DOI: 10.1590/1089-6891v18e-40703

CIÊNCIAS BIOLÓGICAS

BETA DIVERSITY OF BIRDS (Passeriformes, Linnaeus, 1758) IN SOUTHERN AMAZON

DIVERSIDADE BETA DE PÁSSAROS (Passeriformes, Linnaeus, 1758) NA AMAZÔNIA MERIDIONAL

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Abstract

The importance of estimating the biological diversity and understanding how ecological specialization of species changes with spatially-organized habitats in undeniable. High beta diversity between neighboring places means an elevated number of species living within small distances, which usually are adapted to local conditions and highly vulnerable to anthropogenic actions as deforestation and burning. We investigated beta diversity of birds from the order Passeriformes in Southern Amazon, within landscapes with a large heterogeneous vegetation cover (habitats with flooded forest, dry forest, and marsh palm) through sound, observational, and photographic censuses. We marked 126 points in equidistant transects. A total of 148 species of birds were identified, distributed in 27 families. We found that 97% of the species foraged in flooded forest, 77% in dry forest and 19% in marsh palms, and only 18% foraged in the three habitats. An ordination analyses revealed which species showed the strongest preference to each habitat. The analysis for the Global beta diversity showed that this value is high (Whittaker: 7.7405), and the same pattern was obtained with the measure of pairwise dissimilarity. An influence of spatial distance was clearly observed in the cluster analysis and confirmed with a partial Mantel analysis; however, this was not observed at points that coincided with the transition and substitution of species. The influence of spatial distance in the dissimilarity index (beta diversity) was significant (r: 0.0608, p: 0.0049). The assemblage of species in small local populations with high beta diversity may be at risk if deforestation, selective logging, and poaching continue. In summary, this study provides important information on specific habitats with high beta diversity that may be at risk of destabilization of its populations due to continuing environmental changes imposed by humans.

Keywords: Amazon birds; conservation; distance influence; high richness.

Resumo

Estimar a diversidade biológica e entender as mudanças acerca da especialização ecológica das espécies entre habitats em uma organização espacial é importante. A alta diversidade beta reflete numa pequena distância entre locais, mas que contêm alta incorporação de espécies, que geralmente possuem grande sensibilidade e não estão adaptadas ao estreitamento causado pelo desmatamento ou a presença de queimadas por ações antrópicas. Investigou-se a diversidade beta de pássaros (Passeriformes) na Amazônia Meridional em paisagens com coberturas vegetais mais heterogêneas: habitats de floresta alagada (iguapó), floresta de terra firme e buritis através de censo de audições, observações e fotografias. Marcaram-se pontos em equidistantes transectos. Em todo o estudo foram amostrados 126 pontos. Identificaram-se 148 espécies de pássaros da ordem Passeriformes, distribuídas em 27 famílias. A classificação sobre os habitats de forrageamento resultou em 97% das espécies que forrageiam em iguapó, 77% em floresta de terra firme e 18,1% em buritis, apenas 18% forragem nos três habitats. A análise de ordenação mostrou quais espécies estão mais relacionadas com cada habitat, a análise para a Beta diversidade Global certificou que a diversidade beta é alta (Whittaker: 7,7405). Como era esperado encontrou-se o mesmo padrão quando foi utilizada a medida de dissimilaridade por pares. Na análise de agrupamento, pode-se ver claramente a influência da distância espacial, mas em alguns pontos isto não ocorre. Estes pontos indicam o momento de transição e substituição de espécies. Na maioria dos casos, a influência da distância espacial é predominante e confirmou-se na análise de Mantel parcial. A influência da distância espacial entre o índice de dissimilaridade (diversidade beta) foi significante (r:0,0608, p:0,0049). Esta composição de espécies organizadas em pequenas populacões locais mas com alta diversidade beta não pode ser exposta ao desmatamento, corte seletivo de madeira e a caça furtiva como tem acontecido. Este estudo provê informações de habitats específicos de alta diversidade beta que estão correndo risco na estabilidade de suas populacões em face às mudanças ambientais contínuas nesta área de estudo.

Palavras-chave: conservação; influência da distância; pássaros da Amazônia; riqueza.

Received on: April, 12th, 2016

Accepted on: October, 4th, 2016

Introduction

Ecologists have long been curious to understand how biological diversity changes with the environment, in particular species specialized in different ecologies in spatially-organized habitats(1). The smaller fraction of regional gamma diversity corresponds to the local alpha diversity and represents the number of species within small areas of similar and uniform habitats. Beta diversity represents the rate of species variation (turnover rate) between habitats(2). Beta diversity frequently measures the substitution of species without considering the relative abundance(3). However, the inclusion of the relative abundance or frequency index allows a more informative evaluation of species diversity, especially when it varies between habitats(4). Studies that compare variation in the number of species between local habitats are necessary to determine patterns, particularly in places in the world that are enriched in bird species(5). In these areas, deforestation

and controlled burnings for agricultural expansion along with hunting pressure are decreasing species richness.

High beta diversity along an environmental gradient reflect the specialization of species in habitats. The quantification of this parameter can be used to design strategies for protection of bird diversity in these areas[6]. A high beta diversity within small distances reflects the presence of abundant species between neighboring habitats, which generally are locally specialized and highly susceptible to anthropogenic action[3]. The spatial variation of birds composition with types of habitats is rarely measured, but it has shown to be important to define the area needed to protect some species[3]. There are some studies on the changing of the composition of animal communities along altitudinal gradients, but beta diversity in tropical systems is particularly misunderstood[7,8]. According to these studies, a gradual change in composition occurs with altitude, although some results may have been affected by the sampling method[9]. Instead of using the total animal community, quantification of beta diversity using a specific taxonomic group, such as birds (order Passeriformes), may be easier in terms of research planning[10]. Despite the apparent capacity for dispersion, many factors seem to influence variation of bird diversity or delimit their geographic distribution, for example the presence of rivers[4]. Habitats created by rivers, such as floodplain forest, flooded habitats, and habitats with fluctuations in vegetation, present about 15% regional birds, suggesting that watercourses may have had a relevant role in the origin of different bird species in the current region of Southern Amazon. The present study investigated the change in the composition of bird species of the order Passeriformes along gradients in the Alto-Guaporé region, Southern Amazon, a region that presents an elevated richness of birds and has a constant substitution of species due to a high diversity of environments. We aimed to answer two questions: Are spatially closed habitats more similar in species composition (beta diversity)? Are there differences in species richness among the type of sampled habitats (flooded forest, dry forest, and marsh palm with palm tree fruits)? We used the observed patterns of variation in species composition obtained within a bird community and explored possible implications for conservation planning.

