Instituto Nacional de Pesquisas da Amazônia
Programa de Pós-Graduação em Ecologia

Distribuição de aves de sub-bosque ao longo de gradientes ambientais na Amazônia central

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Manaus, Amazonas, Brasil
Agosto, 2010

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Dissertação apresentada ao Programa de Pós-Graduação em Ecologia do Instituto Nacional de Pesquisas da Amazônia, como parte dos requisitos para obtenção do título de Mestre em Biologia (Ecologia).

Manaus, Amazonas, Brasil
Agosto, 2010

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Distribuição de aves de sub-bosque ao longo de gradientes ambientais na Amazônia centra l/ Anderson Saldanha Bueno.--- Manaus : [s.n.], 2010.

viii, 38 f. : il. color.

Dissertação (mestrado)-- INPA, Manaus, 2010

Orientador : William Ernest Magnusson

Co-orientador : Tânia Margarete Sanaiotti

Área de concentração : Ecologia

1. Aves – Ecologia. 2. Matas ripárias. 3. Ecologia de comunidades. 4. Reserva Florestal Adolpho Ducke (AM). 5. Distribuição de espécies. 6. Redes de neblina. 7. Gradientes ambientais. I. Título.

CDD 19. ed. 598.298113

Agradecimentos

Sou grato ao estímulo e suporte que meus pais sempre me deram para estudar. Por respeitarem e confiarem nas minhas escolhas e por se sentirem felizes com as minhas conquistas.

Às minhas irmãs por me deixarem contente em saber que acham tri legal ter irmão biólogo, que faz mestrado com passarinhos lá na Amazônia.

Aos meus eternos grandes amigos, Afonso, Diego, Fabiano (Bode), Ronaldo e Vitor (Cabra), simplesmente por sempre cultivarem a nossa amizade. Em especial ao Vitor, que posso chamar de irmão, por ser tão importante para a família que também faz parte.

À minha amada namorada, Aline Jaime Leal, por acreditar, juntamente comigo, que os desafios fortalecem o nosso amor e que a distância só nós deixa com mais vontade de ficarmos juntos.

Aos colegas e amigos da Universidade Federal de Santa Maria, Cristian, Ígor, Daiani e Mauro, que vieram comigo para a Amazônia, por fortalecerem os nossos laços de amizade e por terem sido referências para mim em uma terra distante das minhas origens.

Aos amigos que fiz em Manaus pela alegria proporcionada pela nossa vivência como uma grande família de estudantes felizes em conviver uns com os outros.

Aos meus “irmãos”, Marlos e Andressa, e ao Jarbas, que começaram a fazer parte da minha vida em Manaus, pela grande e sincera amizade que construímos.

Aos colegas e amigos da universidade, Gabriel e Franchesco, por fazerem minhas visitas à Santa Maria tão saudosistas e felizes.

Ao INPA que viabilizou, por meio de sua infra-estrutura, professores e funcionários, a realização do meu mestrado e à CAPES pela concessão da minha bolsa de mestrado.

Ao meu orientador, William Ernest Magnusson, por me conceder a oportunidade de realizar este estudo, por ter confiado em mim durante todas as etapas do mestrado, por ter compartilhado o seu conhecimento comigo e por ter me tornado um cientista melhor.

À minha co-orientadora, Tânia Margarete Sanaiotti, por ter me ajudado a planejar e a executar o meu projeto de mestrado.

À Jess pela revisão do *abstract* e por tantas outras revisões de inglês.

Por fim, agradeço a todos os que fizeram parte da experiência de vida que tive durante minha estadia na Amazônia.

Resumo

Zonas ripárias são reconhecidas pela sua importância na manutenção da biodiversidade regional. Diversos estudos compararam a distribuição de aves em zonas ripárias e não-ripárias a fim de avaliar o valor para conservação das zonas ripárias. Contudo, nenhum estudo se dedicou a estabelecer até que distância em relação ao riacho as aves reconhecem como ripária. Nós investigamos a distribuição de aves de sub-bosque ao longo dos gradientes ambientais de distância do riacho, conteúdo de argila e inclinação do terreno em uma floresta de terra firme na Amazônia central. Para amostrar a comunidade de aves de sub-bosque, utilizamos redes de neblina em 45 parcelas, sendo cada parcela amostrada três vezes. Utilizamos *Non-metric Multidimensional Scaling* (NMDS) para reduzir a dimensionalidade dos dados de composição quantitativa (abundância) e qualitativa (presença-ausência) de espécies em um eixo de ordenação multivariada. Em 9720 horas-rede, nós capturamos 1506 aves pertencentes a 98 espécies em 28 famílias. A estimativa da largura da zona ripária indicada pelas aves de sub-bosque na Reserva Ducke dependeu do atributo da comunidade considerado: composição quantitativa (100 m), composição qualitativa (140 m). A distribuição de espécies esteve relacionada com o conteúdo de argila, mas não esteve relacionada com a inclinação do terreno. Na Reserva Ducke, distância do riacho apresenta correlação com o conteúdo de argila, mas não apresenta correlação com inclinação do terreno. Conteúdo de argila afeta a composição de espécies vegetais, que, por sua vez, pode afetar a composição de aves. Contudo, o padrão de distribuição de aves em locais próximos e afastados do riacho é consistente entre estudos realizados em diversas geomorfologias, tanto em regiões temperadas quanto em regiões tropicais, o que indica um efeito da distância do riacho *per se*. A proteção de faixas adjacentes a riachos constitui umas das estratégias de conservação mais utilizadas. No Brasil, a faixa protegida ao redor do riacho se estende até 30 m. Nós demonstramos que a faixa protegida deve ser aumentada consideravelmente para que a legislação ambiental brasileira seja eficiente em cumprir o seu papel de proteger a biodiversidade associada a zonas ripárias.

Abstract

Riparian zones are recognized by their importance to maintaining the regional biodiversity. Several studies compared the bird distribution between riparian and non-riparian zones to evaluate the conservation value of riparian zones. However, no study aimed to establish how wide is the riparian zone recognized by birds in relation to distance from the stream. We investigated the distribution of understory birds along the environmental gradients of distance from the stream, clay content and slope of the terrain in a *terra firme* central Amazonian forest. We sampled understory birds using mist nets in 45 plots, sampling each plot three times. We used Non-metric Multidimensional Scaling (NMDS) to reduce the data dimensionality of species quantitative (abundance) and qualitative (presence-absence) composition in one multivariate axis. In 9720 mist-net hours, we captured 1506 birds belonging to 98 species in 28 families. Estimation of the width of riparian zone as indicated by understory birds in Reserva Ducke depended on the community attribute considered: species quantitative composition (100 m), species qualitative composition (140 m). The species distribution was related to clay content, but it was not related to slope of the terrain. In Reserva Ducke, distance from the stream is correlated with clay content, but it is not correlated with slope of the terrain. Clay content affects the plant species composition, which in turn could affect the bird species composition. However, the distribution pattern of birds in places near to and away from the stream is consistent among the studies carried out in diverse geomorphologies in both temperate and tropical regions, indicating an effect of distance from the stream itself. The protection of strip's adjacent to streams is one of the most used conservation strategies. In Brazil, the protected strip around the stream extends to 30 m. We demonstrated that the width of the protected strip should be increased considerably for the Brazilian environmental legislation to be effective in fulfilling its role of protecting the biodiversity associated with the riparian zones.

Sumário

Introdução

A alta especificidade das espécies ao habitat (Tuomisto *et al*. 1995; Jankowski *et al*. 2009) pode levar à formação de assembléias de espécies distintas em uma dada comunidade devido à heterogeneidade ambiental (Keller *et al*. 2009). Contudo, a formação de assembléias em ambientes heterogêneos não se aplica a qualquer grupo taxonômico (Aguiar, Gualberto & Franklin 2006), sendo mais claras em uns (Drucker, Costa & Magnusson 2008) do que em outros (Kinupp & Magnusson 2005).

Em geral, aves apresentam alta especificidade ao habitat como demonstrado pela sua distribuição em função dos estratos verticais da vegetação (MacArthur & MacArthur 1961). A seleção de habitat por aves pode ser determinada pela fisionomia da vegetação (Rotenberry & Wiens 1980) ou, em uma mesma fisionomia vegetal, pela composição de espécies vegetais (Lee & Rotenberry 2005) e pelas características (Banks-Leite & Cintra 2008) e dinâmica de formação de clareiras (Schemske & Brokaw 1981). A distribuição de espécies de aves também é determinada pela distância em relação a riachos (Willis 1977; Cohn-Haft, Whittaker & Stouffer 1997; Woinarski *et al*. 2000; Cintra & Cancelli 2008).

Dois tipos de ambientes são reconhecidos em função da distância a riachos: ripários e não-ripários, cada qual com características e dinâmica próprias (Naiman, Décamps & Pollock 1993). Diversos estudos reportaram diferenças existentes entre a composição e a abundância de aves de zonas ripárias e não-ripárias (Bub, Flaspohler & Huckins 2004; Palmer & Bennett 2006; Lehmkuhl *et al*. 2007), a fim de avaliar o valor para a conservação das zonas ripárias. A largura da zona ripária protegida por lei é arbitrariamente definida e variável entre jurisdições. Determinar a distância em relação aos riachos que as espécies indicam como sendo ripária é de suma importância para formular leis mais eficientes para proteger as espécies associadas a zonas ripárias. De nosso conhecimento, nenhum estudo se dedicou a estabelecer até que distância em relação a riachos as aves indicam como sendo ripária.

