Taking into account the contacts numbers of the species the large frugivores guild was closely associated to the upland forest, while bamboo and vine-tangles insectivore, canopy insectivores, edge omnivores, ground omnivore and midstory insectivores were those more closely related to the riparian forest.
KEY WORDS. Bird abundance; bird guild species; semi-deciduous forest.

RESUMO. **A importância da floresta ripária para a manutenção da riqueza de espécies de aves em um remanescente de Floresta Atlântica no sul do Brasil.** Comparamos a composição e a estrutura de guilda da comunidade de aves da floresta ripária e alta em uma reserva de Floresta Atlântica, o Parque Estadual Mata dos Godoy (GP), no norte do Paraná, sul do Brasil. Pontos de escutas com distância ilimitada foram realizados mensalmente de setembro-dezembro de 2001, ao longo de quatro trilhas. Duas trilhas na floresta alta (TA e TB) paralelas uma a outra e com distância de 300 m. Duas trilhas na floresta ripária (TC e TD) ao longo do Rio Apertados, distantes 100 m do rio. Um total de 145 espécies foi registrado: 81 espécies foram registradas em ambas as florestas, 19 espécies foram registradas somente na floresta alta e 45 espécies foram registradas exclusivamente na floresta ripária. Entre as 81 espécies que ocorrem nos dois tipos de florestas, 18 espécies tiveram maior número significativo de contato na floresta ripária enquanto somente 8 espécies tiveram maior número significativo de contatos na floresta alta. Considerando o número de contato das espécies, a guilda grande frugívoros foi mais relacionada com a floresta alta, enquanto as guildas insetívoros de bambu e reboleira, insetívoros de copa, onívoros de bordas, onívoros de solo e insetívoros de sub-bosque foram relacionados com a floresta ripária.
PALAVRAS-CHAVE. Abundância de aves; floresta estacional semi-decídua; guildas.

Riparian forests are considered an important habitat for local variation in bird communities, because a gradient in the vegetation can be detected in relation to the surrounding upland areas, resulting in an increased regional bird diversity (Pollock *et al.* 1998, Bub *et al.* 2004). Topography, plant community, hydrologic regimes, and soil type typically distinguish riparian areas from upland areas (Bianchini *et al.* 2001, Shirley 2005). The increase in avian richness promoted by riparian forest has been demonstrated for several ecosystems in North America, from arid regions to north-temperate rainforests (Szaro & Jakle 1985, Wilson & Comet 1996, Bub *et al.* 2004, Shirley 2005). Naiman *et al.* (2000) noted that about 34% of bird species in the Pacific Coast rain forest, require riparian areas; they are 'riparian obligates'. Shirley (2005) working in British Columbia found vegetation and bird community differences between adjacent upland and riparian forests (more deciduous trees in riparian forests). In the Amazon basin, riparian forests and other river-created habitats harbor a rich and entirely endemic bird fauna, thus contribut-

ing to the unrivaled avian richness observed in Amazonian lowlands (Remsen & Parker 1983, Robinson & Terborgh 1997). However, the importance of surrounding forest of streams and rivers for bird communities and abundance in Brazilian Atlantic Forest has received less attention.

The Brazilian Atlantic forest, one of the world's 25 biodiversity hot spots because of its high species richness and number of endemism, occupies the mountains (usually below 1000 m a.s.l.) and lowlands of the eastern coast, from the states of Ceará to Rio Grande do Sul (Mittermeier *et al*. 2000). Large and small rivers flow from hills to the lowlands. In the present study, we compared the bird community of the riparian forest with that of the surrounding upland forest in an Atlantic forest reserve, the Godoy State Park (GP, 656 ha), in northern Paraná State, southern Brazil. Our major goal is to document the composition and structure of the bird community associated with the riparian forest at GP, and to understand its contribution to the overall species richness now present in this important Atlantic forest remnant of southern Brazil.