Methods

This study was performed from December 2011 to September 2012, in three large localities (A,B,C) in the region of Alto-Guaporé in Southern Amazon, a region characterized by a heterogeneous vegetation cover (180879.94S, 8331318.14W between 780708.00S, 8507364W; see Fig.1)

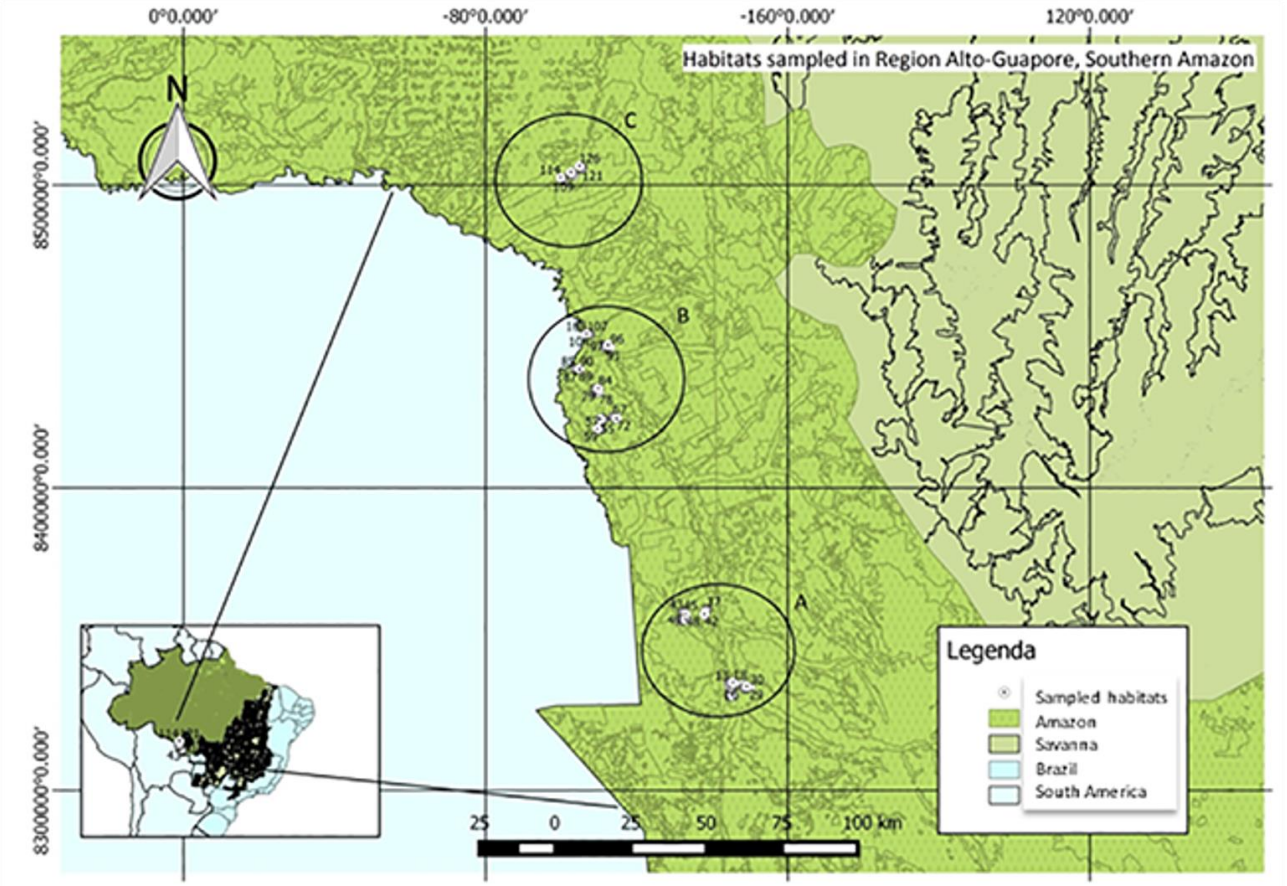

Figure1. Habitats sampled in three locations (A, B, C) in Alto-Guapore region, Southern Amazo

We sampled three types of local habitats: marsh palm, dry forest, and flooded forest. The marsh palms are habitats of planes in Southern Amazon with riparian areas dominated by *Mauritia flexuosa*, flooded during the rainy period and permanently humid in the dry periods (n: 18 points). In the dry forest there is no rainfall, the height of trees fluctuates between 30 and 60 m, with closed canopy and thick bush (n: 72 points). Flooded habitats occur along the banks of the rivers Alegre, Verde, and Guaporé. These habitats are always flooded and the trees present a maximum height of 20 m with lianas and aquatic plants, and without sub-woods (n: 36 points). The census procedures included the most efficient hearing census[11], and observational census with the utilization of binoculars and photographic equipment. Identification of each foraging bird species was accomplished with the collected photographs and recordings. We also referred to specific bibliography to associate the diet of each bird species with the food available in each sampled habitat[11-18], so that we could make inferences on each foraged habitat per bird species. We used the quantitative lifting method (adapted from Blondel et al.)[19]. We sampled points in transects equidistant 5 km from each other. Each transect had six points located 200 m apart (this distance was adequate to avoid juxtaposition of territory between most species and allowed us to cover all habitats). In total, 126 points were sampled. The recordings in each point were done using audio digital equipment (96KHz), for 15 minutes during the morning (period of the day when birds are most active), three times in different days. The sampling effort consisted of 63 days of census and 31 hours and 50 minutes of recordings covering approximately 700 km in length, in total. The vocalizations were then edited and the species identified, and finally revised by a bird specialist (records were deposited in the Laboratory of Mammalogy, UNEMAT, Brazil).

To investigate the presence of clustering of species relative to the type of sampled habitat, the PCA method was applied (Principal Components Analysis is a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components). We calculated the global β diversity to measure diversity between the sampled habitats[2]. The Index quality of Jaccard (cc), a matrix of presence and absence for a dataset, represents the macrostructure of species distributed between the habitats, although application is restricted to habitats with more than seven species. This Index was calculated with the following formula:

$cc= c/ (a+b+c)*100$[1], or

$cc=c/ (A+B-c)*100$[2]

where: "a" is the number of species unique to sample 1, "b" is the number of specie unique to sample 2, "c" is the number of species common to samples 1 and 2, "A" is the total number of species in sample 1, and "B" is the total number of species in sample 2.

The distance values are plotted as similarity dendograms, the lower the index the less the similarity, created through the UPGMA (Unweighted Pair Group Method with Arithmetic Mean). The correlation between two matrices of dissimilarity was evaluated: one matrix of spatial distance (Euclidean) and the other one of species dissimilarity (Bray-Curtis) utilized the Mantel Test (Number of permutatitons: 999) (20). All analyzes were performed using R version 2.14.0.2011 program[21].