O Código Florestal brasileiro (lei nº 4.771/65) considera zonas ripárias como áreas de preservação permanente (APPs). A maior parte da Amazônia brasileira é coberta por uma densa rede de rios e riachos (Sioli 1991). Os pequenos riachos na maior parte da bacia amazônica têm APPs que se estendem por 30 m de cada lado dos corpos d’água. Mesmo sem considerar os efeitos de borda (Brosofske *et al*. 1997) e os processos ecossistêmicos, tais como fluxo de águas superficiais e subterrâneas, 30 m é muito menos do que a faixa em que assembléias de ervas de sub-bosque associadas a zonas ripárias são distintas das assembléias mais afastadas do riacho (Drucker, Costa & Magnusson 2008).

O Código Florestal brasileiro determina que cada propriedade rural situada em área de floresta na Amazônia Legal deve manter uma cobertura florestal de 80% (sem considerar as APPs). Entretanto, existe um forte movimento rural interessado em reduzir essa área para 50%. De qualquer forma, se a largura da faixa em relação ao riacho utilizada pelas espécies associadas a zonas ripárias é maior que 30 m, o Código Florestal brasileiro seria mais eficiente em proteger essas espécies se considerasse a configuração da paisagem em relação às APPs. Possivelmente, 50% de cobertura florestal contígua às APPs seria mais eficiente que 80% de cobertura, se os 20% desmatados isolarem as APPs da floresta circundante e a faixa de 30 m não for suficiente para manter as populações que estão isoladas.

Neste estudo, nós investigamos a distribuição de aves de sub-bosque em relação à distância do riacho e a variáveis edáficas e topográficas (conteúdo de argila e inclinação do terreno), que sabidamente são correlacionadas com a composição de espécies de plantas (Costa, Magnusson & Luizão 2005; Kinupp & Magnusson 2005; Poulsen, Tuomisto & Balslev 2006; Bohlman *et al.* 2008; Drucker, Costa & Magnusson 2008), em uma floresta de terra firme na Amazônia central. Nós mostramos que aves de sub-bosque indicam uma zona ripária que se estende muito além da largura de vegetação adjacente a cursos d'água protegida pela legislação ambiental.

Objetivos

- Estimar a largura da zona ripária para aves de sub-bosque em uma floresta de terra firme na Amazônia central.
- Determinar o efeito dos gradientes ambientais de distância do riacho, conteúdo de argila e inclinação do terreno na distribuição de aves de sub-bosque.

Artigo formatado conforme as normas da revista Journal of Applied Ecology

Title: The width of riparian zones for understory birds in central Amazonia

Running head: Riparian zones for understory birds

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Summary

1. Riparian zones are important for maintenance regional biodiversity. Many studies have compared bird distributions between riparian and non-riparian zones, but no published study has been designed to establish how wide is the riparian zone recognized by birds in relation to distance from the stream.

2. We investigated the distribution of understory birds along environmental gradients of distance from the stream, clay content and terrain slope in a central Amazonian forest. We sampled understory birds using mist nets in 45 plots, sampling each plot three times. We used Non-metric Multidimensional Scaling (NMDS) to reduce the dimensionality of species quantitative (abundance) and qualitative (presence-absence) composition to one multivariate axis.

3. Estimation of the width of the riparian zone as indicated by understory birds depended on the community attribute considered: species quantitative composition (100 m), species qualitative composition (140 m). Species distributions were associated with clay content, but were largely independent of slope.

4. Distance from the stream is correlated with clay content, but is largely independent of slope in the study site. Clay content affects plant species composition, which in turn may influence bird species composition. However, distribution patterns of birds with respect to distance from the stream are consistent among studies in both temperate and tropical regions, indicating an effect of distance from the stream itself.

5. *Synthesis and applications*. The protection of riparian zones is one of the most widely used conservation strategies. Under Brazilian law, the protected strip around small streams extends to 30 m. We show that the protected strip should be much wider and we recommend that Brazilian environmental legislation be changed to fulfill its role of protecting biodiversity associated with riparian zones.

Key words: biodiversity conservation, ecological boundaries, environmental legislation, species distribution, environmental gradients, tropical forest, riparian zones, Neotropical birds, mist nets

Introduction

Habitat specificity at the species level (Tuomisto *et al.* 1995; Jankowski *et al.* 2009) can generate distinct species assemblages within a given community due to environmental heterogeneity (Keller *et al.* 2009). However, this phenomenon is not universal among taxonomic groups (Aguiar, Gualberto & Franklin 2006), being stronger in some (Drucker, Costa & Magnusson 2008) and weaker in others (Kinupp & Magnusson 2005).

Birds typically show high habitat specificity, as shown in the classic study of their distribution in vertical vegetation strata (MacArthur & MacArthur 1961). Habitat selection in birds may be determined by vegetation type (Rotenberry & Wiens 1980), or, within the same vegetation type, by plant species composition (Lee & Rotenberry 2005) and treefall-gap characteristics (Banks-Leite & Cintra 2008) and dynamics (Schemske & Brokaw 1981). Bird species distributions also vary in relation to distance from streams (Willis 1977; Cohn-Haft, Whittaker & Stouffer 1997; Woinarski *et al.* 2000; Cintra & Cancelli 2008).

Ecologists typically recognize two habitat types along the gradient of increasing distance from the stream: riparian and non-riparian, each with its own characteristics and dynamics (Naiman, Décamps & Pollock 1993). Many studies of the conservation value of riparian zones have documented differences between the species composition and abundance distributions of bird communities in these two habitat types (Bub, Flaspohler & Huckins 2004; Palmer & Bennett 2006; Lehmkuhl *et al.* 2007). Since the width of riparian zones as defined by environmental legislation is typically arbitrary, and varies between jurisdictions, making that legislation more effective will require studies to determine the true width of habitat that species recognize as riparian. To our knowledge, no published study has been designed to establish how wide is the riparian zone recognized by birds in relation to distance from the stream.

Brazil's forestry code (law nº 4771/65) designates riparian zones as areas meriting permanent protection (hereafter referred to by the Portuguese acronym APP). In most of the Brazilian Amazon, where the landscape is criss-crossed by a dense network of rivers and streams (Sioli 1991), APPs for small streams are defined as strips 30 m wide on each side of small streams. However, Drucker, Costa & Magnusson (2008) showed that understory-herb assemblage associated with riparian zones extends much farther from streams than this. Also, 30 m may not account for edge effects (Brosofske *et al.* 1997) and ecosystem processes, such as above- and below-ground water flow.

The Brazilian forestry code mandates that all rural landholdings in the country's Amazon region must maintain at least 80% forest cover (not including APPs). A strong political movement is currently pressuring the government to reduce this to 50%. If the width of the riparian zone used by riparian-associated species is greater than 30 m, then the spatial arrangement of the forest cover which rural landholders must maintain might determine the effectiveness of APPs. For example, maintaining 50% of forest cover that is contiguous to APPs could be more efficient than maintaining 80% of forest cover that is not contiguous to APPs, since the latter arrangement would strand populations of riparian species in narrow, isolated strips of forest extending 30 m to each side of streams.

In this study, we examined the distribution of understory birds in a *terra firme* forest in central Amazonia in relation to both distance from the stream and edaphic and topographic variables (clay content and terrain slope), which are known to be related to plant species composition (Costa, Magnusson & Luizão 2005; Kinupp & Magnusson 2005; Poulsen, Tuomisto & Balslev 2006; Bohlman *et al.* 2008; Drucker, Costa & Magnusson 2008). We show that understory birds recognize a riparian zone that extends much farther than the width of strips of riparian vegetation protected by environmental legislation.

Materials and methods

STUDY AREA

This study was carried out in the Reserva Ducke, administered by Instituto Nacional de Pesquisas da Amazônia (INPA), in Manaus, central Amazonia (02º55'–03º01' S, 59º53'–59º59' W). The reserve protects 10,000 ha of well-drained relatively undisturbed *terra firme* forest that is not subject to long-term floods (Ribeiro *et al*. 1999). The understory is dominated by sessile palms and shaded by a closed canopy approximately 30-37 m high, in which occasional emergent trees reach 40–45 m (Ribeiro *et al*. 1999).

Topography at the site is a mosaic of plateaus and valley bottoms, the latter with riparian areas (Ribeiro *et al*. 1999) along streams that are typically less than 10 m wide. The elevational difference between the highest and lowest points in the reserve is 87 m (Drucker, Costa & Magnusson 2008), while the difference between plateaus and adjacent valley bottoms is generally 30 m (Castilho *et al*. 2006). The clay content of soils varies with elevation, such that soils in higher areas contain more clay (Chauvel, Lucas & Boulet 1987). The strong correlation between clay content and elevation ($r_s = 0.916$, $P < 0.001$) means that elevation is an effective proxy for clay content (Costa, Magnusson & Luizão 2005). Distance from the stream is correlated with clay content ($r_s = 0.764$, $P < 0.001$) but not with slope ($r_s = -0.055$, $P = 0.773$). There is a rainy season at the site which typically extends from November to May, and a dry season from July to October (Marques Filho *et al*. 1981). Between April 1965 and November 1980, mean annual temperature was 26 ºC and mean annual precipitation was 2362 mm (Marques Filho *et al*. 1981).

