Universidade
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ISABELLA DE ASSIS BARRETO

EFFECTS OF CHANGE IN VEGETATION QUALITY ON RICHNESS AND ABUNDANCE OF FOREST BIRDS GUILDS IN ATLANTIC RAINFOREST, SOUTHERN BRAZIL

Londrina
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RESUMO

Os insetívoros de sub-bosque são considerados sensíveis à perturbação antrópica, devido à vulnerabilidade das espécies a modificações da vegetação geradas, por exemplo, por corte seletivo de árvores e por fragmentação florestal. Alguns pesquisadores mostraram que esse grupo é um dos primeiros a desaparecer em florestas tropicais quando perturbadas. Como consequência da extinção local dessas espécies ocorre um efeito cascata na cadeia alimentar, gerando aumento na abundância de artrópodes na área. Neste estudo avaliamos a abundância e riqueza de espécies de aves para entender a sensibilidade de diferentes guildas de aves às mudanças na qualidade da vegetação, e analisamos se as insetívoras do sub-bosque são realmente mais afetadas do que outros grupos. O estudo foi realizado no Parque Nacional do Iguaçu, uma área com vegetação preservada, e na Reserva Biológica das Perobas, uma área que passou por corte seletivo de árvores e, assim, teve sua vegetação alterada. Dados sobre vegetação e aves foram obtidos em vinte pontos de amostragem em cada área de estudo. Os dados de vegetação representam a observação de dezoito variáveis em cada ponto, que foram analisadas individualmente, dez destas também foram combinadas para obter a Avaliação Ecológica Rápida (AER) e medir a qualidade da vegetação. Para avaliar o efeito da qualidade da vegetação, separamos as aves em cinco guildas: insetívoros de sub-bosque, insetívoros de sub-dossel, insetívoros não-especialistas, frugívoros e onívoros. Amostragem por pontos de escuta foi utilizada na primavera de três anos consecutivos, 2016-2018, nas duas Unidade de Conservação. Modelos Lineares Generalizados (GLM) para avaliar a interação entre a abundância, a riqueza de espécies de cada grupo e a AER, e GLM multivariados para as análises incluindo todas as variáveis individualmente. Baseado em artigos publicados anteriormente, esperamos que a guilda das aves insetívoras do sub-bosque seja a mais sensível à alteração da vegetação. Porém, nossos resultados sugerem que esse grupo, como também as onívoras, são negativamente associadas à qualidade da vegetação. Ou seja, encontramos que o distúrbio causado pelo corte seletivo diminuiu a qualidade da vegetação, mas favoreceu ambas as guildas. Assim, áreas com vegetação secundária favorece um aumento na riqueza e abundância de aves insetívoras de sub-bosque e onívoras. Especificamente, a presença de *Euterpe edulis* exerceu uma influência negativa na abundância e riqueza de espécies de insetívoros do sub-bosque, insetívoros não-especialistas, onívoros e na abundância de frugívoros. A presença de espécies exóticas não-gramíneas influenciou positivamente a guilda de insetívoros não-especialistas. A abundância de epífitas influenciou negativamente a abundância de onívoros e a abundância e riqueza de espécies frugívoras, mas a abundância de Orchidaceae influenciou positivamente a abundância de aves frugívoras. As análises desenvolvidas sugerem que as aves insetívoras do estrato inferior podem não ser sensíveis a alterações na qualidade da vegetação em certos contextos de corte seletivo de árvores. Assim, a importância desta guilda como indicador ambiental em áreas que sofreram corte seletivo deve ser avaliada cuidadosamente considerando principalmente o histórico e condições locais.

Palavras-chave: insetívoros de sub-bosque; onívoros; avaliação rápida; avifauna; corte seletivo.

BARRETO, Isabella de Assis. **Effects of change in vegetation quality on richness and abundance of forest birds guilds in Atlantic Rainforest, southern Brazil**. 2022. 49 p. Dissertation (Master’s degree in Biological Sciences) – Universidade Estadual de Londrina, Londrina, 2022.

ABSTRACT

Understory insectivores are known as sensitives to anthropogenic disturbance, due to the vulnerability of the species to changes in vegetation generated, for example, by selective logging and fragmentation. Some researchers have shown that this group is one of the first to disappear in tropical forests when disturbed. Because of the local extinction of these species, there is a trophic cascade in the food chain, generating an increase in the abundance of arthropods in the area. In this study, we evaluated the abundance and richness of bird to understand the sensitivity of different bird guilds to changes in vegetation quality, and we analyzed whether understory insectivores are actually more affected than other groups. The study was carried out in the Iguaçu National Park, an area with preserved vegetation, and in the Perobas Biological Reserve, an area that underwent selective logging and, thus, had its vegetation altered. Vegetation and bird data were obtained at twenty sampling points in each study area. The vegetation data represents the observation of eighteen variables at each point, which were analyzed individually, ten of these were also combined to obtain the Rapid Ecological Assessment (REA) and measure the quality of the vegetation. To evaluate the effect of vegetation quality, we distributed the birds into five guilds: understory insectivores, sub-canopy insectivores, primarily insectivores, frugivores and omnivores. Sampling by point counts was used in the spring of three consecutive years, 2016-2018, in the two protected areas. Generalized Linear Models (GLM) to assess the interaction between abundance, species richness of each group and REA, and multivariate GLM for the analyzes including all variables individually. Based on previously published articles, we expect the understory insectivorous guild to be the most sensitive to vegetation alteration. However, our results suggest that this group, as well as omnivores, are negatively associated with vegetation quality. That is, we found that the disturbance caused by selective logging reduced the quality of the vegetation but favored both guilds. Thus, areas with secondary vegetation favor an increase in the richness and abundance of understory and omnivorous insectivorous birds. Specifically, the presence of *Euterpe edulis* exercised a negative influence on the abundance and species richness of understory insectivores, non-specialist insectivores, omnivores, and the abundance of frugivores. The presence of non-grassy exotic species positively influenced the non-specialist insectivore guild. The abundance of epiphytes negatively influenced the abundance of omnivores and the abundance and richness of frugivorous species, but the abundance of Orchidaceae positively influenced the abundance of frugivorous birds. The analyzes developed suggest that understory insectivorous birds may not be sensitive to changes in vegetation quality in certain contexts of selective logging. Thus, the importance of this guild as an environmental indicator in areas that have undergone selective cutting must be carefully evaluated considering mainly the history and local conditions.

Key-words: understory insectivorous; omnivores; rapid assessment; avifauna; selective logging.