MATERIAL AND METHODS

Study area

The study was conducted in Godoy State Park (23°27'S, 51°15W, 656 ha) located 15 km south of Londrina, Paraná, in southern Brazil. It is the largest well-preserved forest remnant of the northern Paraná State with semi-deciduous forest, a type of Atlantic forest covering the interior of southern and southeastern Brazil and northeastern Argentina. The matrix surrounding GP is manly covered by agricultural landscape. The southern border of GP (460-480 m a.s.l.) is the Apertados River, 0.5-3 m deep, 5-8 m wide. From the Apertados River towards the northern part of GP, a slope about 300 m long rises and eventually reaches a plateau (between 610 m and 650 m, Fig. 1). Due to the elevation, two forests types can be defined in GP: upland forest, which occupies the plateau, and riparian forest, a strip of 300-400 m wide along the Apertados River. The upland forest has a dense, closed canopy between 12 m to 20 m. The most abundant tree species are *Cabralea canjerana* (Vell.) Mart. (Meliaceae), *Euterpe edulis* Mart. (Arecaceae), *Ocotea indecora* (Schott) Mez (Lauraceae), and *Nectandra megapotamica* (Spreng.) Mez (Lauraceae). Sparsely distributed emergent tree species (reaching more than 30 m) include *Aspidosperma polyneuron* Müll. Arg. (Apocynaceae), *Sloanea monosperma* Vell. (Elaeocarpaceae) and *Gallesia integrifolia* (Spreng.) Harms (Phytolaccaceae). Because of the dense canopy, the midstory and understory are dark, and the understory is relatively open, with short trees and bushes such as *Eugenia verrucosa* A. Rich. (Myrtaceae), *Sorocea bonplandii* (Baill.) W.C. Burger, Lanj. & Wess. Boer (Moraceae), *Miconia tristis* Spring (Melastomataceae), *Maranta* sp (Marantaceae) and *Piper* sp (Piperaceae) (Torezan 2002, Diaz *et al*. 2002). The riparian forest has a much less dense canopy, with the sparsely distributed taller trees including *Chrysophyllum gonocarpum* (Mart. & Eichler ex Miq.) Engl.

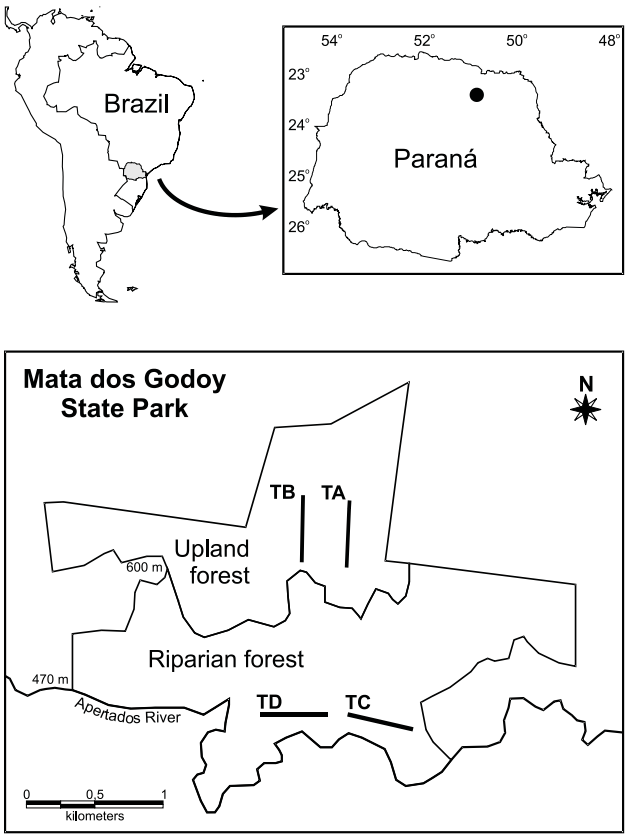

Figure 1. Localization of the Godoy State Park, in north of Paraná State, southern Brazil, and transects TA and TB in the upland forest and TC and TD in the riparian forest.