Bird species composition in the Reserva Ducke is well known. Avifaunal studies conducted during the last 40 years were listed by Cintra (2008). Since the first bird species list (Willis 1977), nearly 50 species were added by Cohn-Haft, Whittaker & Stouffer (1997), Naka (2004), and Banks-Leite & Cintra (2008), summing to more than 340 species recorded in the reserve and its surroundings.

SAMPLING DESIGN

As Site # 1of Brazil's Long-term Ecological Research program (PELD), Reserva Ducke possesses a standard RAPELD sampling grid (Magnusson *et al*. 2005) established by the Brazilian Biodiversity Research Program (PPBio). This 25-km^2 grid is composed of six north-south trails and six east-west trails, each measuring 5 km long and spaced from adjacent trails at 1-km intervals (Fig. 1). This trail system provides access to 45 plots measuring 250 m long, whose widths vary depending on the taxonomic group being studied (Magnusson *et al*. 2005). Thirty of these 45 plots are evenly spaced on the grid at 1-km intervals and 15 are close (3.7±1.2 m) to stream margins and thus classified as riparian. Plots are not rectangular, but follow landscape features. The evenly spaced plots follow topographic contour lines in order to minimize edaphic variation within each plot (Magnusson *et al*. 2005), while the riparian plots follow the course of streams.

DATA COLLECTION

We sampled bird communities in three discrete periods in 2009: 10 January to 25 May, 12 July to 7 September, and 19 September to 19 November. We sampled each of the 45 plots once in each sampling period. We used 16 9-m mist nets arranged in pairs along the 250-m length of each plot, such that each pair was separated from adjacent pairs by 10 m. As sampling effort is usually measured as net-hours (i.e., one 12-m mist net open for one hour; Keyes & Grue 1982), we converted our sampling effort with 9-m mist nets to those units. In the first sampling period, we used eight mist nets with 50 mm mesh and eight mist nets with 70 mm mesh. In the later sampling periods, all mist nets had 32 mm mesh.

Mist nets were left open from 06:00 to 12:00 h and revised hourly. Captured birds were identified using the field guide of Restall, Rodner & Lentino (2007) and banded with standard CEMAVE bands (ICMBIO/SNA permission nº 3052). Birds that could not be identified in the field were collected (IBAMA/SISBIO permission nº 17229-1) or photographed and later identified by specialists. All collected birds were deposited in the INPA Bird Collection.

The distance between each plot and the nearest stream was measured at six points spaced at 50-m intervals along the central line of each plot with a measuring tape, and the mean distance was used in analyses for plots whose starting point was less than 30 m from the stream. For the other plots, the linear distance between the geographic coordinates of the plot center and the nearest stream was used. A soil sample was collected to a depth of 5 cm at each of the same six points per plots. These samples were mixed to form a composite sample for each plot, 500 g of which was analyzed for clay content in INPA's soil laboratory. Slope was measured with a clinometer on a 3-m line perpendicular to the central line (1.5 m to each side) at each of the same six points per plots. The mean of the six values for each plot was used in analyses.

Data on distance from the stream were obtained for all 45 plots, while data on slope and clay content were obtained for the 30 evenly spaced plots. Distance from the stream was measured in previous studies and the data provided by R. de Fraga, F. R. C. Costa, and J. Schietti. Slope and clay-content data, as well as information on the collection methods and the researchers involved are available online at the PPBio website (http://ppbio.inpa.gov.br).

DATA ANALYSIS

Dissimilarity in species composition between plots was calculated with both abundance data (referred to hereafter as quantitative composition) and presence-absence data (qualitative composition). Patterns in quantitative data are typically driven by common species, which tend to have large differences in abundances between plots. Qualitative data give more weight to rare species, because common species occur in most plots and contribute little to between-plot differences.

We used Non-metric Multidimensional Scaling (NMDS) to reduce the dimensionality of species composition data to one axis of a multivariate ordination, in order to describe the major patterns in understory bird community (McCune & Grace 2002). The ordinations with quantitative data were based on a matrix of similarities calculated with the Bray-Curtis index. Abundance of each species in each plot was standardized by converting it to relative abundance prior to analysis. Abundance of a given species in a given plot was calculated as the total number of individuals captured in the three sampling periods, excluding recaptures of banded birds in the plot where they were originally captured. Ordinations of qualitative data were based on Sørensen's index.

We tested the effect of distance from the stream on species quantitative and qualitative composition, represented by NMDS scores. To identify discontinuities in community attributes with increasing distance from the stream, we used piecewise regression, a statistical technique useful to identify ecological thresholds (Toms & Lesperance 2003). Piecewise regression identifies the two lines which best characterize variance in the data. The intersection point of these two lines was considered as an indicator of the size of the riparian zone for understory birds. The piecewise regression was performed using the statistical package SiZer (see Sonderegger *et al.* 2009) in the program R, version 2.8.1. We used direct gradient analysis (McCune & Grace 2002) to illustrate in a compound graph (developed in the program R by C. S. Dambros) the distribution of species in relation to distance from the stream, based on qualitative data.

Results

THE UNDERSTORY BIRD COMMUNITY

In 9720 net-hours in the 45 plots, we captured 1506 birds belonging to 98 species in 28 families. In the 30 evenly spaced plots in 6480 net-hours, we captured 918 birds belonging to 80 species and 24 families. We captured two species (*Glaucis hirsutus* and *Neopipo cinnamomea*) not previously recorded for the Reserva Ducke (Willis 1977; Cohn-Haft, Whittaker & Stouffer 1997; Naka 2004; Banks-Leite & Cintra 2008). The number of species captured in each plot varied from 10 to 28 (18.31 ± 3.85) and the number of individuals captured varied from 15 to 58 (33.47 ± 9.64). The 20 most-captured species ($n \geq 23$) accounted for 72% of all captures. Twenty-five species were captured only once (Table 1).

THE EFFECT OF ENVIRONMENTAL VARIABLES ON THE DISTRIBUTION OF UNDERSTORY BIRDS

For the ordination of quantitative data from the 45 plots, one NMDS axis explained 40% of the variation in the matrix of original differences between plots. The quantitative composition of birds, represented by the NMDS axis, showed turnover throughout the gradient of increasing distance from the stream (Fig. 2a). The piecewise regression indicated that the effect of distance from the stream on the relative abundance of species extended to approximately 100 m (CI = 45.5 – 492.9) from streams ($r^2 = 0.213$, d.f. = 42, $P = 0.002$).

For the ordination of qualitative data from the 45 plots, one NMDS axis explained 36% of the variation in the matrix of original distances between plots. The qualitative composition of birds, represented by the NMDS axis, showed turnover throughout the gradient of increasing distance from the stream (Fig. 2b). The piecewise regression indicated that the effect of distance from the stream on the presence-absence of species extended approximately 140 m (CI = 50.5 – 429.1) from streams ($r^2 = 0.359$, d.f. = 42, $P < 0.001$).

Based on the distance from the stream at which qualitative composition showed a distinct turnover, we consider riparian plots to be those within 140 m of streams and non-riparian plots to be all others. Using this criterion, 26 of all 45 plots were in the riparian zone and 19 in the non-riparian zone (Fig. 3). More species were captured in riparian plots ($n = 81$) than in non-riparian plots ($n = 69$; t = 2.769, d.f. = 43, $P = 0.008$). Most species ($n = 52$) were captured in both riparian and non-riparian plots. The number of species captured per riparian plot was greater than the number per plot captured exclusively in non-riparian plots (t = 3.334, d.f. = 60.981, $P = 0.001$). The number of individuals captured was also greater in riparian plots than in non-riparian plots (t = 3.979, d.f. = 43, $P < 0.001$).

For the ordination of quantitative data from the 30 evenly spaced plots, a single NMDS axis explained 45% of the variation in the matrix of original distances between plots. Clay content and slope are not highly correlated ($r_s = -0.096$, $P = 0.612$) and were used in a multiple regression model. Together, the two variables predicted 14% of the variation in scores on the NMDS axis (quantitative composition = 0.143 – 0.004clay + 0.002slope, $r^2 = 0.14$, d.f. = 27, $P = 0.049$). Variation in scores on the NMDS axis was related to clay content (t = 2.508, d.f. = 27, $P = 0.018$), but was independent of slope (t = 0.198, d.f. = 27, $P = 0.845$).

For the ordination of qualitative data from the 30 evenly spaced plots, a single NMDS axis explained 35% of the variation in the matrix of original distances between plots. Both clay content (t = 0.753, d.f. = 27, $P = 0.458$) and slope (t = 0.677, d.f. = 27, $P = 0.504$) were not related to variation in scores on the NMDS axis ($r^2 = -0.04$, d.f. = 27, $P = 0.653$).