Results

A total of 148 species of birds (order Passeriformes) were identified and distributed in 27 families. Of these, 97% (n= 145) of the species foraged in flooded forests, 77% (n= 114) in dry forests, and 18.91% (n= 28) in marsh palm. Only 18% (n= 27) of the bird species foraged in all three habitats. The habitat with the highest species richness was the flooded forest[7] (Table 1). The value of species richness per habitat and sampling areas can be seen in Table 2. The ordination showed that most species are highly associated with a habitat, for instance, *Mimus saturninus* is mainly observed within the flooded forest habitat, and *Empidonomus varius*, *Onychorhynchus coronatus*, *Thamnomanes caesius*, *Myrmotherula menetriesii*, and *Dysithamnus mentalis* in the dry forests (Figure 2). The analysis of the global beta diversities in total showed that substitution of species is predominant (Whittaker: 7.7405, Harrison: 0.14334, Cody: 554.5, Routledge: 0.700, Wilson-Shmida: 32.97, Mourelle: 0.610, Harrison2: 0.024, Williams: 0.5714). These values indicate that beta diversity is high. As expected, we found the same pattern when applying the measure of pairwise dissimilarity. In the cluster analysis (Figure 3), the effect of spatial distance is clear because in groups 1 and 2 the habitats closer to each other are very similar (according to the Jaccard similarity index; r= 0.872, p = 0,002). This is not observed with the points of groups 3 and 4; these points corresponded to the moment of transition and substitution of species. However, in the majority of cases, the influence of spatial distance was confirmed with the partial Mantel analysis. The influence of spatial distance on the dissimilarity index (beta diversity) was significant (Mantel statistic r: 0.0608, p (value): 0.0049) (Figure 4).

Table I. Composition of the list of birds (order Passeriformes) in *Alto-Guapore* region, Southern Amazon 2012

Name Taxon Passeriformes (order)	Popular Name in Brazil	English Name	Habitats		
Thamnophilidae					
Microrhopias quixensis	*papa-formiga-de-bando*	dot-winged antwren		dry	floo
Myrmotherula axillaris	*choquinha-de-flanco-branco*	white-flanked antwren	ma	dry	floo
Myrmotherula menetriesii	*choquinha-de-garganta-cinza*	gray antwren	ma	dry	floo
Formicivora grisea	*papa-formiga-pardo*	white-fringed antwren		dry	floo
Thamnomanes caesius	*ipecuá*	cinereous antshrike	ma	dry	floo
Dysithamnus mentalis	*choquinha-lisa*	plain antvireo	ma	dry	floo
Herpsilochmus longirostris	*chorozinho-de-bico-comprido*	large-billed antwren		dry	floo
Thamnophilus torquatus	*choca-de-asa-vermelha*	rufous-winged antshrike		dry	floo
Thamnophilus schistaceus	*choca-de-olho-vermelho*	plain-winged antshrike		dry	floo
Thamnophilus stictocephalus	*choca-de-natterer*	natterer's slaty-antshrike		dry	floo
Thamnophilus aethiops	*choca-lisa*	white-shouldered antshrike		dry	floo
Thamnophilus amazonicus	*choca-canela*	amazonian antshrike		dry	floo
Taraba major	*choró-boi*	great antshrike		dry	floo
Hypocnemoides maculicauda	*solta-asa*	band-tailed antbird		dry	floo
Sclateria naevia	*papa-formiga-do-igarapé*	silvered antbird		dry	floo
Myrmoborus myotherinus	*formigueiro-de-cara-preta*	black-faced antbird	ma	dry	floo
Pyriglena leuconota	*papa-taoca*	white-backed fire-eye		dry	floo
Cercomacra nigrescens	*chororó-negro*	blackish antbird		dry	floo
Hypocnemis ochrogyna	*cantador-ocráceo*	rondonia warbling-antbird		dry	floo
Willisornis poecilinotus	*rendadinho*	common scale-backed antbird		dry	floo
Phlegopsis nigromaculata	*mãe-de-taoca*	black-spotted bare-eye		dry	floo
Melanopareiidae					
Melanopareia torquata	*tapaculo-de-colarinho*	collared crescentchest	ma	dry	floo
Formicariidae					
Formicarius colma	*galinha-do-mato*	rufous-capped antthrush		dry	floo
Dendrocolaptidae					
Dendrocincla fuliginosa	*arapaçu-pardo*	plain-brown woodcreeper		dry	floo
Sittasomus griseicapillus	*arapaçu-verde*	olivaceous woodcreeper		dry	floo
Campylorhamphus trochilirostris	*arapaçu-beija-flor*	red-billed scythebill		dry	floo
Dendroplex picus	*arapaçu-de-bico-branco*	straight-billed woodcreeper		dry	floo
Xenopidae					
Xenops rutilans	*bico-virado-carijó*	streaked xenops		dry	floo
Furnariidae					
Furnarius rufus	*joão-de-barro*	rufous hornero		dry	floo
Certhiaxis cinnamomeus	*curutié*	yellow-chinned spinetail		dry	floo
Synallaxis frontalis	*petrim*	sooty-fronted spinetail		dry	floo
Synallaxis scutata	*estrelinha-preta*	ochre-cheeked spinetail	ma	dry	floo

To be continued...

Continuation

Name Taxon	Popular Name in Brazil	English Name	Habitats		
Passeriformes (order)					
Pipridae					
Neopelma pallescens	*fruxu-do-cerradão*	pale-bellied tyrant-manakin		dry	floo
Manacus manacus	*rendeira*	white-bearded manakin		dry	floo
Heterocercus linteatus	*coroa-de-fogo*	flame-crowned manakin		dry	floo
Machaeropterus pyrocephalus	*uirapuru-cigarra*	fiery-capped manakin		dry	floo
Xenopipo atronitens	*pretinho*	black manakin		dry	floo
Oxyruncidae					
Oxyruncus cristatus	*araponga-do-horto*	sharpbill		dry	floo
Onychorhynchidae					
Onychorhynchus coronatus	*maria-leque*	royal flycatcher	ma	dry	floo
Terenotriccus erythrurus	*papa-moscas-uirapuru*	ruddy-tailed flycatcher		dry	floo
Tityridae					
Schiffornis virescens	*flautim*	greenish schiffornis		dry	floo
Schiffornis turdina	*flautim-marrom*	thrush-like schiffornis			floo
Tityra inquisitor	*anambé-branco-de-bochecha-parda*	black-crowned tityra	ma	dry	floo
Tityra cayana	*anambé-branco-de-rabo-preto*	black-tailed tityra	ma	dry	floo
Tityra semifasciata	*anambé-branco-de-máscara-negra*	masked tityra			floo
Pachyramphus viridis	*caneleiro-verde*	green-backed becard	ma	dry	floo
Pachyramphus polychopterus	*caneleiro-preto*	white-winged becard		dry	floo
Pachyramphus validus	*caneleiro-de-chapéu-preto*	crested becard	ma	dry	floo
Cotingidae					
Lipaugus vociferans	*cricrió*	screaming piha			floo
Gymnoderus foetidus	*anambé-pombo*	bare-necked fruitcrow			floo
Cotinga cayana	*anambé-azul*	spangled cotinga		dry	floo
Cephalopterus ornatus	*anambé-preto*	amazonian umbrellabird			floo
Platyrinchidae					
Platyrinchus mystaceus	*patinho*	white-throated spadebill		dry	floo
Rhynchocyclidae					
Mionectes oleaginous	*abre-asa*	ochre-bellied flycatcher			floo
Corythopis delalandi	*estalador*	southern antpipit		dry	floo
Tolmomyias sulphurescens	*bico-chato-de-orelha-preta*	yellow-olive flycatcher		dry	floo
Todirostrum cinereum	*ferreirinho-relógio*	common tody-flycatcher	ma	dry	floo
Hemitriccus margaritaceiventer	*sebinho-de-olho-de-ouro*	pearly-vented tody-tyrant	ma	dry	floo
Tyrannidae					
Inezia inornata	*alegrinho-do-chaco*	plain tyrannulet		dry	floo
Camptostoma obsoletum	*risadinha*	southern beardless-tyrannulet			floo
Elaenia flavogaster	*guaracava-de-barriga-amarela*	yellow-bellied elaenia		dry	floo
Elaenia chilensis	*guaracava-de-crista-branca*	chilean elaenia		dry	floo
Elaenia parvirostris	*guaracava-de-bico-curto*	small-billed elaenia		dry	floo