(Sapotaceae), *Campomanesia xanthocarpa* O. Berg (Myrtaceae), and *Parapiptadenia rigida* (Benth.) Brenan (Fabaceae). The midstory, however, has a higher density of smaller tree species, such as *N. megapotamica*, *Alseis floribunda* Schott (Rubiaceae), *Matayba elaeagnoides* Radlk. (Sapindaceae), *Lonchocarpus muehlbergianus* Hassl. (Fabaceae), Sebastiana commersoniana (Baillon) Smith & Downs (Euphorbiaceae), *E. verrucosa*, and *Trichilia casaretti* C. DC. (Meliaceae). Fallen trees, especially emergent ones, are common in the riparian forest. Gaps created by the fallen trees are covered by patches of *Chusquea* sp (Poaceae) bamboos and *Celtis iguanaea* (Jacq.) Sarg. (Ulmaceae, Torezan 2002, Diaz *et al*. 2002). During the November-February wet season, the Apertados River has short periods of flooding of 3-7 days. Flooding has created a strip 50-100 m wide along the river where soil is quite wet and the understory is dominated by ferns.

We considered riparian forest to include this strip of floodplain along the Apertados River as well as the adjacent sloped area, where not had influence of floodplain; the upland forest is restricted to the plateau.

Field work

Point counts of unlimited distance were sampled (always by the same observer, LdA) monthly, September-December 2001, along four trails (Fig. 1). Two trails in the upland forest (TA and TB) were cut parallel to each other about 300 m apart. Two trails to sample the riparian forest (TC and TD) were cut along the Apertados River, about 100 m away from the river, TD beginning about 200 m from the end of TC. In each trail, 5 points were established every 100 m and numbered in sequence (1 to 5). Sampling began at dawn in the first point and ended about 3 hr later at the fifth point. The sequence of sampled points was always the same in each trail and the sampling period in each point was 20 minutes. Species were identified primarily by sound (99%). Each pair or flock of each species was counted once (one contact) while vocalizing. Care 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. The collection of bird recordings of Londrina State University was used to aid identification. In addition, some individuals vocalizing were recorded (UHER 4400 play recorder and Sennheiser ME66 microphone) and collected in the region (remnants far away from PG, not used for point counts) in order to confirm identification. Collected specimens were deposited in the Zoological Collection of the Londrina State University.

Statistics and additional comments

The Morisita-Horn index (Magurran 1988) was adopted to measure similarities in the bird communities among riparian and upland forest using quantitative data: $C_{MH} = 2\Sigma(an_i x bn_i)/[(da+db)aNxbN]$, where aN is the number of individuals in site A, bN is the number of individuals in site B, an_i is the number of individuals in the ith species in site A and bn_i is the number of individuals in the ith species in site B; da is calculated as $\Sigma an_i^2/aN^2$ and db as $\Sigma bn_i^2/bN^2$. Spearman rank correlation (r_S) was used to measure the relation between the composition and abundance (number of contacts) of guild community in riparian and upland forest. This analysis did not include guilds with only one registered species. Differences in number of species or number of contact of species and guild community were tested with G_{adj}-test, with a correction factor (William's correction) at $p < 0.05$. Guild characterization was based on Willis (1979). We followed the taxonomy presented in Comitê Brasileiro de Registros Ornitológicos (2006).

RESULTS

A total of 145 species was recorded in the four transects: 81 (55.86%) species were recorded in both upland and riparian forests trails, 19 (13.11%) species were recorded only in upland forest and 45 (31.30%) species were recorded exclusively in riparian forest (Tab. I). Among the 81 species occurring in both forest types, 18 species had a significantly higher number of contacts in the riparian forest while only eight species had significantly higher number of contacts in the upland forest (*G*-test, df = 1, $p < 0.05$).

Despite similarity in the number of contacts, upland and riparian forest has a moderate Morisita-Horn index ($C_{MH} = 0.67$).

Taking into account the contact number of the species in their guilds the large frugivores was the guild more closely related to the upland forest ($G_{adj} = 28.18$, df = 1, $p < 0.01$), while bamboo and vine-tangles insectivores ($G_{adj} = 179.97$, df = 1, $p < 0.01$), canopy insectivores ($G_{adj} = 7.31$, df = 1, $p < 0.01$), edge omnivores ($G_{adj} = 151.88$, df = 1, < 0.01), ground omnivore ($G_{adj} = 23.38$, df = 1, $p < 0.01$) and midstory insectivores ($G_{adj} = 16.94$, df = 1, $p < 0.01$) were those more closely related to the riparian forest. Only bamboo and vine-tangles insectivores ($G_{adj} = 8.01$, df = 1, $p < 0.01$) had significantly species number in riparian forest (Tab. II). The Spearman rank showed significant correlation between the number of species of guild community in both forest ($r_S = 0.80$, $p < 0.01$), however the number of contact had no significant correlation ($r_S = 0.51$, $p = 0.08$).