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LISTA DE ABREVIATURAS E SIGLAS

GLM	Generalized Linear Models
INP	Iguaçu National Park
IPA	Index of Point Abundance
PBR	Perobas Biological Reserve
REA	Universidade Estadual de Londrina
UEL	Universidade Estadual de Londrina

SUMÁRIO

APRESENTAÇÃO

A dissertação será apresentada inicialmente por uma Introdução Geral, onde o tema será abordado de maneira mais ampla, e depois, no formato de artigo científico, que será publicado na revista “Ornithology Research”. As normas de formatação da revista selecionada podem ser acessadas em: <https://www.springer.com/journal/43388/submission-guidelines>

INTRODUÇÃO GERAL

A degradação e destruição de habitats são consideradas as principais causas de extinção de espécies (Barnosky et al. 2011). Dentre as atividades antrópicas que geram degradação de florestas tropicais, o corte seletivo de madeira é responsável pelo aparecimento de grandes clareiras de origem não natural, induzindo a formação de vegetação secundária (Rondon Neto et al., 2000) e a alteração de aspectos abióticos como luminosidade, umidade e temperatura (Almeida 1989). Sob tais circunstâncias, diversas espécies vegetais pioneiras e intolerantes a sombra se estabelecem no local (Tabarelli and Mantovani 1997), gerando também nova composição biótica.

Em estudos que avaliam os efeitos dessa atividade antrópica em comunidade de aves são obtidos resultados que mostram que a biodiversidade local pode aumentar (Holbech 2005; Azevedo-Ramos et al. 2006), diminuir (Thiollay 1992; 1997; Edwards et al. 2013) ou permanecer inalterada (Yap et al. 2007). Essa incerteza é gerada possivelmente porque muitas aves em florestas tropicais têm dietas mistas, e se alimentam de diferentes itens em diversos níveis tróficos, tornando as guildas imprecisas e difíceis de definir (Edwards et al. 2013).

As aves insetívoras do sub-bosque são conhecidas e bastante estudadas devido a sua alta sensibilidade às mudanças nos ecossistemas das florestas tropicais (Sigel et al. 2010). A alta sensibilidade dessas espécies à fragmentação ou outras alterações no ambiente (Peh et al. 2005; Barlow et al. 2006; Yong et al. 2011) se dá pela junção de ameaças antrópicas às florestas tropicais, com a alta vulnerabilidade de espécies altamente especializadas (Şekercioğlu 2011), o que coloca esse grupo em uma situação de alto risco de extinção (Tobias et al. 2013). Os insetívoros de sub-bosque são bastante afetados por desmatamento, fragmentação e distúrbios no meio ambiente (Bregman et al. 2014). Powell et al. (2015) destacaram que as aves insetívoras do sub-bosque podem ser utilizadas como importantes indicadores biológicos da degradação da floresta tropical, devido à sua alta sensibilidade à modificação da vegetação. Os bioindicadores são componentes bióticos de um ecossistema utilizados como medidores da qualidade do ambiente, que quantificam a magnitude de algum estresse (Andréa 2010), sua presença, quantidade e distribuição refletem a magnitude do impacto no ambiente em que ele está (Callisto e Gonçalves 2002). Os indicadores devem apresentar custo de amostragem viável, fácil e confiável identificação, funcionalidade e responder as alterações (Prestes e Vincenci, 2019).

Esse grupo pode ser utilizado como ferramenta de estudo de mudanças ambientais geradas por ações antrópicas, por responder negativamente a esse tipo de distúrbio, perdendo abundância e diversidade (Bregman et al. 2014; Arcilla et al. 2015; Boyel e Siegel 2015; Stratford e Stouffer 2015; Powell et al. 2015), inclusive em estudos que investigam os danos gerados pelo corte seletivo em Florestas Tropicais (Thiollay 1997; Mason e Thiollay 2001).

Apesar de considerados modelos para avaliar o impacto de atividades antrópicas, as aves tropicais ainda não têm suas dietas descritas com detalhes, portanto não é possível mensurar o impacto da perda desses animais no ambiente florestal. Mesmo assim, sabe-se que a extinção dessas espécies pode gerar um efeito cascata na cadeia trófica, afetando vários níveis (Stratford e Şekercioğlu 2015). Pensando nisso, a extinção local de espécies insetívoras pode acarretar um aumento na abundância de insetos, causando prejuízos econômicos no setor primário da economia do país.

Mesmo que muitos estudos evidenciem esse grupo como indicadores biológicos, as respostas desses grupos às alterações ambientais podem variar. Em uma área da Venezuela, as aves declinaram por um ano após o corte seletivo e retornaram a níveis semelhantes após cinco anos (Mason, 1996). No entanto, em uma diferente área, na Guiana Francesa, não houve nenhuma recuperação na diversidade dessas aves, 10 anos após o corte (Thiollay,1992). Outros apontam que mesmo que a floresta secundária consiga se regenerar, pode haver uma perda inicial de espécies por causa da extração de madeira e recuperações tardias da avifauna (Powell et al. 2013).

Apesar de estudos indicarem as aves insetívoras do sub-bosque como muito sensíveis às mudanças na vegetação, poucos estudos se concentraram em comparar este grupo com outros. Por esse motivo, é importante avaliar outros grupos de aves, não apenas insetívoros de sub-bosque, como onívoros e frugívoros, por exemplo, pois estes também podem apresentar respostas negativas às alterações na vegetação e, assim, ajudar a entender o impacto de ações antrópicas, como o corte seletivo (Hamer et al., 2015).

Portanto, o presente estudo teve como objetivo observar os efeitos da qualidade da vegetação sobre diferentes guildas de aves, através de dados da vegetação e da avifauna de duas unidades de conservação, a primeira onde não houve nenhum tipo de degradação recente, com vegetação mais antiga, e a segunda que sofreu corte seletivo de madeira em trechos próximos aos locais de coleta. Além disso, o estudo também buscou avaliar se as aves insetívoras do sub-bosque são realmente mais afetadas por modificações na vegetação do que outros grupos como onívoros, frugívoros e insetívoros não especialistas, para avaliar sua importância como bom indicador ecológico.

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EFFECTS OF CHANGE IN VEGETATION QUALITY ON RICHNESS AND ABUNDANCE OF FOREST BIRDS GUILDS IN ATLANTIC RAINFOREST, SOUTHERN BRAZIL

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Abstract: Understory insectivores are sensitive to disturbance and to vegetation changes generated, for example, by selective logging and fragmentation. Some researchers have shown that this group is one of the first to disappear in disturbed tropical forests. We evaluated the abundance and richness of birds to understand the sensitivity of different guilds to changes in vegetation quality, we analyzed whether understory insectivores are more affected than other groups. The study was carried out in a preserved area, and in an area that underwent selective logging. Vegetation and bird data were obtained at twenty sampling points in each study area. Rapid Ecological Assessment (REA) was used to measure the vegetation quality. Birds were sampling by point counts during the spring of three years, 2016-2018, and distributed into five guilds: understory insectivores, sub-canopy insectivores, primarily insectivores, frugivores and omnivores. We used Generalized Linear Models to assess the interaction between the guilds' abundance, species richness and REA, and for the analyzes including all variables individually. Our results suggest that understory insectivorous and omnivores are negatively associated with vegetation quality. That is, they are favored by the disturbance caused by selective logging that reduced the vegetation quality. Thus, areas with secondary vegetation favor an increase in the richness and abundance of these groups. The analyzes developed suggest that understory insectivorous may not be sensitive to changes in vegetation in certain contexts of selective logging. Thus, the history and local conditions must be evaluated for the use of this guild as a biological indicator.

Key-words: Understory insectivorous; Omnivores; Rapid assessment; Avifauna; Selective logging.