To be continued…

Continuation

Name Taxon	Popular Name in Brazil	English Name	Habitats		
Passeriformes (order)					
Elaenia chiriquensis	*chibum*	lesser elaenia		dry	floo
Myiopagis caniceps	*guaracava-cinzenta*	gray elaenia		dry	floo
Attila cinnamomeus	*tinguaçu-ferrugem*	cinnamon attila		dry	floo
Attila bolivianus	*bate-pára*	dull-capped attila			floo
Attila spadiceus	*capitão-de-saira-amarelo*	bright-rumped attila			floo
Ramphotrigon ruficauda	*bico-chato-de-rabo-vermelho*	rufous-tailed flatbill		dry	floo
Myiarchus swainsoni	*irré*	swainson's flycatcher		dry	floo
Sirystes sibilator	*gritador*	sirystes			floo
Casiornis rufus	*maria-ferrugem*	rufous casiornis		dry	floo
Pitangus sulphuratus	*bem-te-vi*	great kiskadee			floo
Philohydor lector	*bentevizinho-do-brejo*	lesser kiskadee		dry	floo
Machetornis rixosa	*suiriri-cavaleiro*	cattle tyrant			floo
Tyrannopsis sulphurea	*suiriri-de-garganta-rajada*	sulphury flycatcher			floo
Myiozetetes cayanensis	*bentevizinho-de-asa-ferrugínea*	rusty-margined flycatcher		dry	floo
Tyrannus albogularis	*suiriri-de-garganta-branca*	white-throated kingbird	ma	dry	floo
Tyrannus savanna	*tesourinha*	fork-tailed flycatcher	ma	dry	floo
Griseotyrannus aurantioatrocristatus	*peitica-de-chapéu-preto*	crowned slaty flycatcher		dry	floo
Empidonomus varius	*peitica*	variegated flycatcher		dry	floo
Pyrocephalus rubinus	*príncipe*	vermilion flycatcher		dry	floo
Arundinicola leucocephala	*freirinha*	white-headed marsh tyrant		dry	floo
Lathrotriccus euleri	*enferrujado*	euler's flycatcher		dry	floo
Vireonidae					
Vireo olivaceus	*juruviara-boreal*	red-eyed vireo	ma	dry	floo
Corvidae					
Cyanocorax cyanomelas	*gralha-do-pantanal*	purplish jay		dry	floo
Cyanocorax chrysops	*gralha-picaça*	plush-crested jay	ma	dry	floo
Hirundinidae					
Stelgidopteryx ruficollis	*andorinha-serradora*	southern rough-winged swallow			floo
Progne tapera	*andorinha-do-campo*	brown-chested martin			floo
Progne chalybea	*andorinha-doméstica-grande*	gray-breasted martin		dry	floo
Tachycineta albiventer	*andorinha-do-rio*	white-winged swallow		dry	floo
Riparia riparia	*andorinha-do-barranco*	bank swallow	ma	dry	floo
Troglodytidae					
Troglodytes musculus	*corruíra*	southern house wren		dry	floo
Campylorhynchus turdinus	*catatau*	thrush-like wren		dry	floo
Pheugopedius genibarbis	*garrinchão-pai-avô*	moustached wren			floo
Cantorchilus leucotis	*garrinchão-de-barriga-vermelha*	buff-breasted wren		dry	floo
Cantorchilus guarayanus	*garrincha-do-oeste*	fawn-breasted wren		dry	floo
Donacobiidae					
Donacobius atricapilla	*japacanim*	black-capped donacobius			floo

To be continued...

Continuation

Name Taxon	Popular Name in Brazil	English Name	Habitats		
Passeriformes (order)					
Polioptilidae					
Ramphocaenus melanurus	*bico-assovelado*	long-billed gnatwren		dry	
Polioptila dumicola	*balança-rabo-de-máscara*	masked gnatcatcher			floo
Turdidae					
Turdus fumigatus	*sabiá-da-mata*	cocoa thrush		dry	floo
Turdus rufiventris	*sabiá-laranjeira*	rufous-bellied thrush			floo
Mimidae					
Mimus saturninus	*sabiá-do-campo*	chalk-browed mockingbird		dry	floo
Passerellidae					
Arremon taciturnus	*tico-tico-de-bico-preto*	pectoral sparrow		dry	floo
Icteridae					
Psarocolius decumanus	*japu*	crested oropendola			floo
Procacicus solitaries	*iraúna-de-bico-branco*	solitary black cacique		dry	floo
Cacicus haemorrhous	*guaxe*	red-rumped cacique		dry	floo
Cacicus cela	*xexéu*	yellow-rumped cacique		dry	floo
Icterus pyrrhopterus	*encontro*	variable oriole			floo
Icterus croconotus	*joão-pinto*	orange-backed troupial		dry	floo
Gnorimopsar chopi	*graúna*	chopi blackbird		dry	floo
Amblyramphus holosericeus	*cardeal-do-banhado*	scarlet-headed blackbird			floo
Agelasticus cyanopus	*carretão*	unicolored blackbird	ma	dry	
Molothrus oryzivorus	*iraúna-grande*	giant cowbird		dry	floo
Molothrus bonariensis	*vira-bosta*	shiny cowbird		dry	floo
Thraupidae					
Coereba flaveola	*cambacica*	bananaquit		dry	floo
Saltator maximus	*tempera-viola*	buff-throated saltator	ma	dry	floo
Saltator coerulescens	*sabiá-gongá*	grayish saltator		dry	floo
Saltator similis	*trinca-ferro-verdadeiro*	green-winged saltator			floo
Saltator grossus	*bico-encarnado*	slate-colored grosbeak		dry	floo
Nemosia pileata	*saíra-de-chapéu-preto*	hooded tanager		dry	floo
Thlypopsis sordida	*saí-canário*	orange-headed tanager			floo
Ramphocelus carbo	*pipira-vermelha*	silver-beaked tanager			floo
Lanio versicolor	*pipira-de-asa-branca*	white-winged shrike-tanager	ma	dry	floo
Tangara gyrola	*saíra-de-cabeça-castanha*	bay-headed tanager			floo
Tangara chilensis	*sete-cores-da-amazônia*	paradise tanager			floo
Tangara sayaca	*sanhaçu-cinzento*	sayaca tanager		dry	floo
Tangara palmarum	*sanhaçu-do-coqueiro*	palm tanager	ma	dry	floo
Tangara nigrocincta	*saíra-mascarada*	masked tanager			floo
Schistochlamys melanopis	*sanhaçu-de-coleira*	black-faced tanager	ma	dry	floo
Paroaria capitate	*cavalaria*	yellow-billed cardinal		dry	floo
Dacnis cayana	*saí-azul*	blue dacnis		dry	floo
Cyanerpes cyaneus	*saíra-beija-flor*	red-legged honeycreeper			floo