Discussion

Understory bird assemblages in sites closer to streams were more diverse overall and had more habitat-restricted species than those farther from streams. More birds were captured at sites closer to streams, and both quantitative and qualitative compositions were distinct from assemblages farther from streams. These patterns are similar to those documented for bird assemblages in riparian and non-riparian zones throughout the world (Woinarski *et al*. 2000; Catterall *et al*. 2001; Bub, Flaspohler & Huckins 2004; Palmer & Bennett 2006; Lehmkuhl *et al*. 2007; Chan *et al*. 2008), and confirm that riparian zones play an important role in maintaining regional biodiversity (Naiman, Décamps & Pollock 1993).

Previous studies comparing bird assemblages in riparian and non-riparian zones used arbitrarily defined thresholds between these two habitat types. Riparian zones have been defined as anywhere from the stream banks themselves to 30 m, while non-riparian zones have been proposed at anywhere between 100 and 750 m from streams (Catterall *et al*. 2001; Bub, Flaspohler & Huckins 2004; Palmer & Bennett 2006; Lehmkuhl *et al*. 2007; Chan *et al*. 2008). Although all of these studies report differences between sites that are very close to streams and sites that are distant from them, a rigorous comparison of riparian and non-riparian zones is difficult without a standard definition of the size of the riparian zone.

The distribution of species along a given environmental gradient may reflect changes in factors correlated with that gradient (Whittaker 1972). The distribution of understory birds along the gradient of increasing distance from the stream was related to clay content but not with slope. In Reserva Ducke, distance from the stream is correlated with clay content but not with slope. Earlier studies in Reserva Ducke have shown that plant species composition is related to clay content (Costa, Magnusson & Luizão 2005; Costa *et al*. 2008). However, the effect of clay content should be due to its correlation with distance from the stream, since distance from the stream (Drucker, Costa & Magnusson 2008) and soil moisture (Catterall *et* *al*. 2001) were also found to be related to plant species composition. Vegetation is an important determinant of bird species composition (Rotenberry 1985; Lee & Rotenberry 2005; Fleishman *et al*. 2003). A relationship between bird species composition and clay content documented in a tropical savanna in Australia, for example, was more likely driven by changes in vegetation structure (which varied with soil texture) than by intrinsic soil characteristics themselves (Woinarski, Fisher & Milne 1999). Moreover, in a subtropical eucalypt forest in Australia, where plant species composition was independent of clay content, bird species composition was not related to clay content (Catterall *et al*. 2001).

Bird species may respond differently to the gradient of distance from the stream. Some species, such as *Schistocichla leucostigma* (Willis 1977), are more associated with streams, while others, such as *Willisornis poecilinotus* (Cintra & Cancelli 2008), are more often found away from streams. However, the distributions of many species, such as *Dendrocincla fuliginosa* and *D. merula* (Cintra, Maruoka & Naka 2006), are independent of distance from the stream. At the community level, distributional patterns of birds with regard to distance from the stream are comparable in studies carried out in temperate (Bub, Flaspohler & Huckins 2004; Lehmkuhl *et al*. 2007) and tropical regions (Palmer & Bennett 2006; Chan *et al*. 2008). This indicates that distance from the stream itself may exercise an effect on bird species distributions, rather than specific local effects, such as changes in soil. Areas close to streams have more insects and consequently attract more insectivorous birds (Iwata, Nakano & Murakami 2003; Chan *et al*. 2008). In addition, species, such as kingfishers (*Chloroceryle aenea* and *C. inda*), depend on streams for the fish they eat. However, it is difficult to untangle the effects of distance from the stream itself from the effects of environmental variables correlated with that gradient (see Catterall *et al*. 2001). Studies carried out in discretely defined habitats complicate the interpretation of the individual effects of correlated variables, while studies carried out in continuously defined habitats allow for more detailed interpretations, since correlated variables may vary in different ways along a given environmental gradient. Since measures to protect riparian zones are based on distance from the stream, more studies are needed to clarify the effects of distance *per se* on bird community structure.

IMPLICATIONS FOR CONSERVATION

Understanding how biological communities vary at increasing distances from the stream is vital for designing effective conservation strategies, because preserving strips of riparian vegetation is one of the most commonly used conservation strategies (Marczak *et al*. 2010). It is difficult to establish a single riparian strip that protects all species associated with riparian zones, because the optimal width may vary among streams and taxonomic groups (Spackman & Hughes 1995). In order to determine the width of the riparian strip to be protected it is important to consider the specific community attributes used to define the strip which species recognize as riparian (as in this study) as well as the width of the stream (Drucker, Costa & Magnusson 2008).

In Brazil, the strips of riparian vegetation required by law to be retained vary with river size. For streams or rivers less than 10 m wide, mandated strips are 30 m wide. The Brazilian forestry code (law nº 4.771/65) has established permanent protection areas (APPs) in order to "protect hydrological resources and the surrounding landscape, as well as geological stability, biodiversity, and the gene flow of plants and animals, in addition to preserving soils and assuring the well-being of human populations". Studies carried out in Reserva Ducke, where streams are typically less than 10 m wide, have shown that this 30 m definition is too small to protect understory herbs (Drucker, Costa & Magnusson 2008), snakes (Fraga 2009) and understory birds (this study) associated with riparian zones.

The most efficient width of a riparian strip for protecting riparian-associated species depends on the adjacent vegetation (Peak & Thompson III 2006) and on the edge effects that influence populations in riparian zones (Marczak *et al*. 2010). In addition, the specific community attribute used to determine the width of the strip which species recognize as riparian can affect estimates of that width. Since common species tend to occur widely, and are thus poor indicators of specific assemblages (Strong & Bock 1990), qualitative composition may be a more useful attribute for quantifying the distances to which riparian-associated species assemblages extend.

Given that edge effects can extend 30-60 m into riparian zones (Brosofske *et al*. 1997), and given that the effect of distance from the stream on qualitative composition extended for 140 m in this study, we hypothesize that 170-200 m are needed to protect understory birds in the Reserva Ducke. This distance is more than five times the current width for protection of riparian areas as defined by Brazilian environmental legislation. In 2010, the Brazilian parliament is considering modifications of the law that would reduce the width of the protected strips for small stream less than 5 m wide to 15 m. If Brazilian environmental legislation is to effectively protect biodiversity associated with riparian zones, either the width of APPs must be increased considerably, or APPs must be contiguous with other conservation units.

Acknowledgments

We thank INPA staff and the Ducke guards for logistic support. Bruno Henrique Grolli Carvalho, Andressa Barbara Scabin, Robson Disarz and the field assistants who helped in the field, and Mario Cohn-Haft and Erik Johnson who helped identify species. ASB thanks the people that were at Reserva Ducke for the time enjoyed together during the fieldwork, especially Cíntia Gomes de Freitas and Carlos Eduardo Barbosa. We are grateful to the researchers who provided data regarding distance from the stream, clay content, and slope, and to Cristian de Sales Dambros for his valuable help with statistical analyses. We also thank the researchers that evaluated ASB's MSc thesis plan and an early version of this manuscript. The bird bands used in this study were supplied by the Centro Nacional de Pesquisa para Conservação das Aves Silvestres (CEMAVE). ASB was supported by a scholarship from Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). This study was financed by the Brazilian Biodiversity Research Program (PPBio).

References

Aguiar, N.O., Gualberto, T.L. & Franklin, E. (2006) A medium-spatial scale distribution pattern of Pseudoscorpionida (Arachnida) in a gradient of topography (altitude and inclination), soil factors, and litter in a central Amazonia forest reserve, Brazil. *Brazilian Journal of Biology*, **66**, 791–802.

Banks-Leite, C. & Cintra, R. (2008) The heterogeneity of Amazonian treefall gaps and bird community composition. *Ecotropica*, **14**, 1–13.

Bohlman, S.A., Laurance, W.F., Laurance, S.G., Nascimento, H.E.M., Fearnside, P.M. & Andrade, A. (2008) Importance of soils, topography and geographic distance in structuring central Amazonian tree communities. *Journal of Vegetation Science*, **19**, 863–874.

Brosofske, K.D., Chen, J., Naiman, R.J. & Franklin, J.F. (1997) Harvesting effects on microclimatic gradients from small streams to uplands in western Washington. *Ecological Applications*, **7**, 1188–1200.

Bub, B.R., Flaspohler, D.J. & Huckins, C.J.F. (2004) Riparian and upland breeding-bird assemblages along headwater streams in Michigan's Upper Peninsula. *Journal of Wildlife Management*, **68**, 383–392.

Castilho, C.V. de, Magnusson, W.E., Araújo, R.N.O. de, Luizão, R.C.C., Luizão, F.J., Lima, A.P. & Higuchi, N. (2006) Variation in aboveground tree live biomass in a central Amazonian Forest: effects of soil and topography. *Forest Ecology and Management*, **234**, 85–96.

Catterall, C.P., Piper, S.D., Bunn, S.E. & Arthur, J.M. (2001) Flora and fauna vary with local topography in a subtropical eucalypt forest. *Austral Ecology*, **26**, 56–69.

CBRO (Comitê Brasileiro de Registros Ornitológicos) (2009) *Listas das aves do Brasil. Version 9/8/2009*. Available on www.cbro.org.br, accessed 2/3/2010.

Cintra, R. (2008) Aves. *Reserva Ducke: a biodiversidade amazônica através de uma grade* (eds M.L. Oliveira, F.B. Baccaro, R. Braga-Neto & W.E. Magnusson), pp. 77–85. Áttema Design Editorial, Manaus, Amazonas, Brasil.