DISCUSSION

The sloped area of the riparian forest had a clear effect on the increase in the species number of the bamboo and vine-tangles insectivore guild. Fallen taller trees in sloped areas of the riparian forest had a strong positive impact over that guild, because the increase in number of bamboo thickets; 22 species were recorded in the riparian transects while only seven were recorded in the upland ones. In addition, among the seven species occurring in both forest types, three bird species had significantly higher contact numbers in riparian than in upland forests. The created clearings also benefited edge omnivores and midstory insectivores which were both associated to the riparian forest, as attested by Willis (1979). Blake & Loiselle (2001), studying bird assemblages in second-growth and old-growth forests of Costa Rica, mentioned that secondary successional habitats can provide a complex mosaic of microhabitats, which can benefit higher number of species and individuals. Large frugivores, in contrast, were associated with upland forest; perhaps due of the increased vertical complexity of the vegetation and to the larger amount of fruits in the upland forest (Bianchini *et al*. 2001).

The Apertados River could be considered a small river, with a short period of flooding and relatively small flooded area; due to the hilly topography, this same pattern seems commonly found in the Brazilian Atlantic Forest. So, the flooding periods in the Brazilian Atlantic forest would not increase significantly the number of microhabitats, as occurs in the larger Amazonian rivers, where flooding periods take several months and cover large areas (Karr & Roth 1971, Remsen & Parker 1983). However, the pulses of nutrients and energy may have impacts on the food supply. Gende & Willson (2001) showed an increase in density (not in richness) of passerines due to the pulses of the salmon migration in southeastern Alaska; the passerines do not feed directly on salmon (or their offspring) and their density increase was credited only to indirect effects of the energy flow in the ecosystem. The increase of food supply does

Table I. Contact numbers of each bird species recorded in the riparian and in the upland forests of Mata dos Godoy State Park. Species are grouped first in guilds according Willis (1979) and second in Taxonomic order according the Comitê Brasileiro de Registros Ornitológicos (2006). (rip) Species significantly related to the riparian forest, (upf) species related to the upland forest of the Godoy State Park (G_{adj}-test, $p < 0.05$), (TA and TB) Transects in the upland forest, (TC and TD) Transects in the riparian forest.

Guild/Species	Upland Forest		Riparian Forest	
	TA	TB	TC	TD
Bamboo and vine tangle insectivores				
Nonnula rubecula (Spix, 1824)			2	
Mackenziaena leachii (Such, 1825)				1
Mackenziaena severa (Lichtenstein, 1823)	1		15	23
Drymophila rubricollis (Bertoni, 1901)			7	
Drymophila malura (Temminck, 1825)			1	
Conopophaga lineata (Wied, 1831) (rip)	2	1	8	2
Hylopezus ochroleucus (Wied, 1831)				5
Psilorhamphus guttatus (Ménétriès, 1835)			1	9
Scytalopus indigoticus (Wied, 1831)				2
Campylorhamphus falcularius (Vieillot, 1822)				1
Synallaxis ruficapilla (Vieillot, 1819) (rip)		2	9	8
Synallaxis cinerascens Temminck, 1823	1		2	4
Anabacerthia amaurotis (Temminck, 1823)			1	
Automolus leucophthalmus (Wied, 1821)	1		4	7
Heliobletus contaminatus (Berlepsch, 1885)			8	2
Hemitriccus diops (Temminck, 1822)			6	12
Hemitriccus obsoletus (Miranda-Ribeiro, 1906)			2	1
Poecilotriccus plumbeiceps (Lafresnaye, 1846)			8	7
Capsiempis flaveola (Lichtenstein, 1823)			3	3
Myiornis auricularis (Vieillot, 1818)	6	1	1	7
Lathrotriccus euleri (Cabanis, 1868) (rip)	1	2	9	6
Pyrrhocoma ruficeps (Strickland, 1844)			2	11
Diurnal carnivores				
Accipiter striatus (Vieillot, 1808)	1	1	4	
Rupornis magnirostris (Gmelin, 1788)				1
Caracara plancus (Miller, 1777)	3			
Herpetotheres cachinnans (Linnaeus, 1758)			2	
Micrastur ruficollis (Vieillot, 1817)			1	
Micrastur semitorquatus (Vieillot, 1817)			1	1
Canopy insectivores				
Piaya cayana (Linnaeus, 1766)	9	6	7	7
Hypoedaleus guttatus (Vieillot, 1816) (upf)	27	21	12	10
Herpsilochmus rufimarginatus (Temminck, 1822)	6	20		
Philydor rufum (Vieillot, 1818) (rip)	1		14	6
Myiopagis caniceps (Swainson, 1835)	10	13	11	13
Phylloscartes ventralis (Temminck, 1824)	1	2	1	
Tolmomyias sulphurescens (Spix, 1825)			11	13
Sirystes sibilator (Vieillot, 1818)	3	6	8	8
Myiarchus swainsoni (Cabanis & Heine, 1859)		1		