To be continued...

Continuation

Name Taxon	Popular Name in Brazil	English Name	Habitats		
Passeriformes (order)					
Chlorophanes spiza	*saí-verde*	green honeycreeper			floo
Hemithraupis flavicollis	*saíra-galega*	yellow-backed tanager		dry	floo
Conirostrum speciosum	*figuinha-de-rabo-castanho*	chestnut-vented conebill		dry	floo
Sicalis flaveola	*canário-da-terra-verdadeiro*	saffron finch		dry	
Volatinia jacarina	*tiziu*	blue-black grassquit	ma	dry	floo
Sporophila collaris	*coleiro-do-brejo*	rusty-collared seedeater		dry	floo
Sporophila lineola	*bigodinho*	lined seedeater			floo
Sporophila nigricollis	*baiano*	yellow-bellied seedeater			floo
Sporophila bouvreuil	*caboclinho*	cooper seedeater			floo
Sporophila angolensis	*curio*	chestnut-bellied seed-finch		dry	floo
Cardinalidae					
Piranga flava	*sanhaçu-de-fogo*	hepatic tanager			floo
Pheucticus aureoventris	*rei-do-bosque*	black-backed grosbeak	ma	dry	floo
Fringillidae					
Euphonia chlorotica	*fim-fim*	purple-throated euphonia	ma	dry	floo
Euphonia violacea	*gaturamo-verdadeiro*	violaceous euphonia		dry	floo
Family	**27**				
Species	**148**				

Legend: Habitats - ma: marsh palm, dry: dry forest, floo: flooded forest;

Table II. Characteristics of the sampling areas. Latitude and longitude are shown in UTM

Code map	Habitat	Areas	Latitude	Longitude	Passeriformes richness
1	Flooded forest	A	180925	8331295	42
2	Flooded forest	A	181142	8331279	41
3	Flooded forest	A	181372	8331224	50
4	Flooded forest	A	181021	8331896.89	20
5	Dry forest	A	181299	8331786	24
6	Dry forest	A	181531	8331695	1
7	Flooded forest	A	181298	8333552	63
8	Flooded forest	A	181210	8333807	41
9	Flooded forest	A	181133	8334009	48
10	Flooded forest	A	180970	8334329	40
11	Dry forest	A	180869	8334506	34
12	Dry forest	A	180743	8334696	34
13	Flooded forest	A	180507	8335421	30
14	Flooded forest	A	180859	8335484	21
15	Flooded forest	A	181109	8335564	19
16	Flooded forest	A	181345	8335637	0
17	Flooded forest	A	181644	8335637	1
18	Flooded forest	A	181916	8335643	0
19	*Marsh* palm	A	185524.73	8334058.32	3
20	*Marsh* palm	A	185483	8334233	6
21	*Marsh* palm	A	185408	8334423	9
22	*Marsh* palm	A	185274	8334561	13
23	*Marsh* palm	A	185131	8334699	9
24	*Marsh* palm	A	184996	184996	1
25	*Marsh* palm	A	186507.2	8333914.13	2
26	*Marsh* palm	A	186719	8333932	9
27	*Marsh* palm	A	186719	8333932	12
28	*Marsh* palm	A	187144	8334029	7
29	*Marsh* palm	A	187354	8334066	5
30	*Marsh* palm	A	187554	8334110	2
31	*Marsh* palm	A	185494.87	8333830.27	1
32	*Marsh* palm	A	185700	8333887	9
33	*Marsh* palm	A	185901	8333956	9
34	*Marsh* palm	A	186077	8334058	8
35	*Marsh* palm	A	186249	8334220	5
36	*Marsh* palm	A	186402	8334340	2
37	Dry forest	A	819055.33	8359824.1	14
38	Dry forest	A	818975	8359651	9
39	Dry forest	A	818817	8359468	4
40	Dry forest	A	818689	8359326	5

To be continued...

Continuation...

Code map	Habitat	Areas	Latitude	Longitude	Passeriformes richness
41	Dry forest	A	818493	8359114	7
42	Dry forest	A	818255	8358369	8
43	Dry forest	A	811167.56	8359219.72	9
44	Dry forest	A	811318	8359025	9
45	Dry forest	A	811433	8358841	6
46	Dry forest	A	811602	8358642	2
47	Dry forest	A	811854	8358500	2
48	Dry forest	A	812095	8358369	5
49	Dry forest	A	810624.6	8356568.87	8
50	Dry forest	A	810867	8356679	7
51	Dry forest	A	811116	8356721	1
52	Dry forest	A	811397	8356733	1
53	Flooded forest	A	811692	8356753	4
54	Flooded forest	A	811981	8356764	3
55	Dry forest	B	785583	8420492	13
56	Dry forest	B	785329	8420504	4
57	Dry forest	B	785110	8420518	1
58	Dry forest	B	784857	8420483	3
59	Dry forest	B	784609	8420485	3
60	Dry forest	B	784418	8420524	2
61	Dry forest	B	786562.51	8423589.41	6
62	Dry forest	B	786356	8423564	1
63	Dry forest	B	786159	8423565	2
64	Dry forest	B	785941	8423609	5
65	Dry forest	B	785736	8423655	4
66	Dry forest	B	785535	8423743	3
67	Dry forest	B	789791.98	8424305.24	3
68	Dry forest	B	789985	8424198	0
69	Dry forest	B	790212	8424129	3
70	Dry forest	B	790422	8424038	2
71	Dry forest	B	790681	8423946	5
72	Dry forest	B	790951	8423856	3
73	Dry forest	B	784229.14	8432586.27	2
74	Dry forest	B	784437	8432581	4
75	Dry forest	B	784660	8432583	1
76	Dry forest	B	784888	8432615	3
77	Dry forest	B	785113	8432621	1
78	Dry forest	B	785331	8432631	1
79	Dry forest	B	784048.69	8433618.56	2
80	Dry forest	B	784208	8433773	4
81	Dry forest	B	784428	8433825	2

To be continued...