INTRODUCTION

Fragmentation, deforestation, agricultural expansion, selective logging for timber, unbridled urbanization, together with the construction of roads, considerably alter abiotic conditions, becoming major threats to tropical forests (Peres et al. 2006). The anthropic threats to tropical forests, combined with the high vulnerability of highly specialized species (Şekercioğlu 2011) and the high sensitivity to fragmentation (Peh et al. 2005; Barlow et al. 2006; Yong et al. 2011) make understory insectivores birds one of the bird groups most at risk of extinction (Tobias et al. 2013). Understory insectivorous birds exhibits remarkable sensitivity to changes in the tropical forest ecosystems (Sigel et al. 2010), being intensely affected by deforestation, fragmentation, and disturbances in the environment (Bregman et al., 2014). Some studies all over the Tropics has pointed out for this scenario, what motivate the publication of a special issue on this subject in the journal Biological Conservation, organized by Powell and collaborators (2015), presenting studies on the sensitivity of understory insectivorous birds to vegetation. The understory insectivorous birds can be considered important indicators of tropical rainforest degradation, due to their sensitivity to modification of vegetation and vulnerability to forest loss (Powell et al., 2015).

In the Neotropics, the understory insectivores are mainly composed of Thamnophilidae, Furnariidae, Formicariidae, and Tyrannidae species (Powell et al. 2015). Although living in the forest understory, those birds exhibit a variety of foraging techniques to capture prey (Krabbe and Schulenberg 2003a, b; Remsen 2003; Whitney 2003; Zimmer and Isler 2003; Snow 2004a, b; Fitzpatrick et al. 2004). This group can include climbing species, species associated with ants, ground-foraging insectivores, and species that belong to mixed flocks, for example. The variety of niches highlights the radiation of specialization of these groups. Even with such distinct characteristics, these groups respond negatively to changes in vegetation, reducing in species number or declining species abundance (Powell et al. 2015), which makes them an important indicator for the study of environmental changes caused by human action.

Several researchers have shown that this group is one of the first to disappear in disturbed tropical forests (Stratford and Stouffer 1999; Canaday and Rivadeneyra 2001; Peh et al. 2005; Pavlacky et al. 2015). In the Amazon rainforest selective logging caused a loss of species in the understory group of insectivores (Thiollay 1997). In Tanzania, this group is also one of the most sensitive to logging (Mason and Thiollay 2001). Other authors draw attention to the high sensitivity of these species to fragmentation (Newmark, 1991; Stouffer and Bierregaard 1995; Şekercioğlu et al. 2002; Arcilla et al. 2015; Buechley et al. 2015).

The loss of these birds on the forest ecosystem is not very known yet, but the extinction of these species can certainly generate a cascade effect, affecting many trophic levels (Stratford and Şekercioğlu 2015). Therefore, it is important to understand this group's responses to the changes in vegetation.

However, it is importance to assess other groups of birds, not only understory insectivores, such as omnivores, and frugivores, for example, because these can also show some degree of response to changes in vegetation and thus help to understand the impact of anthropic actions, such as selective logging (Hamer et al., 2015). In fact, although several studies indicate understory insectivorous birds as very sensitive to vegetation changes, few studies focused on comparing this group with others.

In this study we look to understand the sensitivity of different bird guilds to changes in vegetation. Specifically, we evaluate if the understory insectivorous birds are more affected by modifications in vegetation quality due actions of selective logging for timber than other groups, what would reinforce its importance as good ecological indicator. We expect that the quality of the vegetation will influence some bird guilds, and that there will be a decline in the richness and abundance of birds with the decrease in the quality of the vegetation. We also expect that understory insectivores will be most affected by this change.

METHODS

Study area

We censored birds in two protected areas in the state of Paraná: the Iguaçu National Park and the Perobas Biological Reserve. These areas were selected because they comprise large areas, suffering little disturbance by fragmentation, but the last area underwent selective logging, which altered the vegetation. The Iguaçu National Park (INP), located in Foz do Iguaçu, western Paraná, Brazil, was founded in 1939 and corresponds to the largest continuous area of Atlantic rainforest in the interior of Brazil, with 185,262.5 hectares. It comprises mainly the seasonal semideciduous forest, with a mild and very humid mesothermal climate, with an annual average temperature between 18ºC and 20ºC, and an annual average rainfall of around 1650 mm. In total, 390 species of birds have already been sampled at the INP (ICMBio, 2018). The location where the study was carried out is at the extreme west of the INP, at altitudes between 200-300 meters a.s.l. (Fig. 1).

The Perobas Biological Reserve (PBR), located between Cianorte and Tuneiras do Oeste counties, Paraná State, Brazil, was created in 2006 and has an area of 8,716 hectares, being the largest forest remnant in the north central region and northwestern of Paraná (Fig. 1). This area is classified as a forest in the middle stage of succession, due to the intense exploitation of wood (Castella and Britez, 2004). However, this exploitation of selective logging for timber was focused mainly at the 100-200m margins of a small trail which cut the Reserve. So, there are areas of secondary forest along this small trail, created due damage of vegetation during the actions of the large trees' extraction, mainly *Aspidosperma polyneuron*. Due to this localized extraction, there are still portions of more conserved vegetation inside this area. PBR is also composed mainly by the seasonal semideciduous forest, presents an average annual temperature between 21 and 22ºC, and an average annual rainfall close to 1600 mm, without a well-defined dry season (ICMBio 2012). In total, 160 bird species have been recorded in PBR, but the estimated total number is 300 species (Anjos and Menq 2014).