Continues

Table I. Continued.

Guild/Species	Upland Forest		Riparian Forest	
	TC	TD	TA	TB
Pachyramphus castaneus (Jardine & Selby, 1827)			1	10
Pachyramphus polychopterus (Vieillot, 1818)			5	2
Pachyramphus validus (Lichtenstein, 1823)			3	
Conirostrum speciosum (Temminck, 1824)	4	1	6	6
Parula pitiayumi (Vieillot, 1817) (rip)		2	17	11
Hylophilus poicilotis (Temminck, 1822)		1		
Canopy omnivores				
Trogon viridis (Linnaeus, 1766)		2		
Trogon surrucura (Vieillot, 1817)	24	23	20	23
Trogon rufus (Gmelin, 1788) (upf)	6	8	4	1
Tityra inquisitor (Lichtenstein, 1823)	2		1	2
Tityra cayana (Linnaeus, 1766)	6	8	9	7
Pipraeidea melanonota (Vieillot, 1819)	1	2	3	
Dacnis cayana (Linnaeus, 1766)	2		2	2
Hemithraupis guira (Linnaeus, 1766) (rip)	4	10	14	19
Euphonia pectoralis (Latham, 1801)	1			
Edge insectivores				
Todirostrum cinereum (Linnaeus, 1766)				1
Troglodytes musculus Naumann, 1823			1	1
Polioptila lactea (Sharpe, 1885)			1	
Edge omnivores				
Claravis pretiosa (Ferrari-Perez, 1886)	6	4	3	3
Elaenia mesoleuca (Deppe, 1830)	1			
Camptostoma obsoletum (Temminck, 1824)			1	2
Myiozetetes similis (Spix, 1825)	1			
Pitangus sulphuratus (Linnaeus, 1766) (rip)	1		5	6
Myiodynastes maculatus (Statius Muller, 1776) (rip)	3	2	13	18
Megarynchus pitangua (Linnaeus, 1766) (rip)	7	7	15	17
Empidonomus varius (Vieillot, 1818)	1	1	1	1
Cyclarhis gujanensis (Gmelin, 1789) (rip)	4	4	24	19
Vireo olivaceus (Linnaeus, 1766)	1	1	1	
Turdus rufiventris (Vieillot, 1818) (rip)	3	4	15	17
Turdus amaurochalinus (Cabanis, 1850)			2	3
Cissopis *leverianus* (Gmelin, 1788)			2	1
Tachyphonus coronatus (Vieillot, 1822)			3	7
Thraupis sayaca (Linnaeus, 1766)	3	4	3	3
Thraupis bonariensis (Gmelin, 1789)	1			
Tersina viridis (Illiger, 1811)	2			
Saltator fuliginosus (Daudin, 1800)			19	22
Saltator similis (d'Orbigny & Lafresnaye, 1837)			25	37
Cacicus haemorrhous (Linnaeus, 1766)	6	4	6	6
Euphonia chlorotica (Linnaeus, 1766)		2	2	2

Continues

Table I. Continued.