Continuation

Code map	Habitat	Areas	Latitude	Longitude	Passeriformes richness
82	Dry forest	B	784658	8433875	0
83	Dry forest	B	784878	8433895	2
84	Dry forest	B	785122	8433926	0
85	Dry forest	B	777628.65	8440405.58	3
86	Dry forest	B	777927	8440412	4
87	Dry forest	B	778204	8440352	3
88	Dry forest	B	778535	8440404	2
89	Dry forest	B	778829	8440401	1
90	Dry forest	B	779083	8440399	2
91	Flooded forest	B	788291	8447170	10
92	Flooded forest	B	788500	8447253	1
93	Flooded forest	B	788723	8447334	4
94	Flooded forest	B	788940	8447398	7
95	Flooded forest	B	789158	8447458	2
96	Dry forest	B	789402	8447510	5
97	Flooded forest	B	787388.85	8447686.02	12
98	Flooded forest	B	787651	8447772	6
99	Flooded forest	B	787875	8447841	3
100	Flooded forest	B	788140	8447970	6
101	Flooded forest	B	788443	8448085	3
102	Dry forest	B	788652	8448150	1
103	Flooded forest	B	782787.56	8451826.06	11
104	Flooded forest	B	782582	8451806	8
105	Flooded forest	B	782381	8451887	6
106	Flooded forest	B	782079	8451917	15
107	Flooded forest	B	781864	8451969	3
108	Dry forest	B	781666	8452017	3
109	Flooded forest	C	775268	8503059	4
110	Flooded forest	C	775018	8503202	9
111	Flooded forest	C	774840	8503339	8
112	Flooded forest	C	774682	8503490	18
113	Flooded forest	C	774517	8503621	15
114	Dry forest	C	774349	8503779	3
115	Dry forest	C	778523.36	8504561.8	1
116	Dry forest	C	778807	8504381	17
117	Dry forest	C	778328	8504678	18
118	Dry forest	C	778178	8504870	15
119	Dry forest	C	777995	8505131	13
120	Dry forest	C	777804	8505374	1
121	Dry forest	C	781622.42	8506496.55	1
122	Dry forest	C	781296	8506654	13

To be continued

Continuation

Code map	Habitat	Areas	Latitude	Longitude	Passeriformes richness
123	Dry forest	C	781175	8506925	11
124	Dry forest	C	781065	8507070	3
125	Dry forest	C	780930	8507258	13
126	Dry forest	C	780708	8507364	1

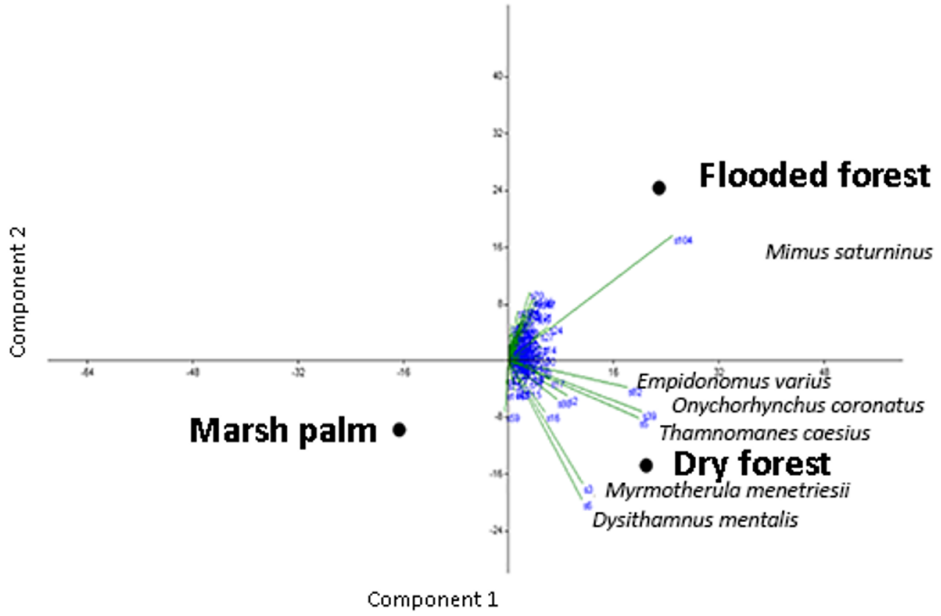

Figure2. PCA-ordination diagram in correlation biplot scaling with birds species (Passeriformes) represented by arrows and habitats by points for data of birds from Southern Amazon, Brazil.

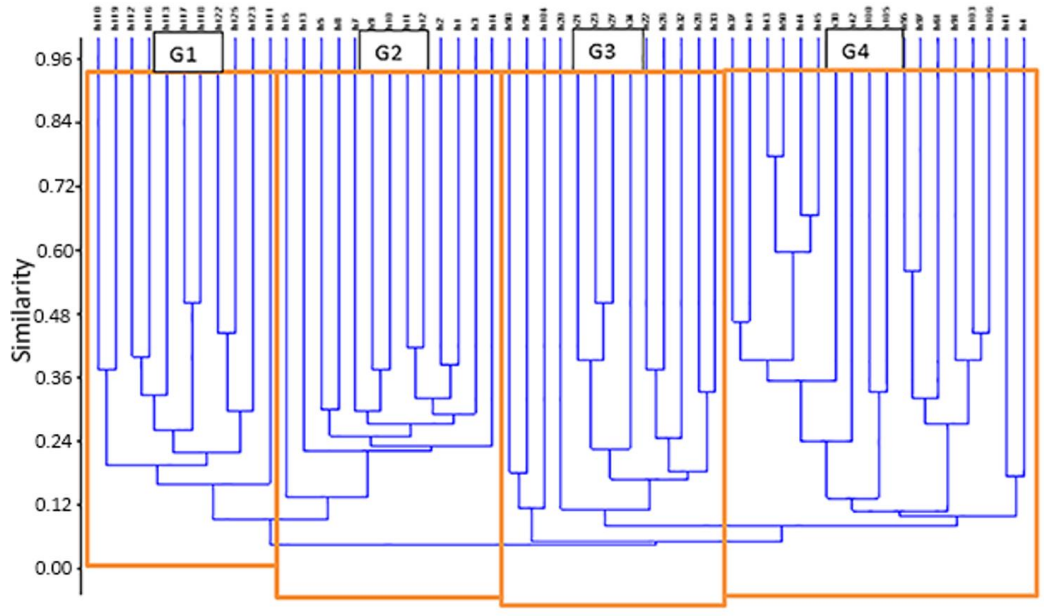

Figure3. Dendogram of index similarity Jaccard (birds order Passeriformes) for habitats (r= 0.872, p = 0.002). Acronyms: h= habitats, see type of habitat according table I and G= groups principals.

