INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA – INPA
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA

EFEITOS DA ESTRUTURA DA FLORESTA DE TERRA-FIRME NO USO DE HABITAT EM CORUJAS (AVES, STRIGIFORMES) NA AMAZÔNIA CENTRAL

PRISCILLA ESCLARSKI
Manaus, Amazonas
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Orientador: **Dr. Renato Cintra**

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

Manaus, Amazonas
Maio, 2014

BANCA EXAMINADORA DA DEFESA ORAL PÚBLICA

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Esclarski, Priscilla
Efeitos da estrutura da floresta de Terra-Firme no uso de habitat em corujas (Aves, Strigiformes) na Amazônia Central. / Priscilla Esclarski. --- Manaus : [s.n], 2014.
x, 61f. : il. color.
Dissertação (Mestrado) --- INPA, Manaus, 2014.
Orientador : Renato Cintra.
Área de concentração : Ecologia.
1. Strigidae. 2. Heterogeneidade ambiental. 3. Estrutura da floresta. 4. Uso de habitat. 5. Amazônia. I. Título.

Sinopse: Este trabalho teve como objetivo Analisar como a heterogeneidade ambiental, determinada por diversos fatores estruturantes da floresta, influencia no uso do habitat pelas corujas em Floresta de Terra-firme na Amazônia Central.

Palavras-chave: Heterogeneidade ambiental, corujas, *Pulsatrix perspicilata*, *Lophostrix cristata*, *Megascops watsonii*, *Glaucidium hardyi,* componentes estruturais da floresta, uso de habitat, aves.

A Deus por estar sempre presente em minha vida,
ao meu pais primeiras e eternas luzes da minha
vida, Aparício e Leocádia pela confiança e a
paciência nestes dois últimos anos.

“Se não puder voar, corra. Se não puder correr, ande.
Se não puder andar, rasteje, mas continue em frente de
qualquer jeito.” (Martin Luther King)

AGRADECIMENTOS

Ao meu orientador Dr. Renato Cintra por todo apoio, confiança, ensinamentos, por toda a paciência e a grande ajuda com o desenvolvimento do projeto, as análises estatísticas e a escrita do manuscrito além da maravilhosa oportunidade de estudar as corujas Amazônicas.

Ao Instituto Nacional de Pesquisas da Amazônia (INPA), em especial a coordenação, em nome das pesquisadoras Dra. Flavia Costa e Dra. Claudia Keller, e ao corpo de pesquisadores docentes do Programa de Pós-graduação em Ecologia. Agradeço todo o suporte durante o curso de mestrado e pelas extraordinárias aulas. Ao Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) pela bolsa de mestrado, ao Programa de Pesquisas Ecologicas de Longa Duração (PELD) e ao Programa de Pesquisas em Biodiversidade (PPBio) por todo o apoio logístico e estrutural.

Aos amigos Rafael Soave Guerta, Glauco Kohler, Matheus Montefusco and Raiclicia Morais e especialmente aos auxiliares de campo Sr. Ayres e Sra Ivanery, pelas trocas de experiências, ajuda em campo, no trabalho braçal e todo o apoio possível.

Aos corretores do meu pré-projeto de dissertação e aos membros titulares e suplente da banca da minha aula de qualificação. Agradeço também a equipe tradutora e revisora do manuscrito.

À todos que me apoiaram emocionalmente durante estes dois anos. Agradeço em especial aos que me acolheram na chegada a Manaus Sr Edino e Nena Moraes, aos meus amigos, vizinhos e parceiros de birdwatching Felipe Bittioli, Renata Lima-Gomes, Marina Maximiano, Leandro Moraes, Vanessa Neves e Marcelo Barreiros, que se tornaram uma verdadeira família em Manaus. Agradeço por todo o suporte nos momentos de estresse e pelas longas discussões científicas que, com certeza, engradeceram nossos trabalhos.

À todas as pessoas que conheci durante minha fantástica estadia na Amazônia. Agradeço a minha turma de mestrado: Fernando, Gilmar, Isabel, Luiza, Karina, Lorena, Natália, Vanessa, Leo, Joselândio, Layon, Cris, Humberto, Eveline, Rafael Jorge, Líliam, Pio, Rafael Guerta, Randolpho, Yuri e Jefferson.

À minha família e aos meus amigos da minha querida terra sulina.

Em especial aos meus pais, Aparício e Leocádia, por toda a força que me deram para continuar em frente, mesmo longe de casa, por acreditarem em mim, apoiarem os meus sonhos e sempre me dar preciosos conselhos.

Aos meus amigos que acompanharam de perto essa breve jornada e por sempre estarem dispostos a me escutar.