Guild/Species	Upland Forest		Riparian Forest	
	TC	TD	TA	TB
Ground omnivores				
Tinamus solitarius (Vieillot, 1819)	4	4		
Crypturellus obsoletus (Temminck, 1815)	13	6	14	18
Crypturellus parvirostris (Wagler, 1827)			3	1
Crypturellus tataupa (Temminck, 1815) (rip)	2	2	7	16
Aramides cajanea (Statius Muller, 1776)			5	4
Aramides saracura (Spix, 1825)	3		2	
Leptotila verreauxi (Bonaparte, 1855) (rip)	17	11	28	27
Leptotila rufaxilla (Richard & Bernard, 1792)	1		3	1
Geotrygon montana (Linnaeus, 1758)	9	9	13	14
Grallaria varia (Boddaert, 1783)		4		
Chamaeza campanisona (Lichtenstein, 1823)	2	3	7	4
Large frugivores				
Penelope superciliaris Temminck, 1815	1	4	2	5
Patagioenas picazuro (Temminck, 1813)	40	37	31	33
Patagioenas cayennensis (Bonnaterre, 1792)	3	1	5	6
Primolius maracana (Vieillot, 1816)				3
Aratinga leucophthalma (Statius Muller, 1776)	5	3		
Aratinga auricapillus (Kuhl, 1820) (upf)	14	10	1	2
Pyrrhura frontalis (Vieillot, 1817) (upf)	13	14	5	4
Brotogeris tirica (Gmelin, 1788)	2			
Pionopsitta pileata (Scopoli, 1769) (upf)	6	5	1	1
Pionus maximiliani (Kuhl, 1820)	16	13	13	17
Amazona aestiva (Linnaeus, 1758) (upf)	5	11	1	
Triclaria malachitacea (Spix, 1824)	2			
Ramphastos dicolorus Linnaeus, 1766	3	5	2	1
Selenidera maculirostris (Lichtenstein, 1823) (upf)	16	14	2	2
Pteroglossus bailloni (Vieillot, 1819)	2	1	2	2
Pteroglossus aracari (Linnaeus, 1758)				1
Nectar and insect eaters				
Phaethornis eurynome (Lesson, 1832) (rip)	4	2	10	6
Chlorostilbon lucidus (Shaw, 1812)		1	1	1
Thalurania glaucopis (Gmelin, 1788)	2	2	2	2
Midstory insectivores				
Coccyzus americanus (Linnaeus, 1758)			1	1
Coccyzus euleri (Cabanis, 1873)	1			
Thamnophilus caerulescens (Vieillot, 1816) (rip)		1	16	21
Dysithamnus mentalis (Temminck, 1823)	9	21	12	14
Pyriglena leucoptera (Vieillot, 1818)	17	20	21	23
Dendrocincla turdina (Lichtenstein, 1820)	7	13		
Dendrocolaptes platyrostris (Spix, 1825)	22	19	15	13
Lochmias nematura (Lichtenstein, 1823)				3

Continues

Table I. Continued.