Cintra, R. & Cancelli, J. (2008) Effects of forest heterogeneity on occurrence and abundance of the scale-backed antbird, *Hylophylax poecilinotus* (Aves: Thamnophilidae), in the Amazon forest. *Revista Brasileira de Zoologia*, **25**, 630–639.

Cintra, R., Maruoka, A.E. & Naka, L.N. (2006) Abundance of two *Dendrocincla* woodcreepers (Aves: Dendrocolaptidae) in relation to forest structure in Central Amazonia. *Acta Amazonica*, **36**, 209–220.

Chan, E.K.W., Yu, Y.T., Zhang, Y. & Dudgeon, D. (2008) Distribution patterns of birds and insect prey in a tropical riparian forest. *Biotropica*, **40**, 623–629.

Chauvel, A., Lucas, Y. & Boulet, R. (1987) On the genesis of the soil mantle of the region of Manaus, Central Amazonia, Brazil. *Experientia*, **43**, 234–241.

Cohn-Haft, M., Whittaker, A. & Stouffer, P.C. (1997) A new look at the "species-poor" central Amazon: the avifauna north of Manaus, Brazil. *Ornithological Monographs*, **48**, 205–235.

Costa, F.R.C., Magnusson, W.E. & Luizão, R.C. (2005) Mesoscale distribution patterns of Amazonian understory herbs in relation to topography, soil and watersheds. *Journal of Ecology*, **93**, 863–878.

Costa, F.R.C., Jean-Louis, G., Lima, A.P. & Pereira, O.S. (2008) Gradients within gradients: the mesoscale distribution patterns of palms in a central Amazonian forest. *Journal of Vegetation Science*, **20**, 69–78.

Drucker, D.P., Costa, F.R.C. & Magnusson, W.E. (2008) How wide is the riparian zone of small streams in tropical forests? A test with terrestrial herbs. *Journal of Tropical Ecology*, **24**, 65–74.

Fleishman, E., Mcdonal, N., Nally, R.M., Murphy, D.D., Walters, J. & Floyd, T. (2003) Effects of floristics, physiognomy and non-native vegetation on riparian bird communities in a Mojave Desert watershed. *Journal of Animal Ecology*, **72**, 484–490.

Fraga, R. de (2009) *A influência de fatores ambientais sobre padrões de distribuição espacial de comunidades de serpentes em 25 km^2 de floresta de terra firme na Amazônia Central*. MSc thesis, Instituto Nacional de Pesquisas da Amazônia, Manaus, Amazonas, Brazil.

Iwata, T., Nakano, S. & Murakami, M. (2003) Stream meanders increase insectivorous bird abundance in riparian deciduous forests. *Ecography*, **26**, 325–337.

Jankowski, J.E., Ciecka, A.L., Meyer, N.Y. & Rabenold, K.N. (2009) Beta diversity along environmental gradients: implications of habitat specialization in tropical montane landscapes. *Journal of Animal Ecology*, **78**, 315–327.

Keller, A., Rödel, M.O., Linsenmair, K.E. & Grafe, T.U. (2009) The importance of environmental heterogeneity for species diversity and assemblage structure in Bornean stream frogs. *Journal of Animal Ecology*, **78**, 305–314.

Keyes, B.E. & Grue, C.E. (1982) Capturing birds with mist nets: a review. *North American Bird Bander*, **7**, 2–14.

Kinupp, V.F. & Magnusson, W.E. (2005) Spatial patterns in the understorey shrub genus *Psychotria* in central Amazonia: effects of distance and topography. *Journal of Tropical Ecology*, **21**, 363–374.

Lee, P.Y. & Rotenberry, J.T. (2005) Relationships between bird species and tree species assemblages in forested habitats of eastern North America. *Journal of Biogeography*, **32**, 1139–1150.

Lehmkuhl, J.F., Burger, E.D., Drew, E.K., Lindsey, J.P., Haggard, M. & Woodruff, K.Z. (2007) Breeding birds in riparian and upland dry forests of the Cascade Range. *Journal of Wildlife Management*, **71**, 2632–2643.

MacArthur R.H. & MacArthur J.W. (1961) On bird species diversity. *Ecology*, **42**, 594–598.

Magnusson, W.E., Lima, A.P., Luizão, R., Luizão, F., Costa, F.R.C., Castilho, C.V. de & Kinupp, V.F. (2005) RAPELD: a modification of the Gentry method for biodiversity surveys in long-term ecological research sites. *Biota Neotropica*, **5**, 1–6.

Marczak, L.B., Sakamaki, T., Turvey, S.L., Deguise, I., Wood, S.L.R. & Richardson, J.S. (2010) Are forested buffers an effective conservation strategy for riparian fauna? An assessment using meta-analysis. *Ecological Applications*, **20**, 126–134.

Marques Filho, A.O., Ribeiro, M.N.G., Santos, H.M. & Santos, J.M. (1981) Estudos climatológicos da Reserva Florestal Ducke – Manaus-AM. IV. Precipitação. *Acta Amazonica*, **11**, 759–768.

McCune, B. & Grace, J.B. (2002) *Analysis of ecological communities*. MjM Software Design, Gleneden Beach, Oregon, USA.

Naiman, R.J., Décamps, H. & Pollock, M. (1993) The role of riparian corridors in maintaining regional biodiversity. *Ecological Applications*, **3**, 209–212.

Naka, L.N. (2004) Structure and organization of canopy bird assemblages in Central Amazonia. *The Auk*, **121**, 88–102.

Palmer, G.C. & Bennett, A.F. (2006) Riparian zones provide for distinct bird assemblages in forest mosaics of south-east Australia. *Biological Conservation*, **130**, 447–457.

Peak, R.G. & Thompson III, F.R. (2006) Factors affecting avian species richness and density in riparian areas. *Journal of Wildlife Management*, **70**, 173–179.

Poulsen, A.D., Tuomisto, H. & Balslev, H. (2006) Edaphic and floristic variation within a 1-ha plot of lowland Amazonian rain forest. *Biotropica*, **38**, 468–478.

Restall, R., Rodner, C. & Lentino, M. (2007) *Birds of northern South America: an identification guide. Volume 2: plates and maps*. Yale University Press, New Haven, Connecticut, USA.

Ribeiro, J.E.L.S., Hopkins, M.J.G., Vicentini, A., Sothers, C.A., Costa, M.A.S., Brito, J.M., Souza, M.A.D., Martins, L.H.P., Lohmann, L.G., Assunção, P.A.C.L., Pereira, E.C., Silva, C.F., Mesquita, M.R. & Procópio, L.C. (1999) *Flora da Reserva Ducke. Guia de identificação das plantas vasculares de uma floresta de terra firme na Amazônia Central*. Editora INPA, Manaus, Amazonas, Brazil.

Rotenberry, J.T. (1985) The role of habitat in avian community composition: physiognomy or floristics? *Oecologia*, **67**, 213–217.

Rotenberry, J.T. & Wiens, J.A. (1980) Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. *Ecology*, **61**, 1228–1250.

Schemske, D.W. & Brokaw, N. (1981) Treefalls and the distribution of understory birds in a tropical forest. *Ecology*, **62**, 938–945.

Sioli, H. (1991) *Amazônia: fundamentos da ecologia da maior região de florestas tropicais*. Editora Vozes, Petrópolis, Rio de Janeiro, Brazil.

Sonderegger, D.L., Wang, H., Clements, W.H. & Noon, B.R. (2009) Using SiZer to detect thresholds in ecological data. *Frontiers in Ecology and the Environment*, **7**, 190–195.

Spackman, S.C. & Hughes, J.W. (1995) Assessment of minimum stream corridor width for biological conservation: species richness and distribution along mid-order streams in Vermont. USA. *Biological Conservation*, **71**, 325–332.

Strong, T.R. & Bock, C.E. (1990) Bird species distribution patterns in riparian habitats in southeastern Arizona. *The Condor*, **92**, 866–885.

Toms, J. D. & Lesperance, M.L. (2003) Piecewise regression: a tool for identifying ecological thresholds. *Ecology*, **84**, 2034–2041.

Tuomisto, H., Ruokolainen, K., Kalliola, R., Linna, H., Danjoy, W. & Rodriguez, T. (1995) Dissecting Amazonian biodiversity. *Science*, **269**, 63–66.

Whittaker, R.H. (1972) Evolution and measurement of species diversity. *Taxon*, **21**, 213–251.

Willis, E.O. (1977) Lista preliminar das aves da parte noroeste e áreas vizinhas da Reserva Ducke, Amazonas, Brasil. *Revista Brasileira de Biologia*, **37**, 585–601.

Woinarski, J.C.Z., Fisher, A. & Milne, D. (1999) Distribution patterns of vertebrates in relation to an extensive rainfall gradient and soil variation in the tropical savannas of the Northern Territory, Australia. *Journal of Tropical Ecology*, **15**, 381–398.

Woinarski, J.C.Z., Brock, C., Armstrong, M., Hempel, C., Cheal, D. & Brennan, K. (2000) Bird distribution in riparian vegetation in the extensive natural landscape of Australia's tropical savanna: a broad-scale survey and analysis of a distributional data base. *Journal of Biogeography*, **27**, 843–868.