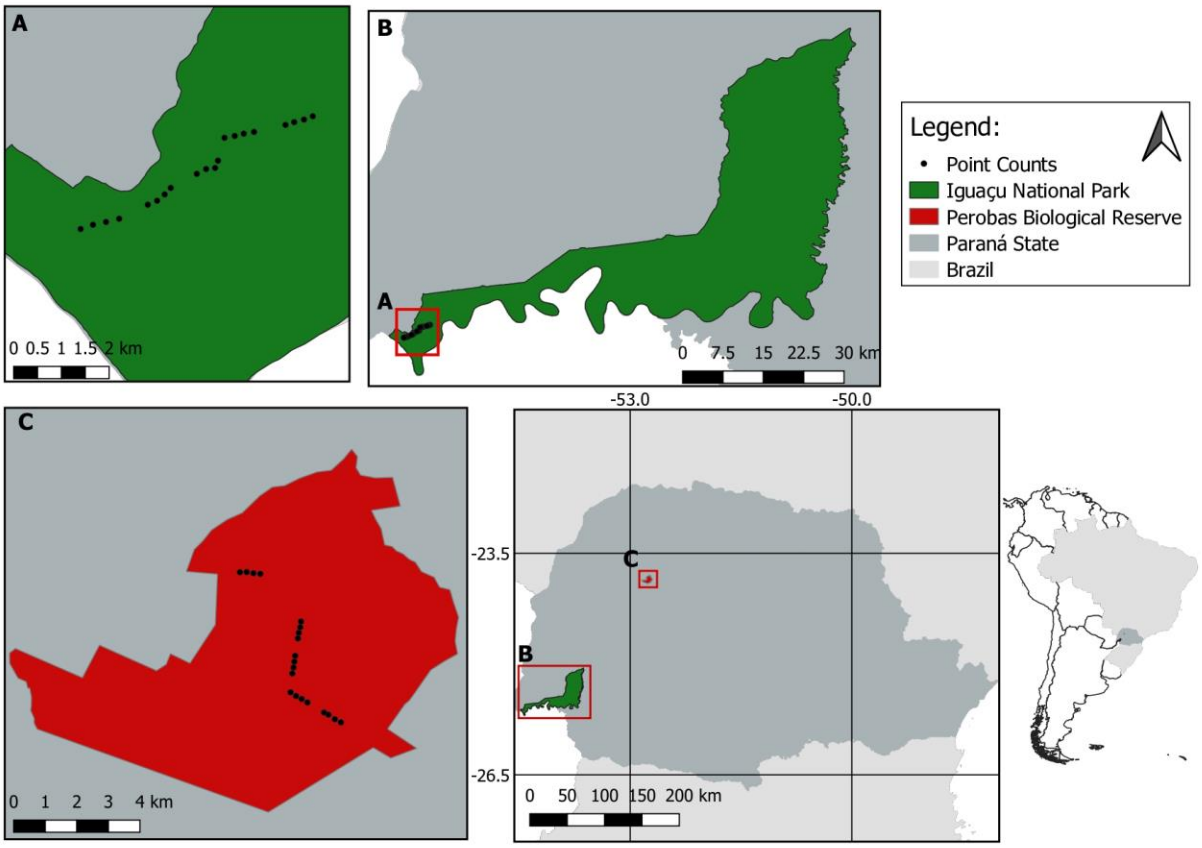

Fig. 1 Point counts sampled in the Iguaçu National Park and in the Perobas Biological Reserve, Paraná state, southern Brazil

Data sampling

The bird data used in the study were collected by L. dos Anjos in 2016, 2017, and 2018, during the birds’ breeding season of each year (spring season, from September to December), at 30 points located on the Poço Preto trail in the Iguaçu National Park (Fig. 1), where conserved vegetation is found, and at 30 points on the trail that passes through the central region of the Perobas Biological Reserve (Fig. 1), where there was selective logging and now has modified vegetation. The sampling method used was the point counts (Blondel et al. 1970; Bibby et al. 2000) where the observer remained for 15 minutes making visual and auditory records at each point. The points were 200m apart, to avoid correlation, and to move between them there was a 15-minutes interval between the 15 minutes of samplings. Sampling always started with the beginning of the birds' vocal activity in the day, in the rising sun. Six points were sampled per day, always following the same sequence, thus requiring five days in the field to complete the sampling at the 30 determined points. Details of this field procedure used in both areas appear in Oliveira and Anjos (2022).

The recorded species were separated into selected guilds. To allocate the registered species to their corresponding guilds, we use the diet categories and nomenclatures suggested by Lopes et al. (2016) and Wilman's et al (2014) database, which provides the percentage of food items consumed and the forest stratum used by each bird to capture food. The species was considered (1) specialist when its diet was composed of 80% of a food category, (2) primarily when this percentage is between 60% and 80%, and finally, considered (3) omnivorous if these percentages are less than 60%. Specialist insectivores were also separated according to the forest stratum most used, resulting in understory and soil insectivores, canopy insectivores, and other insectivores.

According to this procedure we could separate birds in nine categories (see Table 1): understory insectivores specialists; subcanopy insectivores specialists; canopy insectivores specialists; primarily insectivores; frugivore specialists; primarily frugivores; omnivores; nectarivores; carnivores. Three species needed to be relocated, *Picummus temminckii* from understory insectivore to subcanopy insectivore, *Capsiempis flaveola*, and *Psilorhamphus guttatus* from subcanopy insectivores to understory insectivores, to better match the forest stratum used by these species to capture prey, based on what was observed in the field. The Stotz et al. (1996) database was used to indicate birds that are found in edge habitats for a qualitative analysis (Appendix 1).

Table 1 – Proposed bird classification, based on Wilman et al. (2014) foraging database.

Classification	Feeding Habit	Vertical Distribution
Understory insectivores specialists	≥ 80% invertebrates	≥ 80% ground+understory
Subcanopy insectivores specialists	≥ 80% invertebrates	remaining insectivores
Canopy insectivores specialists	≥ 80% invertebrates	≥ 80% canopy
Primarily insectivores	≥ 60%<80% invertebrates	
Frugivore specialists	≥ 80% fruits	
Primarily frugivores	≥ 60%<80% fruits	
Omnivores	<60% of all itens	
Nectarivores	≥60% nectar	
Carnivores	≥60% vertebrates	

The vegetation data, composed by 18 variables, were collected by Larissa Calsavara and Edson Francisco in 2017 within a radius of 20 meters around each point used in avifauna data collection. Of the 18 vegetation variables, 8 were individually evaluated to investigate their influence on the distribution patterns of each group, namely: number of large trees, number of large to medium trees, number of medium trees, and number of small trees, canopy density, bamboo density, medium stratum density, understory density. The other ten variables were evaluated both, separately and combined to obtain a Rapid Ecological Assessment index (REA; Sayre et al. 2000; Medeiros and Torezan 2013).

REA is a measure of vegetation quality, Medeiros and Torezan (2013) adapted this methodology to use in the seasonal semideciduous forest, in northern Paraná, therefore, the same vegetation variables were evaluated in this study: number of standing dead trees, presence and coverage of exotic grasses, presence of other exotic species, the abundance of vines, types of eco-units present (glades with many vines, glades with few vines, low canopy up to 10 m height, open canopy with up to 60% light, and closed canopy with up to 10% light), the abundance of vascular epiphytes (except Orchidaceae), the abundance of fig trees (*Ficus* spp, Moraceae), abundance of Orchidaceae, the abundance of palm (*Euterpe edulis*, Arecaceae), and abundance of Peroba Rosa (*Aspidosperma polyneuron*, Apocynaceae). Each variable receives a value from 1 to 5, which results in a Rapid Ecological Assessment that can range from 10 to 50, where values ≤20 indicate very low integrity, ≥20 and ≤30 low integrity, ≥30 and ≤40 medium integrity, ≥40 and ≤45 high integrity and ≥45 excellent integrity (Medeiros and Torezan 2013). This index allows assessing which guilds are more sensitive to changes in the integrity of the environment.

Data analyses

Since there is a considerable reduction in the vocal activity of the birds with the advance of the morning, reducing the number of contacts in the samplings (Anjos 2007; Araújo et al. 2021), for the analyses carried out in the present study only the first four points of each morning were used. This procedure allowed to avoid the difference in abundance between the points sampled during the same day, totalizing 20 points analyzed in each area (Fig. 1).

All the analyses were performed in software R (R Core Team 2021). The Index of Point Abundance (IPA) was estimated by dividing the total contact number of each group by the total number of years of sampling (3) in each point, to obtain the punctual abundance index (Vielliard et al. 2010). The Rapid Ecological Assessment (REA) index for each point was obtained by the mean of the values of the vegetation variables recorded by the two researchers.