Guild/Species	Upland Forest		Riparian Forest	
	TC	TD	TA	TB
Leptopogon amaurocephalus (Tschudi, 1846) (rip)	8	13	28	16
Corythopis delalandi (Lesson, 1830)			6	1
Platyrinchus mystaceus (Vieillot, 1818)			2	
Piprites chloris (Temminck, 1822)				1
Basileuterus culicivorus (Deppe, 1830)	35	34	26	28
Basileuterus leucoblepharus (Vieillot, 1817)			34	33
Midstory Omnivores				
Baryphthengus ruficapillus (Vieillot, 1818)	12	10	10	10
Mionectes rufiventris (Cabanis, 1846)	4	6	8	2
Chiroxiphia caudata (Shaw & Nodder, 1793)	3	3		
Pipra fasciicauda (Hellmayr, 1906)		1		
Cyanocorax chrysops (Vieillot, 1818)		3	7	4
Turdus subalaris (Seebohm, 1887)	5	2	1	
Turdus leucomelas (Vieillot, 1818)	6	9	4	10
Turdus albicollis (Vieillot, 1818)	6	4	4	4
Trichothraupis melanops (Vieillot, 1818)	8	11	9	5
Habia rubica (Vieillot, 1817) (rip)	1	3	12	11
Trunk and twig insectivores				
Picumnus temminckii (Lafresnaye, 1845)	2	1		2
Melanerpes flavifrons (Vieillot, 1818) (upf)	11	15	2	4
Veniliornis spilogaster (Wagler, 1827)	4	2	4	6
Dryocopus lineatus (Linnaeus, 1766)	5	3	1	4
Sittasomus griseicapillus (Vieillot, 1818)	31	29	28	21
Xiphocolaptes albicollis (Vieillot, 1818)	7	8	2	8
Xiphorhynchus fuscus (Vieillot, 1818) (rip)	1	3	27	8
Lepidocolaptes angustirostris (Vieillot, 1818)	4	4	1	
Cranioleuca obsoleta (Reichenbach, 1853)			3	4
Philydor lichtensteini (Cabanis & Heine, 1859)	18	15	9	18
Xenops rutilans (Temminck, 1821)			4	9
Nocturnal Carnivore				
Glaucidium brasilianum (Gmelin, 1788)	2	4		2
Aerial *insectivore*				
Ictinia plumbea (Gmelin, 1788)	2	1		1
Nocturnal insectivore				
Megascops choliba (Vieillot, 1817)	1			1
Edge Seedeater				
Zonotrichia capensis (Statius Muller, 1776)				3

not seem to be so high in the Apertados river as in Alaska, but certainly ground invertebrates could be benefited with the humidity and could have their abundance increased. The bird guild that could benefit most from increased invertebrate abundance is the ground omnivores (Volpato *et al*. 2006); that guild had almost the twice the number of contacts along the riparian trails (167) compared to the upland ones (90).

In the present study, we showed that 43% of total species in GP were closely associated with riparian forest, which demonstrates its importance for the overall avifauna. However,

Table II. Numbers of species and contacts in the upland and the riparian forests of GP, taking into account the bird guilds. Asterisk (*) indicates significant ($p < 0.01$).

Guilds	Number of species			Number of contacts		
	Upland forest	Riparian forest	G_{adj}-test	Upland forest	Riparian forest	G_{adj}-test
Bamboo and vine-tangles insectivores	7	22	8.01 *	18	200	177.55 *
Diurnal carnivores	2	5	1.24	5	10	1.64
Canopy insectivores	11	12	0.04	134	182	7.31 *
Canopy omnivores	9	7	0.24	99	107	0.31
Edge insectivores	0	3	–	0	4	–
Edge omnivores	15	17	0.12	73	304	151.88 *
Ground omnivores	9	9	–	90	167	23.38 *
Large frugivores	14	13	0.04	246	142	28.18 *
Nectar and insect eaters	3	3	–	11	22	3.68
Midstory insectivores	8	12	0.79	220	315	16.94 *
Midstory omnivores	10	8	0.22	97	101	0.08
Trunk and twig insectivores	9	11	0.20	163	165	0.01
Nocturnal carnivore	1	1	–	6	2	1.97
Aerial insectivore	1	1	–	3	1	0.93
Nocturnal insectivore	1	1	–	1	1	–
Edge seedeater	0	1	–	0	3	–
Total	100	126		1166	1726	

the upland forest of GP seems crucial for conservation of some bird species, such as *Aratinga auricapillus* (Kuhl, 1820) and *Triclaria malachitacea* (Spix, 1824), both considered vulnerable to extinction because of "habitat loss and degradation" (BirdLife International 2000) or *Tinamus solitarius* (Vieillot, 1819) and *Grallaria varia* (Boddaert, 1783), both exclusive of that forest type. So, the heterogeneity of the GP, with both riparian and upland forests, was crucial to its bird richness; it is expected that reserves in Atlantic forest with less heterogeneity would have lower bird richness.

ACKNOWLEDGMENTS

The financial support for this study was provided by CNPq, through the Mata Atlântica Program (690146/01-9) and a research grant to the first author (302556/2004-4). The Environmental Institute of Paraná State gave researching permissions for study in the Godoy State Park. We thank P. Stouffer and R. McNeil and two anonymous referees for their comments and important suggestions on the manuscript.

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Received in 05.VII.2007; accepted in 23.XI.2007.