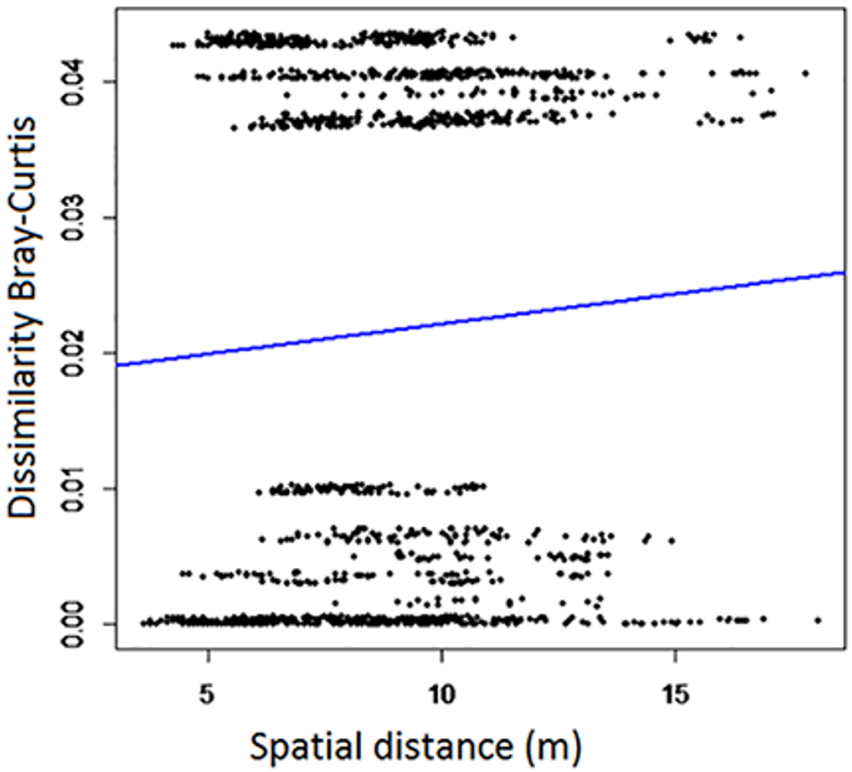

Figure 4. Mantel statistic based on Pearson's product-moment correlation, relation between species dissimilarity and spatial distance in meters of birds (order Passeriformes) in Southern Amazon (r: 0.0608, p: 0.005). Each point represents one pair of compared habitats.

Discussion

Silva[22] suggested that many amazon species penetrate the Brazilian savanna biome following the gallery forest or vice versa, both places presenting a high diversity of birds[23]. In this study, the sampled places are very close to the transition between the Amazon and the Brazilian savanna, and this fact may explain the substitution of species that we observe. The high variability in the composition of species (unequally distributed) in the sampled points also contributed to the high species richness of birds Passeriformes. As suggested by Williams[24], the increased level of environmental heterogeneity in the sampled habitats may be very relevant in explaining the high species richness that we found. Cohn-Haft, Whitaker, and Stouffer[25] also proposed that habitat heterogeneity is the most important determinant for bird species richness inside the Amazon, and not primary productivity or level of rainfall as advocated by other authors.

Concerning the preference for habitats, this study showed that, although some species revealed to be habitat specialists, most bird species of the order Passeriformes explored and foraged many types of habitats. The habitat that presented more species was the flooded forest (Table 2). In this type of habitat, birds may find suitable conditions that directly influence their life cycle, such as, water, food, shelter, and protection from predators[26,27]. In the Amazon, many species, even residents, disperse according to water and food resources and these are abundantly present in the flooded forest habitat. Ferreira et al.[28] found more richness of species at flooded habitats, a finding that agrees with our own results. The species *Mimus saturninus* had the highest level of association with

this type of habitat, though always with open grasslands with scattered trees and shrubs close-by. We believe this may be explained by the fact that this species lives in groups of thirteen individuals and they forage the river for reproduction and food (fruits). In the dry forest habitat there are many winged insects, which could explain the presence of *Empidonomus varius*, *Dysithamnus mentalis*, *Onychorhynchus coronatus*, *Thamnomanes caesius*, and *Mymotherula menetriesii* in this habitat, since they primarily feed in these insects.

The high beta diversity that we found in this study is very important, particularly for strategic conservation plans. We provide specific points along an environmental gradient in the Amazon forest, where a high richness and high variation in species composition within different types of habitats may be found. More attention should be given to the importance of local conservation. High beta diversity should be taken into consideration when designing a natural reserve, particularly in including, placing and in the extension of contiguous heterogeneous habitats[29], which contrast with lowland habitats where species are widely distributed[11,30,31]. The positive correlation between the species dissimilarity and geographic distance observed for Passeriformes in this study is in line with the Neutral Theory[32], which states that species similarity in a community decreases with increased geographic distance between different environments. This means that because of the limitation in species distribution, the more distant the habitats are, the more different they will be in terms of species composition[33]. This author assumes that the limitation in species distribution is a function of immigration and local extinction, with species appearing and disappearing. Therefore, for species that have a small distribution, local and regional variation will impact their distribution the most. The analysis of the Jaccard similarity index revealed a major point where substitution of species is significant. Groups 3 and 4 appear on a point of transition and mixture of species close to the North Amazon, where in a small space, many different species may be found. This species composition is organized in limited local populations with high beta diversity that should be protected from the deforestation, selective logging, and poaching that have been occurring because this community is particularly vulnerable to disruption, and immediate recovery will most likely lead to reorganization of an unbalanced ecosystem. Thus, this study provides important information on specific habitats with high beta diversity whose stability is at risk in the face of continuing environmental challenges.

Acknowledgements

To the BioNorte Project - Knowledge, Sustainable Use and Bioprospecting of Biodiversity in the Southern Amazon for funding the project and to CAPES (Coordination for the Improvement of Higher Education Personnel) for the scholarship granted.