Using Linear Models (Chambers 1992), the correlation between the IPA of each bird group and the REA was evaluated to understand the influence of vegetation quality on the bird groups. The variables that did not pass the normality test were submitted to Tukey's transformation. The interaction between the species richness of each group and the REA was made using GLM from the Poisson family.

Multivariate GLMs with Gaussian distribution were used to model the relationship between the abundance of each guild and the vegetation variables and to understand which vegetation variables have the greatest influence on the abundance of each guild. Only the canopy density and lower stratum density variables presented normal distribution. The variables that did not pass the normality test were transformed by square root. Poisson multivariate GLMs was used to find the best model that explains the relationship between the guild species richness and vegetation variables.

The correlation between the variables was evaluated with the aid of the packages "vegan", "ggplot" and "ggcorrplot". Variables with the variance inflation factor (VIF) value greater than 3 were excluded from the analysis to avoid redundancy (Zuur et al. 2009). Adjustment of the models was verified by visual exploration of the residues in search of compliance with the assumptions of normality and homoscedasticity. In particular, it was verified the occurrence of overdispersion in Poisson models (Legendre and Legendre 2012; Zuur et al. 2009).

RESULTS

A total of 133 bird species were sampled and classified according to their diet and foraging substrate. The groups of specialist canopy insectivores, carnivores, granivorous and nectarivores had an insufficient sample size for statistical analyses and were removed. Specialist frugivores and primarily frugivores were united into a single group called Frugivores. Therefore, only five groups, totalizing 115 species, presented a sufficient sample size for the tests: specialist understory insectivores (24 species), specialist sub-canopy insectivores (34 species), primarily insectivores (23 species), frugivores (17 species), and omnivores (17 species). The remaining 18 not evaluated species are showed in Appendix 1.

In the INP, where there is more preserved vegetation, the points presented a Rapid Ecological Assessment value in a range of 30 to 37.33, and an average of 34.03, being classified as a site with medium integrity. In the PBR, where there was selective logging, the points presented values from 22.5 to 31.17 and an average of 26.69, therefore it was classified as a site with low integrity according to classification of Medeiros and Torezan (2013).

To apply the linear regression tests, the IPA values of understory insectivores and omnivores underwent Tukey's transformation, to produce a more normally distributed vector of values. The linear models of Rapid Ecological Assessment (REA) and Index of Point Abundance (IPA) revealed a negative relationship between REA values and the abundance of understory insectivores and omnivores. The other groups of birds do not appear to be influenced by the vegetation quality, represented by the REA values (Fig.2). The same situation is repeated in GLM Poisson between the Rapid Ecological Assessment (REA) and the species number of each group. Only the richness of understory insectivores and omnivores are negatively influenced by the REA value, while subcanopy insectivores, primarily insectivores and frugivores are not influenced by REA (Fig.3).

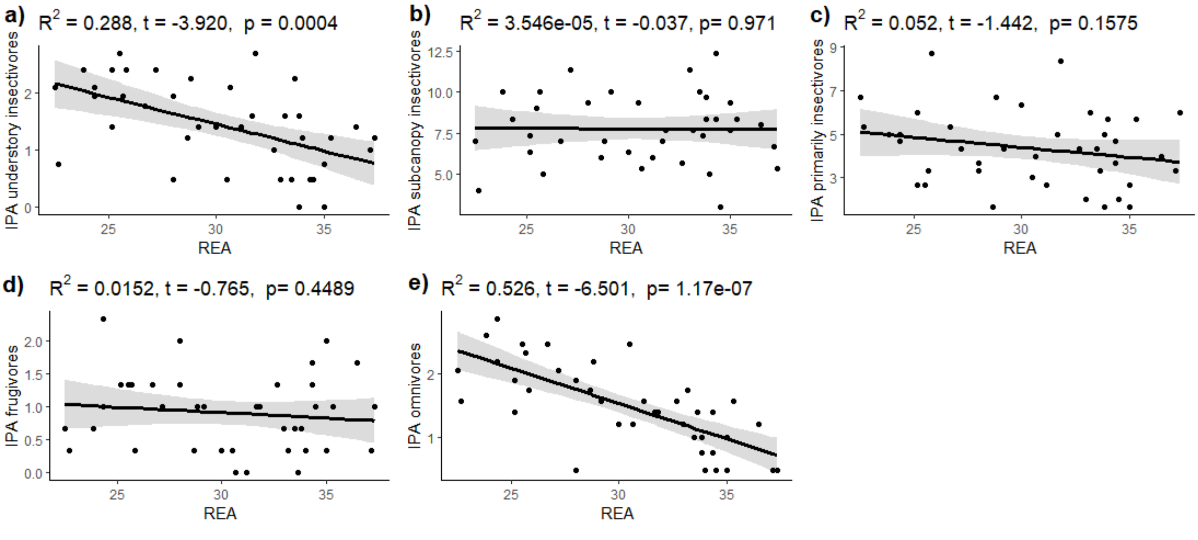

Fig.2 Linear Models between Rapid Ecological Assessment (REA) and Index of Point Abundance (IPA) of five guilds of birds: a) understory insectivores, b) subcanopy insectivores, c) primarily insectivores, d) frugivores, e) omnivores. The black line represents the model, and the shadow represents the 95% confidence interval of each model

In multivariate GLM models only the canopy density and the understory density variables presented normal data distribution, according to the

Shapiro-Wilk test (p>0.05). The variables number of medium to large trees and number of medium trees presented normal distribution after square root transformation. The other variables did not fit (p<0.05). The abundance of vines, types of eco-units, bamboo density, canopy density and medium stratum density were excluded from the analysis for presenting VIF greater than three and a high degree of correlation (Fig. 4).

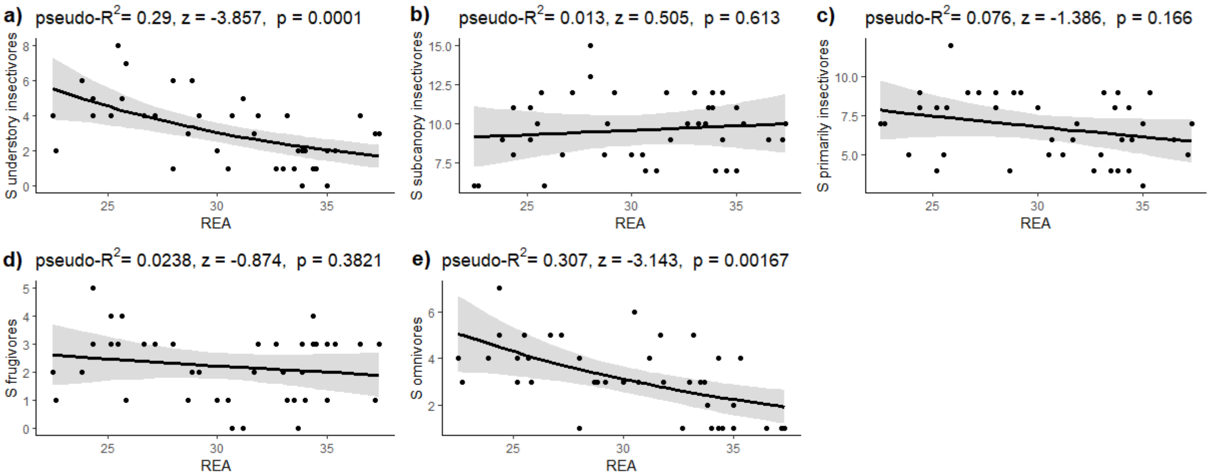

Fig.3 GLM Poisson between Rapid Ecological Assessment (REA) and richness of five guilds of birds: a) understory insectivores, b) subcanopy insectivores, c) primarily insectivores, d) frugivores, e) omnivores. The black lines represent the models, and the shadow represents the 95% confidence interval of each model