Figure legends

Fig. 1. Topography and streams at the study area in the Reserva Ducke, showing the trails and plots of the RAPELD sampling grid. White dots indicate the location of the evenly distributed plots and yellow dots indicate riparian plots. The lighter regions indicate lower areas, whereas darker regions indicate the highest areas. Modified from Ribeiro *et al*. (1999).

Fig. 2. Effects of distance from the stream on (a) quantitative and (b) qualitative composition of understory birds in the Reserva Ducke.

Fig. 3. Occurrence of understory bird species in relation to distance from the stream in 45 plots in the Reserva Ducke. The vertical line indicates the estimated distance from the stream up to which streams influence species qualitative composition.

Figures

Fig. 1.

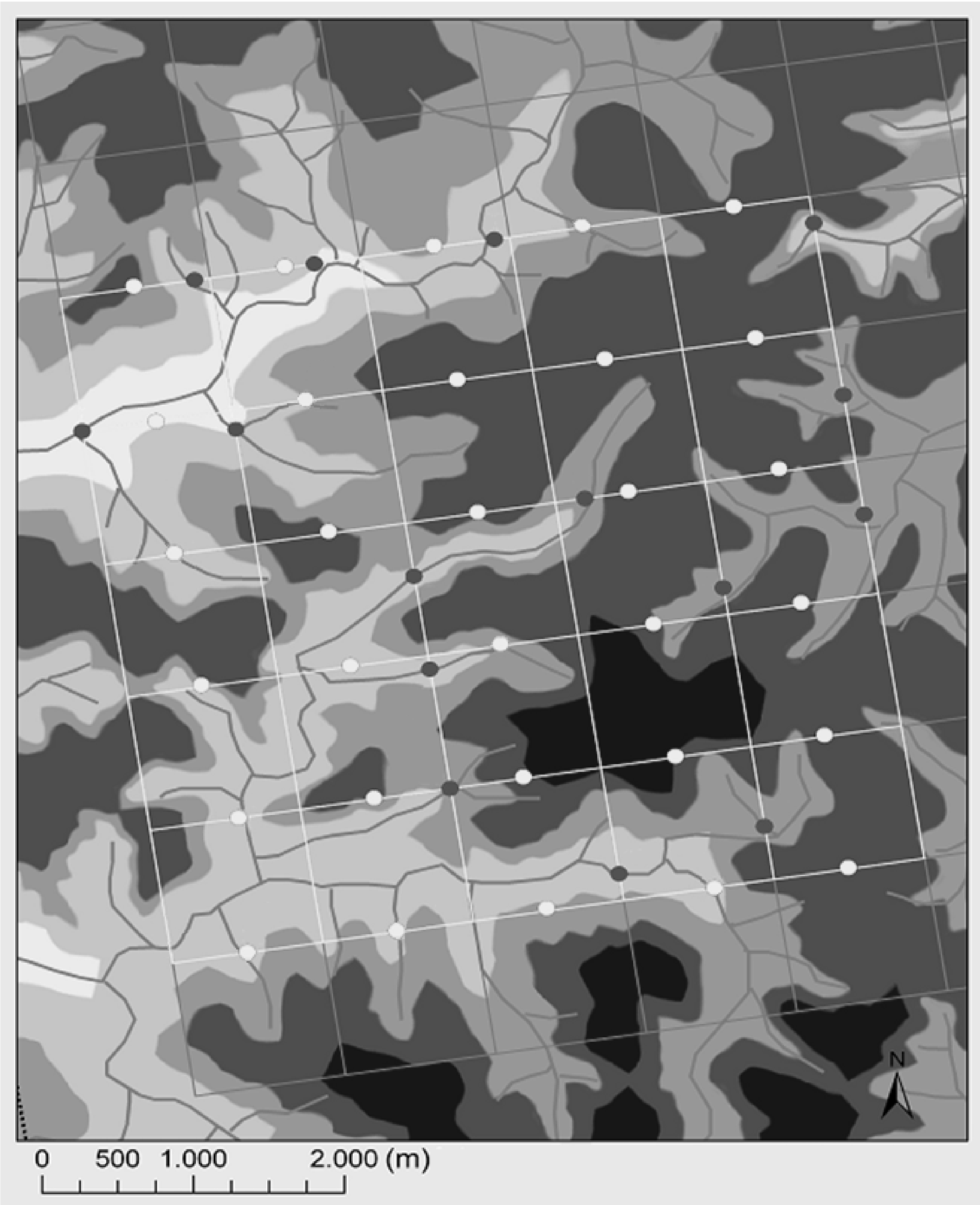


Fig. 2.

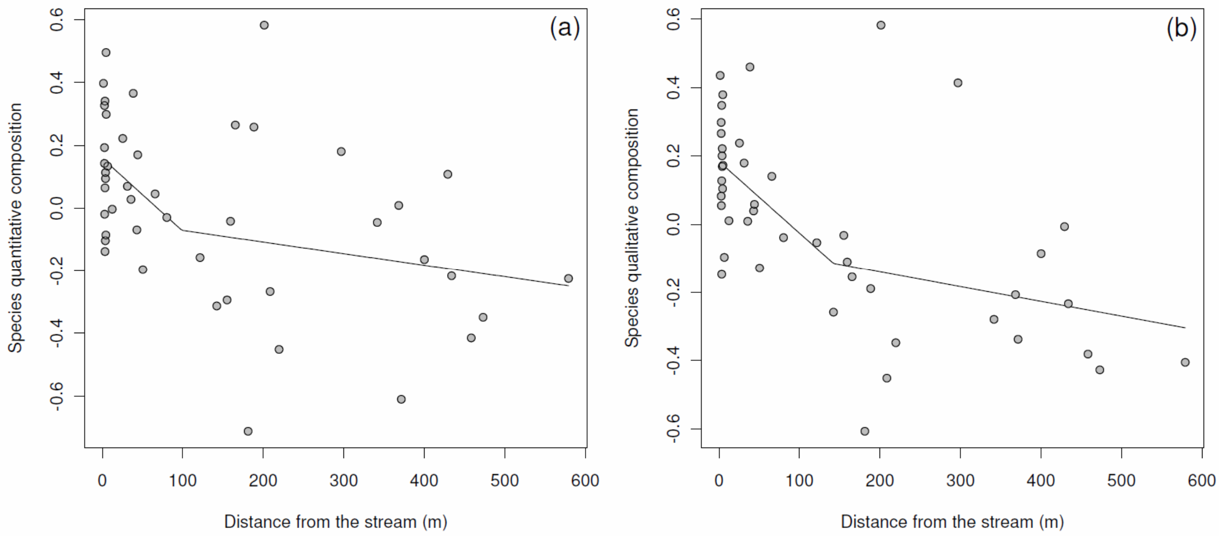
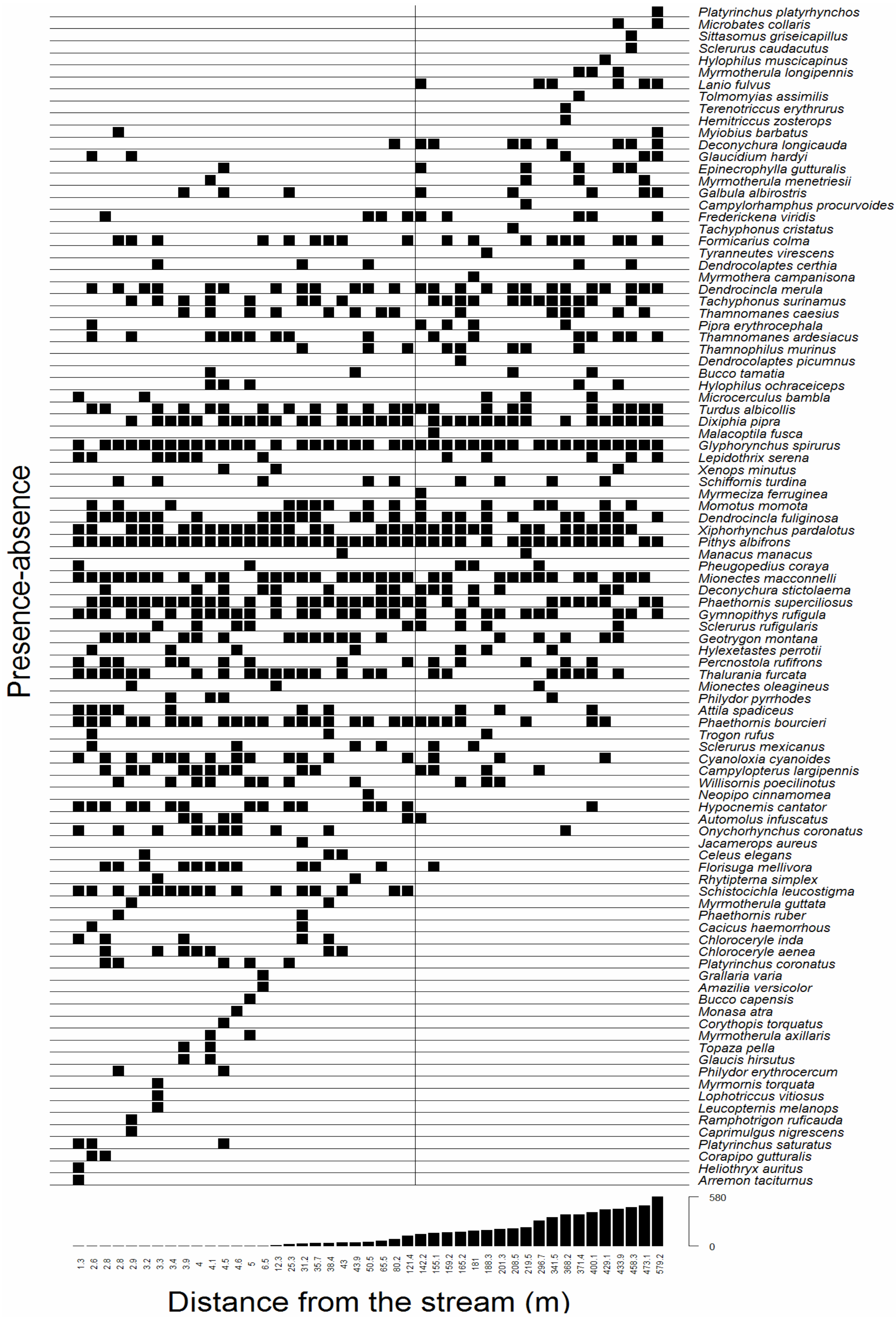

(a)
Species quantitative composition
Distance from the stream (m)
(b)
Species qualitative composition
Distance from the stream (m)

Fig. 3.