References

1. Orians GH. The number of bird species in some tropical forests. Ecology. 1969, 50: (5) 783-801. http://dx.doi.org/10.2307/1933692

2. Whittaker RH. Communities and Ecosystems. Macmillan, New York. 1975, 583p. English.

3. Koleff P, Gaston KJ, Lennon JJ. Measuring beta diversity for presence absence data. Journal of Animal Ecology. 2003, 72: (3) 367–382. http://dx.doi.org/10.1046/j.1365-2656.2003.00710.x

4. Blair RB. Birds and butterflies along an urban gradients: Surrogate taxa for assessing biodiversity? Ecological Applications. 1999, 9: (1) 164-170. http://www.jstor.org/stable/2641176

5. Cracraft J. "Historical Biogeography and Patterns of Differentiation within the South American Avifauna: Areas of Endemism". Ornithological Monographs. 1985, 36: 49-41. http://dx.doi.org/10.2307/40168278

6. Magurran AE. Measuring biological diversity. Oxford: Blackwell Publishing. ISBN 0-632-05633-9. 2004, 2064p. English.

7. Young BE, DeRosier D, Powell GVN. Diversity and conservation of understory birds in the Tilarán mountains, Costa Rica. Auk. 1998, 115: (4) 998–1016. http://dx.doi.org/10.2307/4089518

8. Blake JG, Loiselle BA. Diversity of birds along an elevational gradient in the Cordillera Central, Costa Rica. Auk. 2000, 117: 663–686. http://dx.doi.org/10.1642/0004-8038(2000)117[0663:DOBAAE]2.0.CO;2

9. Kitayama K. An altitudinal transect study of the vegetation of Mount Kinabalú, Borneo. Vegetatio. 1992, 102: (2) 149–171. http://dx.doi.org/10.1007/bf00044731

10. Aleixo A. Lacunas de conhecimento, prioridades de pesquisa e perspectivas futuras na conservação de aves na Amazônia Brasileira. 2009, 54p. In: De Luca A, Develey PF, Bencke GA, Goerck JM. (Orgs.). Áreas importantes para a conservação das aves no Brasil: parte II – Amazônia, Cerrado e Pantanal. São Paulo: SAVE Brasil. 361p.

11. Terborgh J, Robinson SK, Parker III TA, Munn CA, Pierpont N. Structure and organization of an Amazonn forest bird community. Ecological Monographs. 1990, 60: (2) 213–238. http://dx.doi.org/10.2307/1943045

12. Moojen J, Carvalho JC, Lopes HS. Observações sobre o conteúdo gástrico das aves brasileiras. Rio de Janeiro, Memórias do Instituto Oswvaldo Cruz. 1941, 36 (3): 405-444. http://dx.doi.org/10.1590/S0074-02761941000300016

13. Hempel A. Estudo da alimentação natural de aves silvestres do Brasil. São Paulo, Arquivos do Instituto Biológico. 1949, 19: 237-268. http://www.scielo.br/scielo.php?script=sci_nlinks&ref=000042&pid=S0071-12761951000100022000009&lng=en

14. Kuhlmann M, Jimbo S. A flora na alimentação das aves brasileira: I Generalidades. São Paulo, Papéis Avulsos de Zoologia. 1957, 13(7): 85-97. http://www.scielo.br/scielo.php?script=sci_nlinks&ref=7299265&pid=S0101-81752005000400024000028&lng=en

15. Schubart O, Aguirre AC, Sick H. Contribuição para o conhecimento da alimentação das aves brasileiras. São Paulo, Arquivos de Zoologia. 1965, 12: 95-249. http://www.scielo.br/scielo.php?script=sci_nlinks&ref=7299277&pid=S0101-81752005000400024000040&lng=en

16. Willis EO. The compositions of avian communities in remanescents woodlots in southern Brazil. Papéis Avulsos do Museu de Zoologia. 1979, 33:1-25. http://www.scielo.br/scielo.php?script=sci_nlinks&ref=7357770&pid=S0101-81752007000200015000025&lng=en

17. Motta-Junior JC. Estrutura trófica e composição das avifaunas de três habitats terrestres na região central do Estado de São Paulo. Ararajuba. 1990, 1:65-71.

18. Sick H. Ornitologia brasileira. Rio de Janeiro, Nova Fronteira, II+862. SIMBERLOFF, D. 1997, 862p.

19. Blondel J, Ferry C, Frochot B. Point counts with unlimited distance. Stud. Avian Biol. 1981, 6: 414-420.

20. Mantel N. The detection of disease clustering and a generalized regression approach. Cancer Research.

1967, 27: 209–220.

21. R Development Core Team. R: A language and environment for statistical computing. Vienna, R Foundation for Statistical Computing, ISBN 3900051-07-0. 2011. available online at: http://www.R-project.org.

22. Silva JMC. Distribuition of Amazonn and Atlantic birds in gallery forest of the Cerrado region, South America. Ornit. Neot. 1967, 7 (1) :1-18.

23. Tocantins. Avaliação Ecológica Rápida do Parque Estadual do Cantão. Secretaria do Planejamento e Meio Ambiente do Estado do Tocantins, Palmas. 2004a.

24. Williams CB. Patterns in the balance of nature. New York: New York Academic Press. 1964, 300p. English

25. Cohn-Haft M, Whittaker A, Stouffer PC. A second look at the "species-poor" central Amazon: the avifauna north of Manaus, Brazil. 1967, 235p. in: Remsen, J.V., ed. Studies in Neotropical ornithology honoring Ted Parker. Ornithological Monograph. 1967, 48. http://dx.doi.org/10.2307/40157535

26. Parker III. Neotropical birds: ecology and conservation. Chicago, University of Chicago Press.

27. Willson MF. Avian community organization and habitat structure. Ecology. 1974, 55: (5) 1017-1027. http://dx.doi.org/10.2307/1940352

28. Ferreira LV, Almeida SS, Amaral DD, Parolin P. Riqueza e Composição de Espécies da Floresta de Igapó e Várzea da Estação Científica Ferreira Pena: Subsídios para o plano de Manejo da Floresta Nacional de Caxianã. 2005, [cited 2016 Jun 7]. Available from: http://www.anchietano.unisinos.br/publicacoes/botanica/botanica56.htm#05

29. Lombard AT, Hilton-Taylor C, Rebelo AG, Pressey RL, Cowling RM. Reserve selection in the Succulent Karoo, South Africa: coping with high compositional turnover. Plant Ecology. 1999, 142: (1/2) 35–55. http://dx.doi.org/10.1023/a:1009866126729

30. Robinson WD, Brawn JD, Robinson SK. Forest Bird Community Structure In Central Panamá: Influence Of Spatial Scale And Biogeography. Ecological Monographs. 2000, 70, 209–235.

31. Condit R, Pitman N, Leigh Jr EG, Chave J, Terborgh J, Foster RB, Nuñez VP, Aguilar S, Valencia R, Villa G, Muller-Landau HC, Losos E, Hubbell SP. Beta-diversity in tropical forest trees. Science. 2002, 295, 666–669.

32. Hubbell SP. The united neutral theory of biodiversity and biogeography. Princeton University Press, Princeton. 2001, "The Unified Neutral Theory of Biodiversity and Biogeography (MPB-32)"

33. Hubbell SP. Neutral theory and the evolution of ecological equivalence. Ecology. 2006, 87: (6) 1387-1398. http://dx.doi.org/10.1890/0012-9658(2006)87[1387:ntateo]2.0.co;2