The generated statistical models show that the abundance and richness of understory insectivores are negatively influenced by the abundance of *Euterpe edulis* (t= -5.23, p<0.05; z= -4.25, p<0.05). The abundance of subcanopy insectivores is positively influenced by the presence and coverage of exotic grasses (t= 2.018, p=0.05) while the species richness of this group is not related to any of the vegetation variables (p>0.5). The abundance and the richness of insectivores primarily are positively associated with the presence of other exotic species (t= 2.843, p<0.05; z=2.129, p<0.05) and negatively with the abundance of *Euterpe edulis* (t= -3.084, p<0.05; z= -2.786, p<0.05). The abundance of the frugivore group is negatively affected by the abundance of *Euterpe edulis* (t= -2.149, p<0.05) and epiphytes (t= -2.329, p<0.05), and positively by the abundance of Orchidaceae (t= 3.371, p<0.05), but the species richness of this group is not influenced by any of the variables (p>0.05). The abundance of the omnivore group is also negatively affected by the abundance of *Euterpe edulis* (t= -4.406, p<0.05) and epiphytes (t= -3.64, p<0.05), and their species richness is only influenced by the abundance of *Euterpe edulis* (z= -2.894, p<0.05) (Table 2 and 3). The models fit the assumptions of normality and homoscedasticity of residuals, and in models with Poisson distribution there was no overdispersion.

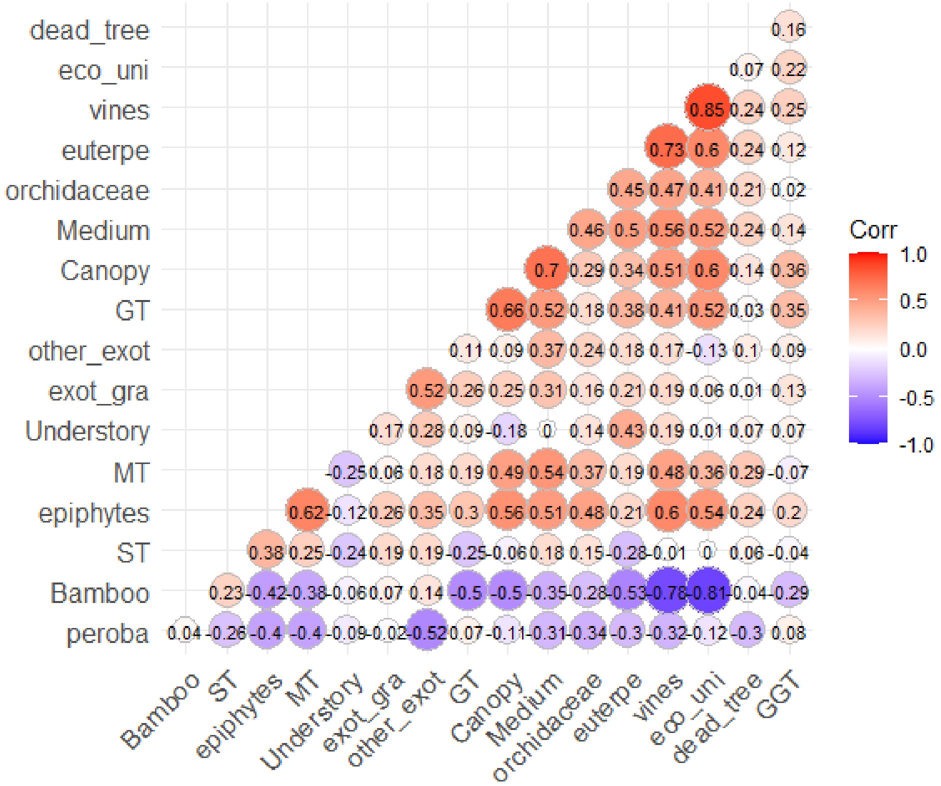

Fig. 4 Correlation Matrix of vegetation variables: Number of standing dead trees, types of eco-units, abundance of vines, abundance of palm (*Euterpe edulis*, Arecaceae), abundance of Orchidaceae, medium stratum density, canopy density, number of large to medium trees (GT), presence of other exotic species, presence and coverage of exotic grasses, understory density, number of medium trees (MT), abundance of vascular epiphytes (except

Orchidaceae), number of small trees (ST), bamboo density, abundance of Peroba Rosa (*Aspidosperma polyneuron*, Apocynaceae)

Table 2 – General Linear Models (GLM) about the variation in the abundance of groups of birds in relation to the vegetation variables.

Models	*Coefficients*	*Estimate*	*t*	*Pr(>|t|)*
IPA understory insec ~ Euterpe	Intercept	2.19399 ± 0.17411	12.6	**< 0.0001**
	Euterpe	-0.28838 ± 0.05514	-5.23	**< 0.0001**
IPA subcanopy insec ~ exotic grass	Intercept	-0.4314 ± 4.0793	-0.106	0.9163
	Exotic grass	1.6762 ± 0.8307	2.018	0.052
IPA primarily insec ~ other exotic + Euterpe	Intercept	-5.4482 ± 3.8234	-1.425	0.16255
	Other exotic	2.2520 ± 0.7922	2.843	**< 0.01**
	Euterpe	-0.4391 ± 0.1424	-3.084	**< 0.01**
IPA frugivores ~epiphytes + Orchidaceae + Euterpe	Intercept	0.88918 ± 0.22120	4.02	**< 0.001**
	Epiphytes	-0.19797 ± 0.085	-2.329	**0.025**
	Orchidaceae	0.55206 ± 0.16375	3.371	**< 0.01**
	Euterpe	-0.11509 ± 0.05357	-2.149	**0.038**
IPA omnivores ~ epiphytes + Euterpe	Intercept	4.04173 ± 0.35411	11.414	**< 0.0001**
	Epiphytes	-0.48367 ± 0.13289	-3.64	**< 0.001**
	Euterpe	-0.3751 ± 0.08514	-4.406	**< 0.0001**

Table 3 - General Linear Models (GLM) Poisson about the variation in the species richness of groups of birds in relation to the vegetation variables.