Presence-absence
Platyrinchus platyrhynchos
Microbates collaris
Sittasomus griseicapillus
Sclerurus caudacutus
Hylophilus muscicapinus
Myrmotherula longipennis
Lanio fulvus
Tolmomyias assimilis
Terenotriccus erythrurus
Hemitriccus zosterops
Myiobius barbatus
Deconychura longicauda
Glaucidium hardyi
Epinecrophylla gutturalis
Myrmotherula menetriesii
Galbula albirostris
Campylorhamphus procurvoides
Frederickena viridis
Tachyphonus cristatus
Formicarius colma
Tyranneutes virescens
Dendrocolaptes certhia
Myrmothera campanisona
Dendrocincla merula
Tachyphonus surinamus
Thamnomanes caesius
Pipra erythrocephala
Thamnomanes ardesiacus
Thamnophilus murinus
Dendrocolaptes picumnus
Bucco tamatia
Hylophilus ochraceiceps
Microcerculus bambla
Turdus albicollis
Dixiphia pipra
Malacoptila fusca
Glyphorynchus spirurus
Lepidothrix serena
Xenops minutus
Schiffornis turdina
Myrmeciza ferruginea
Momotus momota
Dendrocincla fuliginosa
Xiphorhynchus pardalotus
Pithys albifrons
Manacus manacus
Pheugopedius coraya
Mionectes macconnelli
Deconychura stictolaema
Phaethornis superciliosus
Gymnopithys rufigula
Sclerurus rufigularis
Geotrygon montana
Hylexetastes perrotii
Percnostola rufifrons
Thalurania furcata
Mionectes oleagineus
Philydor pyrrhodes
Attila spadiceus
Phaethornis bourcieri
Trogon rufus
Sclerurus mexicanus
Cyanoloxia cyanoides
Campylopterus largipennis
Willisornis poecilinotus
Neopipo cinnamomea
Hypocnemis cantator
Automolus infuscatus
Onychorhynchus coronatus
Jacamerops aureus
Celeus elegans
Florisuga mellivora
Rhytipterna simplex
Schistocichla leucostigma
Myrmotherula guttata
Phaethornis ruber
Cacicus haemorrhous
Chloroceryle inda
Chloroceryle aenea
Platyrinchus coronatus
Grallaria varia
Amazilia versicolor
Bucco capensis
Monasa atra
Corythopis torquatus
Myrmotherula axillaris
Topaza pella
Glaucis hirsutus
Philydor erythrocercum
Myrmornis torquata
Lophotriccus vitiosus
Leucopternis melanops
Ramphotrigon ruficauda
Caprimulgus nigrescens
Platyrinchus saturatus
Corapipo gutturalis
Heliothryx auritus
Arremon taciturnus
580
0
1.3 2.6 2.8 2.8 2.9 3.2 3.3 3.4 3.9 4 4.1 4.5 4.6 5 6.5 12.3 25.3 31.2 35.7 38.4 43 43.9 50.5 65.5 80.2 121.4 142.2 155.1 159.2 165.2 181 188.3 201.3 208.5 219.5 296.7 341.5 368.2 371.4 400.1 429.1 433.9 458.3 473.1 579.2
Distance from the stream (m)

Table 1. List of understory bird species recorded in the Reserva Ducke, Manaus, Brazil. OR = number of riparian plots where the species was recorded (n = 26), TR = total number of individuals captured in riparian plots, OU = number of non-riparian plots where the species was recorded (n = 19), TU = total number of individuals captured in non-riparian plots, T = total number of individuals captured, summed over riparian and non-riparian plots (n = 45). Species names follow CBRO (2009).

Species	OR	TR	OU	TU	T
Accipitridae					
Leucopternis melanops	1	1			1
Alcedinidae					
Chloroceryle aenea	7	7			7
Chloroceryle inda	5	5			5
Bucconidae					
Bucco capensis	1	1			1
Bucco tamatia	2	2	2	2	4
Malacoptila fusca			1	1	1
Monasa atra	1	1			1
Caprimulgidae					
Caprimulgus nigrescens	1	1			1
Cardinalidae					
Cyanoloxia cyanoides	13	20	3	3	23
Columbidae					
Geotrygon montana	14	20	5	8	28
Dendrocolaptidae					
Campylorhamphus procurvoides			1	1	1
Deconychura longicauda	1	1	8	12	13
Deconychura stictolaema	8	10	7	8	18
Dendrocincla fuliginosa	15	21	10	22	43
Dendrocincla merula	12	21	13	20	41
Dendrocolaptes certhia	3	3	2	2	5
Dendrocolaptes picumnus			1	1	1
Glyphorynchus spirurus	22	67	18	46	113
Hylexetastes perrotii	4	5	3	4	9
Sittasomus griseicapillus			1	1	1
Xiphorhynchus pardalotus	19	39	14	25	64
Emberizidae					
Arremon taciturnus	1	2			2
Formicariidae					
Formicarius colma	9	11	9	13	24

Furnariidae					
Automolus infuscatus	5	7	1	1	8
Philydor erythrocercum	2	2			2
Philydor pyrrhodes	3	3	1	1	4
Xenops minutus	2	4	1	1	5
Galbulidae					
Galbula albirostris	3	7	5	9	16
Jacamerops aureus	1	1			1
Grallariidae					
Grallaria varia	1	1			1
Myrmothera campanisona			1	1	1
Icteridae					
Cacicus haemorrhous	2	3			3
Momotidae					
Momotus momota	9	10	6	7	17
Picidae					
Celeus elegans	3	3			3
Pipridae					
Corapipo gutturalis	2	2			2
Dixiphia pipra	18	37	15	26	63
Lepidothrix serena	7	10	5	5	15
Manacus manacus	1	1	1	1	2
Pipra erythrocephala	1	1	4	5	6
Tyranneutes virescens			1	1	1
Polioptilidae					
Microbates collaris			2	2	2
Scleruridae					
Sclerurus caudacutus			1	1	1
Sclerurus mexicanus	4	5	2	2	7
Sclerurus rufigularis	5	6	4	5	11
Strigidae					
Glaucidium hardyi	2	2	3	3	5
Thamnophilidae					
Epinecrophylla gutturalis	1	1	5	7	8
Frederickena viridis	4	7	5	6	13
Gymnopithys rufigula	18	45	10	22	67
Hypocnemis cantator	14	32	1	1	33
Myrmeciza ferruginea			1	2	2
Myrmornis torquata	1	1			1
Myrmotherula axillaris	2	2			2
Myrmotherula guttata	2	5			5
Myrmotherula longipennis			3	5	5
Myrmotherula menetriesii	1	1	3	4	5
Percnostola rufifrons	9	16	5	14	30

Pithys albifrons	26	135	16	60	195
Schistocichla leucostigma	16	25			25
Thamnomanes ardesiacus	9	21	7	17	38
Thamnomanes caesius	8	9	6	7	16
Thamnophilus murinus	3	5	5	10	15
Willisornis poecilinotus	8	13	3	4	17
Thraupidae					
Lanio fulvus			6	7	7
Tachyphonus cristatus			1	1	1
Tachyphonus surinamus	8	12	12	19	31
Tityridae					
Schiffornis turdina	5	7	4	4	11
Trochilidae					
Amazilia versicolor	1	1			1
Campylopterus largipennis	10	12	4	5	17
Florisuga mellivora	11	16	1	1	17
Glaucis hirsutus	2	2			2
Heliothryx auritus	1	1			1
Phaethornis bourcieri	20	36	7	10	46
Phaethornis ruber	2	2			2
Phaethornis superciliosus	22	61	10	11	72
Thalurania furcata	17	34	7	7	41
Topaza pella	2	2			2
Troglodytidae					
Microcerculus bambla	2	3	3	3	6
Pheugopedius coraya	2	4	3	3	7
Trogonidae					
Trogon rufus	2	2	1	1	3
Turdidae					
Turdus albicollis	13	16	10	12	28
Tyrannidae					
Attila spadiceus	7	10	3	4	14
Corythopis torquatus	1	1			1
Hemitriccus zosterops			1	1	1
Lophotriccus vitiosus	1	1			1
Mionectes macconnelli	21	61	12	25	86
Mionectes oleagineus	2	2	1	1	3
Myiobius barbatus	1	1	1	1	2
Neopipo cinnamomea	1	1			1
Onychorhynchus coronatus	9	13	1	1	14
Platyrinchus coronatus	5	7			7
Platyrinchus platyrhynchos			1	1	1
Platyrinchus saturatus	3	4			4
Ramphotrigon ruficauda	1	1			1