Models	*Coefficients*	*Estimate*	*z*	*Pr(>|z|)*
Richness understory insec ~ *Euterpe*	Intercept	1.75341 ± 0.15225	11.52	**< 0.0001**
	Euterpe	-0.26046 ± 0.06129	-4.25	**< 0.0001**
Richness subcanopy insec ~ epiphytes	Intercept	2.12870 ± 0.11460	18.575	**< 0.0001**
	Epiphytes	0.06087 ± 0.04617	1.318	0.187
Richness primarily insec ~ other exotic + *Euterpe*	Intercept	-0.29969 ± 1.16076	-0.258	0.796
	Other exotic	0.50607 ± 0.23768	2.129	**0.033**
	Euterpe	-0.10406 ± 0.03736	-2.786	**<0.01**
Richness frugivores ~epiphytes	Intercept	1.0144 ± 0.2344	4.327	**< 0.0001**
	Epiphytes	-0.1026 ± 0.1027	-0.999	0.318
Richness omnivores ~ *Euterpe*	Intercept	1.55139 ± 0.15545	9.980	**< 0.0001**
	Euterpe	-0.16519 ± 0.05709	-2.894	**<0.01**

DISCUSSION

Our data suggest that understory insectivorous birds are negatively associated with vegetation quality, a result contrary to what we expected, since this group is known to be sensitive to anthropogenic disturbances (Boyel and Siegel 2015; Bregman et al. 2014; Arcilla et al. 2015; Stratford and Stouffer 2015), including the disturbance generated from selective cutting in other Tropical Forests (Thiollay 1997; Mason and Thiollay 2001). The other bird groups were not associated to vegetation quality, excepted omnivores. In fact, omnivores had richness and abundance negatively associated with vegetation quality, as understory insectivores.

It means that, contrary to our expectations, the set of vegetation variables that compose the Rapid Ecological Assessment (REA), when they are analyzed together, exerts a negative influence on the abundance and species richness in understory insectivores, and also omnivores, in the studied sites. The disturbance caused by selective logging formed areas with secondary vegetation which favored an increase in the richness and abundance of omnivorous and understory insectivorous birds. Because the PBR harbor both, areas of secondary forest along 100-200 along the trail and well preserved vegetation beyond that, we suggest four explanations for our unexpected result: (1) nearby populations of understory birds of primary forest of PBR could maintain those of the secondary forests close to the trail; (2) damage of vegetation was not so strong at the point to affect substantially the vegetation, which allowed the understory insectivores birds to survive in secondary forest; (3) some species of understory birds, could be favored in disturbed vegetation, including those more associated to the forest edge; (4) vegetation recovered after few years from the selective logging. There can also be some effect on the results because they are two different areas

The first and the second explanations are difficult to test, but some information could be added to the third and fourth ones. On the third explanation, there is evidence from other studies that bird species of forest edge and forest interior could coexist leading to an increase in local richness (Schemske and Brokaw 1981; Felton *et al.* 2008). Of the 115 species evaluated, 30 are from edge habitats, according to Stotz et al. (1996), and 14 of these were sampled only in the PBR (Appendix 1). It is possible that the increase on the abundance and richness of omnivores and understory insectivores may be associated with greater availability of perches, prey, or a general improvement in prey visibility, factors resulting from change in vegetation (Cody 1980). On the fourth explanation, the selective logging in the PBR took place only in the stretches close to the trail and it was banned in 2006, ten years before samplings evaluated of this study were considered. In Venezuela, the bird communities declined for one year after cutting and returned to similar levels after five years of non-harvesting, in Venezuela (Mason 1996). Therefore, 10 years may have been enough time for the avifauna to recover or the production of areas of secondary vegetation contributed to the increase in species richness and abundance. However, in French Guiana even 10 years after logging, no recovery was observed (Thiollay 1992). Other papers also point to the loss of species because of the logging on the Amazonian rainforest (Thiollay 1992) and late recoveries, if the secondary forest manages to regenerate (Powell et al. 2013).

The difference between the response to logging in the Amazonian and Atlantic Forest can be explained by the aggressiveness of the techniques of select logging in the Amazonian rainforest, mostly due to the opening of roads to assess the areas (Johns 1988; Aleixo ,1999). The sensitivity to logging can also reflect the historical differences in the evolution of the avifauna, since Atlantic Forest species tend to use secondary forest areas more when compared to Amazon Forest species (Stotz et al. 1996, Aleixo ,1999), where insectivorous birds occupy microhabitats not found in secondary forests (Stratford and Stouffer, 2013). Some guilds can also adapt and increase in abundance after selective logging, but they tend to return to their common abundance levels and can also fall below their pre-logging abundance (Burivalova et al. 2015).

It is important to also highlight that the Rapid Ecological Assessment, like many other rapid assessments, is based on data from only one taxonomic group (Diffendorfera et al. 2007), in this case, it was used to assess vegetation quality and works very well for that taxonomic group (Medeiros and Torezan 2013). This method proved to be effective in comparing the distribution of abundance and richness of bird species with the vegetation quality of each studied point. However, other characteristics of the environment and vegetation may be more associated with the distribution of birds than the variables analyzed in the REA method. Therefore, this may be a misleading method to compare the distribution of other taxonomic groups richness and abundance, requiring adaptations to fit the method. As an attempt to improve the method, the Integrated Biotic Integrity Index (IBIint) can combine plant and bird data to assess the ecological integrity of tropical forest fragments, by associating two rapid assessment methods: the Rapid Ecological Assessment for plants (Medeiros and Torezan 2013) and the Biotic Integrity Index for birds (Anjos et al. 2009; Medeiros et al., 2015). The IBIint proved to be a very good Rapid Assessment and was explained by all landscape variables in their study. Therefore, it is important to consider the limitation of each Indexes to interpret results correctly.

Different groups may also have differences in recovery time. Non-sensitive species generally have a wider distribution, indicating a greater ability to adapt to new habitat arrangements. Sensitive species tend to remain unstable and tend to respond later, even without further changes in the landscape (Uezu and Metzger 2016). Although in areas that underwent selective logging, the abundance and richness of species increased in the groups of understory insectivores and omnivores and did not change in other groups of insectivores and frugivores, the change in the environment can contribute to physiological changes in individuals, and not just in population or community size. Omnivores and frugivores in selective logging forests in Borneo suffered body size reduction (Messina et al. 2021), showing the importance of evaluating phenotypic and physiological metrics to assess the real influence of logging on birds (Cosset et al. 2019).

By isolating the variables, we realize that the variable that evaluates the presence of exotic non-grass species had a positive influence on primarily insectivores' guild. This may be associated with the formation of borders, which are occupied by forest edge species of plants and birds or may be associated with greater abundance and better visibility of prey (Cody 1980). Reinforcing this, we have that of the 23 species sampled in this group, 8 are from edge habitats (Appendix 1).

The variable that corresponds to the abundance of palm (*Euterpe edulis*) is the one that exerts a negative influence on the abundance and richness of birds. In addition, this variable also had a negative effect on the abundance and richness of primarily insectivores and the abundance of frugivores. Although the results showed that the abundance of *Euterpe edulis* has a negative influence on the abundance and richness of the bird groups, palms in general are considered keystones resources for frugivores as birds, bats, monkeys, and rodents, because this species produces great number of fruits during periods of food scarcity in tropical forests (Terborgh 1986 a, b; Peres 1994; Ratsirarson et al. 1996). Samplings were not carried out during the fruiting period of the *Euterpe edulis*, which may explain the low abundance of birds. This shows us that, despite the areas with palm seeming to be a negative factor for birds in our analyzes, it is known that this plant species is essential for the maintenance of the bird populations. These results also suggest a type of spatial seasonality in Tropical Forest, where palm areas could be a “desert” for birds for most of year but a key food source, at least for some bird species, in certain periods.

The abundance of epiphytes and abundance of vascular epiphytes (except Orchidaceae) had a negative influence on the abundance of omnivores and the abundance and species richness of frugivores, this may be related to the fact that epiphyte species richness is significantly affected by insolation, appearing in lower abundance in forest edges (Bianchi and Kersten 2014). In contrast, the abundance of Orchidaceae had a positive influence on the abundance of frugivores birds, while this variable and the abundance of other epiphytes were expected to have a similar influence on birds, since both can be considered good indicators of tropical forest conservation, and both are sensitive to microclimate changes (Oberbauer et al. 1996; Pierce et al. 2006).

In the present study the understory insectivorous birds, as well as omnivores, were favored by lower vegetation quality. Our results suggests that the use of understory insectivorous birds and other bird groups as ecological indicators of high quality of vegetation should be considered carefully in the case of areas of selective logging, particularly considering the local history and conditions.

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APPENDIX

Appendix 1 - List of species classified into guilds based on Wilman et al. (2014) foraging database, n INP and n PBR represent, respectively, the species abundance sampled in the Iguaçu National Park and the Perobas Biological Reserve. Marked in the "Edge" column are species that utilize edge habitats, according to the Stotz et al. (1996) database.

Guilds	Species	n INP	n PBR	Edge
Understory insectivores	*Automolus leucophthalmus*	19	4	
	Capsiempis flaveola	2	26	x
	Coccyzus euleri		5	
	Coccyzus melacoryphus	3	6	
	Conopophaga lineata	3	16	
	Corythopis delalandi	15	3	
	Dendrocolaptes platyrostris	25	4	
	Dromococcyx pavoninus	1	1	
	Drymophila malura		6	
	Eleoscytalopus indigoticus		5	
	Geothlypis aequinoctialis		2	
	Hemitriccus diops		1	
	Myiothlypis flaveola		1	
	Nonnula rubecula		1	
	Platyrinchus mystaceus	1		
	Poecilotriccus plumbeiceps		3	
	Psilorhamphus guttatus		1	
	Pyriglena leucoptera	5	22	x
	Pyrrhocoma ruficeps		3	
	Synallaxis frontalis		8	x
	Synallaxis ruficapilla	1	20	
	Synallaxis spixi		2	
	Tapera naevia		6	
	Troglodytes musculus	1	2	
Subcanopy insectivores	*Anabacerthia lichtensteini*	36	36	
	Basileuterus culicivorus	88	70	
	Cacicus solitarius	1		x
	Campephilus robustus	4		
	Campylorhamphus falcularius		1	
	Colonia colonus		1	x
	Cyanocorax chrysops	2	4	
	Cyclarhis gujanensis		5	x
	Dendrocincla turdina	25		
	Dryocopus lineatus		3	x
	Dysithamnus mentalis	44	54	
	Habia rubica	35	10	
	Herpsilochmus rufimarginatus	55	56	
	Hypoedaleus guttatus		59	
	Leptopogon amaurocephalus	16	9	

	Megascops choliba	1		x
	Myiornis auricularis	12	21	
	Notharchus swainsoni	1		
	Philydor atricapillus	1	1	
	Philydor rufum	3	1	
	Phylloscartes eximius	8		
	Phylloscartes paulista	1		
	Phylloscartes ventralis	2		
	Picumnus albosquamatus		5	x
	Picumnus temminckii	1		
	Sittasomus griseicapillus	66	17	
	Thamnophilus caerulescens	1	49	x
	Tolmomyias sulphurescens	2	5	
	Trogon surrucura	39	50	
	Tyrannus melancholicus		1	x
	Veniliornis spilogaster		5	
	Xenops rutilans		2	
	Xiphocolaptes albicollis	8	1	
	Xiphorhynchus fuscus	13	2	
Canopy insectivores	*Hemithraupis guira*	9	2	
	Ictinia plumbea		2	
	Myiopagis caniceps	19	5	
	Phyllomyias fasciatus	1		
	Piaya cayana	3		
	Piprites chloris	3	3	
	Sirystes sibilator	2	10	
Primarily insectivores	*Baryphthengus ruficapillus*	31	17	
	Cacicus haemorrhous	7	9	x
	Camptostoma obsoletum		6	
	Celeus flavescens	10	4	
	Chamaeza campanisona	7	15	
	Conirostrum speciosum	4	3	
	Empidonomus varius		1	x
	Glaucidium brasilianum	14	3	x
	Hylophilus poicilotis	2		
	Icterus pyrrhopterus	1		x
	Mackenziaena severa		30	
	Megarynchus pitangua	3	20	x
	Myiopagis viridicata	8	17	
	Phyllomyias virescens		1	
	Saltator fuliginosus		5	
	Saltator similis	1	20	x
	Setophaga pitiayumi	25	1	
	Tachyphonus coronatus		6	x

	Trichothraupis melanops	21	26	
	Trogon rufus	12	3	
	Turdus albicollis	13	3	
	Turdus leucomelas	83	56	x
	Vireo olivaceus	15	21	
Frugivore	*Chlorophonia cyanea*	2		
	Euphonia chlorotica		4	x
	Euphonia violacea		1	x
	Penelope superciliaris	3	2	
	Pipra fasciicauda		3	
	Ramphastos dicolorus	8	3	
	Tityra cayana	1	4	
	Tityra inquisitor		1	
	Cissopis leverianus	1	3	
	Euphonia pectoralis	19	4	
	Patagioenas cayennensis	2	8	x
	Pteroglossus castanotis	2	1	
	Pyroderus scutatus	3		
	Ramphastos toco	1		
	Selenidera maculirostris	8	13	
	Turdus amaurochalinus	1	6	x
	Turdus subalaris		4	
Omnivores	*Amazona aestiva*	2		
	Chiroxiphia caudata	7	8	
	Crypturellus obsoletus	23	1	
	Crypturellus tataupa		21	x
	Cyanoloxia glaucocaerulea		3	x
	Dacnis cayana	1	4	
	Melanerpes flavifrons	3	7	
	Myiodynastes maculatus	1	10	x
	Pachyramphus polychopterus	1	2	x
	Patagioenas picazuro	4	84	
	Pionopsitta pileata	1		
	Psittacara leucophthalmus	13	7	x
	Pyrrhura frontalis	8	13	
	Schiffornis virescens		9	
	Tangara sayaca		1	x
	Tinamus solitarius	5		
	Turdus rufiventris		1	x
Nectarivore	*Chlorostilbon lucidus*		2	x
	Hylocharis chrysura		3	x
	Phaethornis eurynome	1		
	Thalurania glaucopis		1	

Carnivore	*Herpetotheres cachinnans*		1	x
	Micrastur ruficollis	4		
	Micrastur semitorquatus		5	
Granivore	*Claravis pretiosa*		10	x
	Leptotila rufaxilla		8	x
	Leptotila verreauxi	1	24	x
	Pionus maximiliani	29	17	