Rhytipterna simplex	2	2			2
Terenotriccus erythrurus			1	1	1
Tolmomyias assimilis			1	1	1
Vireonidae					
Hylophilus muscicapinus			1	2	2
Hylophilus ochraceiceps	3	4	2	5	9

Conclusões

- A estimativa da largura da zona ripária não depende apenas do local do estudo, do grupo taxonômico ou da largura do riacho, mas também do atributo da comunidade considerado. A composição qualitativa de espécies provavelmente é o atributo da comunidade mais útil para estabelecer a distância em relação ao riacho que delimita a assembléia de espécies associadas a zonas ripárias.
- A distribuição de aves de sub-bosque esteve relacionada com a distância do riacho e com o conteúdo de argila, mas não esteve relacionada com a inclinação do terreno. Apesar de distância do riacho apresentar correlação com o conteúdo de argila na Reserva Ducke, o padrão de distribuição de aves em locais próximos e afastados do riacho é consistente entre estudos realizados em diversas geomorfologias, tanto em regiões temperadas quanto em regiões tropicais, o que indica um efeito da distância do riacho *per se*.
- Para que o Código Florestal brasileiro seja eficiente em cumprir o seu papel de proteger a biodiversidade associada a zonas ripárias, a largura das Áreas de Preservação Permanente (APPs) deve ser aumentada consideravelmente ou as APPs devem ser associadas de forma contígua a outras áreas de conservação.

Apêndices

PG·ECO·INPA
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Ministério da Ciência e Tecnologia
BRASIL UM PAÍS DE TODOS
GOVERNO FEDERAL

AULA DE QUALIFICAÇÃO

PARECER

Aluno(a): ANDERSON SALDANHA BUENO
Nível: MESTRADO
Orientador(a): WILLIAM ERNEST MAGNUSSON
Co-Orientador(a): TÂNIA SANAIOTTI

Título:

"Distribuição de aves de sub-bosque em uma floresta de terra firme na Amazônia Central".

BANCA JULGADORA:

TITULARES:
Marcelo Menin (UFAM)
Mario Cohn-Haft (INPA)
Luiza Magalli Henriques (INPA)

SUPLENTES:
Albertina Lima (INPA)
Regina Luizão (INPA)

EXAMINADORES	PARECER		ASSINATURA
Marcelo Menin (UFAM)	(X) Aprovado	( ) Reprovado	[assinatura]
Mario Cohn-Haft (INPA)	(X) Aprovado	( ) Reprovado	[assinatura]
Luiza Magalli Henriques (INPA)	(X) Aprovado	( ) Reprovado	[assinatura]
Albertina Lima (INPA)	( ) Aprovado	( ) Reprovado	
Regina Luizão (INPA)	( ) Aprovado	( ) Reprovado	

Manaus(AM), 30 de março de 2009

OBS: A banca recomenda que o aluno se aprofunde na literatura regional e que reflita se suas amostragens serão suficientes para responder seus objetivos ecológicos propostos.

PROGRAMA DE PÓS-GRADUAÇÃO EM BIOLOGIA TROPICAL E RECURSOS NATURAIS – PIPG BTRN
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA PPG-ECO/INPA
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Instituto Nacional de Pesquisas da Amazônia - INPA
Programa de Pós-graduação em Ecologia

Avaliação de dissertação de mestrado

Título: **Distribuição de aves de sub-bosque ao longo de gradientes ambientais na Amazônia central**

Aluno: **ANDERSON SALDANHA BUENO**

Orientador: **William Ernest Magnusson** Co-orientador: **-----**

Avaliador: **James J. Roper**

Por favor, marque a alternativa que considerar mais apropriada para cada ítem abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	(X)	( )	( )	( )
Revisão bibliográfica	(X)	( )	( )	( )
Desenho amostral/experimental	(X)	( )	( )	( )
Metodologia	(X)	( )	( )	( )
Resultados	( )	(X)	( )	( )
Discussão e conclusões	( )	(X)	( )	( )
Formatação e estilo texto	( )	(X)	( )	( )
Potencial para publicação em periódico(s) indexado(s)	(X)	( )	( )	( )

PARECER FINAL

( ) **Aprovada**

(X) **Aprovada com correções** (indica que as modificações mesmo extensas podem ser incluídas a juízo do orientador)

( ) **Necessita revisão** (indica que há necessidade de uma reformulação do trabalho e que o revisor quer avaliar a nova versão do trabalho antes de emitir uma decisão final)

( ) **Reprovada** (indica que o trabalho não tem o nível de qualidade adequado para uma tese)

Curitiba, 18 de abril de 2010,

Local **Data** **Assinatura**

Comentários e sugestões podem ser enviados como uma continuação desta ficha, como arquivo separado ou como anotações no texto impresso ou digital da tese. Por favor, envie a ficha assinada, bem como a cópia anotada da tese e/ou arquivo de comentários por e-mail para pgecologia@gmail.com **e** claudiakeller23@gmail.com **ou por correio ao endereço abaixo. O envio por e-mail é preferível ao envio por correio. Uma cópia digital de sua assinatura será válida.**

Endereço para envio de correspondência:

Claudia Keller
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Instituto Nacional de Pesquisas da Amazônia - INPA
Programa de Pós-graduação em Ecologia

Avaliação de dissertação de mestrado

Título: **Distribuição de aves de sub-bosque ao longo de gradientes ambientais na Amazônia central**

Aluno: **ANDERSON SALDANHA BUENO**

Orientador: **William Ernest Magnusson** Co-orientador: **-----**

Avaliador: **Philip Stouffer**

Por favor, marque a alternativa que considerar mais apropriada para cada ítem abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
Relevância do estudo	(x)	( )	( )	( )
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Potencial para publicação em periódico(s) indexado(s)	( )	( )	(x)	( )

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Baton Rouge, Louisiana, Estados Unidos, _20 de abril de 2010_, Philip C Stouffer _
Local **Data** **Assinatura**

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Avaliação de dissertação de mestrado

Título: **Distribuição de aves de sub-bosque ao longo de gradientes ambientais na Amazônia central**

Aluno: **ANDERSON SALDANHA BUENO**

Orientador: **William Ernest Magnusson** Co-orientador: **-----**

Avaliador: **Marina Anciães**

Por favor, marque a alternativa que considerar mais apropriada para cada ítem abaixo, e marque seu parecer final no quadro abaixo

	Muito bom	Bom	Necessita revisão	Reprovado
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( ) **Reprovada** (indica que o trabalho não tem o nível de qualidade adequado para uma tese)

Florianopolis, 08 de abril de 2010

Local Data **Assinatura**

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ATA DA DEFESA PÚBLICA DA DISSERTAÇÃO DE MESTRADO DO PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA DO INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA.

Aos 29 dias do mês de julho do ano de 2010, às 10:00 horas, na sala de aula do Programa de Pós-Graduação em Ecologia PPG-ECO/INPA, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: **Dr. Bruce Walker Nelson**, do Instituto Nacional de Pesquisas da Amazônia, **Dr. Thierry Ray Jehlen Gasnier** , da Universidade Federal do Amazonas, **Dr. Renato Cintra Soares**, do Instituto Nacional de Pesquisas da Amazônia, tendo como suplentes o Dr. George Henrique Rebêlo, do Instituto Nacional de Pesquisas da Amazônia, e o Dr. Paulo Estefano Dineli Bobrowiec, do Instituto Nacional de Pesquisas da Amazônia, sob a presidência do(a) primeiro(a), a fim de proceder a argüição pública da **DISSERTAÇÃO DE MESTRADO** de **ANDERSON SALDANHA BUENO**, intitulada "Distribuição de aves de sub-bosque ao longo de gradientes ambientais na Amazônia central", orientado pelo Dr. William Ernest Magnusson e co-orientação da Dra. Tânia Margarete Sanaiotti, do Instituto Nacional de Pesquisas da Amazônia.
Após a exposição, o(a) discente foi argüido(a) oralmente pelos membros da Comissão Examinadora, tendo recebido o conceito final:

[X] APROVADO(A) [ ] REPROVADO(A)

[ ] POR UNANIMIDADE [X] POR MAIORIA

Nada mais havendo, foi lavrada a presente ata, que, após lida e aprovada, foi assinada pelos membros da Comissão Examinadora.

Dr(a). Bruce Walker Nelson ______________________

Dr(a). Thierry Ray Jehlen Gasnier ______________________

Dr(a). Renato Cintra Soares ______________________

pl ______________________
Claudia Keller
Coordenação do PPG-ECO/INPA

____
Beatriz Rochi Teles
Coordenação de Capacitação do INPA