RESUMO

As corujas, apesar atuarem na regulação de presas e controle biológico, representam um grupo ainda pouco estudado quanto à distribuição e abundância, principalmente as espécies neotropicais. Os componentes da estrutura da floresta têm sido usados para explicar padrões de uso de habitat e a estrutura de comunidades, porém, os estudos relacionando tais componentes às corujas concentram-se em espécies do hemisfério norte. O presente estudo analisou se os componentes de estrutura da floresta influenciam o uso de habitat (ocorrência e abundância) por seis espécies de corujas em uma floresta de Terra-Firme na Amazônia Central. Para amostrar ocorrência e abundância foi usado o método playback, em 30 pontos distantes entre si em 1 km, nos meses de outubro e novembro de 2012. Em análise de regressão linear múltipla obtivemos relação entre a abundância de quatro espécies de corujas e componentes da estrutura da floresta associados à disponibilidade de alimento; *Glaucidium hardyi* (caburé-da-amazônia) teve maior abundância conforme aumentou a distância do igarapé com p=0,023, já *Megascops watsonii* (corujinha-orelhuda) foi mais abundante com a diminuição da profundidade da serrapilheira com p=0,045, a abundância de *Lophostrix cristata* (coruja-de-crista) e *Pulsatrix perspicillata* (murucututu) aumentou juntamente com a abundância de troncos mortos no chão com p=0,042, e p=0,009 respectivamente. Já na regressão logística múltipla obtivemos relação somente entre a ocorrência *Pulsatrix perspicillata* (muucututu) e troncos mortos no chão com p=0,050. Assim, a influência dos componentes da estrutura da floresta difere de acordo com a espécie de coruja, demonstrando as diferenças interespecíficas no uso de micro-habitats, porém, reflete a importância da disponibilidade de recurso alimentar na percepção de habitat ideal pelas corujas.

Palavras-chave: Heterogeneidade ambiental, corujas, *Pulsatrix perspicilata*, *Lophostrix cristata*, *Megascops watsonii*, *Glaucidium hardyi*, estrutura da floresta, uso de habitat, aves.

ABSTRACT

Owls, despite a well-established role in prey regulation and biological control, are a poorly-studied avian group. For Neotropical species distribution and abundance are especially poorly known. Structural components of forests have been used to explain patterns of owl habitat use and community structure, but such analyses have largely focused on species in the northern hemisphere. The present study examines whether components of forest structure influence habitat use (occurrence and abundance) for six species of owls in an upland Terra firme forest in central Amazonian Brazil. Between October and November 2012, a playback method was used to sample occurrence and abundance in 30 points, each separated from the next by 1km. Multiple linear models revealed relationships between the abundance of four owl species and components of forest structure associated with food availability: *Glaucidium hardyi* (Amazonian Pygmy Owl) had greater abundance as increased of the distance to nearest creek, with $p = 0.023$, *Megascops watsonii* (Northern Tawny-bellied Screech Owl) was more abundant with decreasing leaf litter depth, with $p = 0.045$, the abundance of the *Lophostrix cristata* (Crested Owl) and *Pulsatrix perspicillata* (Spectacled Owl) increased along with the abundance of dead fallen trunks on forest floor, with $p = 0.042$, end $p = 0.009$, respectively. A multiple logistic regression also revealed a significant association ($p = 0.050$) between the occurrence of *Pulsatrix perspicillata* (Spectacled Owl) and abundance of dead fallen trunks on forest floor. The influence of the components of forest structure differs according to the owl species, demonstrating interspecific differences in micro-habitat use, and reflecting the importance of food resource availability in owl habitat choice.

Key words: Environmental heterogeneity, owls, *Pulsatrix perspicilata Lophostrix cristata, Megascops watsonii, Glaucidium hardyi,* forest structure, habitat use, birds.

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INTRODUÇÃO GERAL

Heterogeneidade foi definida como o grau de descontinuidade das condições ambientais numa paisagem (Morrison, 1998). Tais condições variam de acordo com a composição e estrutura da vegetação ou de acordo com o fluxo de energia e demais recursos essenciais para determinado organismo. Nos últimos anos, a heterogeneidade ambiental tem sido adotada para explicar padrões de uso de habitat e estrutura de comunidades, a partir do conceito de habitat e nicho (Day, 2000; Gaston, 2000; Allen & Gillooly, 2006).

Dentre muitos conceitos sobre hábitat e nicho, adotamos o que mais se adéqua aos termos propostos pelo estudo. Assim, hábitat é, por conceito, o local onde o organismo vive, bem como as condições que permitem a sobrevivência deste organismo. Nicho, por sua vez, é a descrição das condições do habitat que satisfazem os requerimentos mínimos da espécie de forma que, a taxa de natalidade seja igual ou maior que a taxa de mortalidade, considerando os impactos da população nas condições ambientais (Chase & Leibold, 2003).

Torna-se possível inferir sobre quais fatores ecológicos e evolutivos determinam os padrões de ocupação e permanência de habitat, somente a partir do momento em que se compreende como os organismos se distribuem (Ganey & Balda, 1994; Ricklefs, 2004; Graham et al., 2006). De acordo com Enfjäll & Leimar (2009) a capacidade de perceber e adquirir informações sobre as diferentes características do ambiente varia muito entre organismos, porém todos acompanham as mudanças na localização de habitats adequados pela dispersão. A percepção de habitat ideal depende de diferentes fatores, incluindo características morfológicas da espécie (Srugley Chai, 1990; Hughes et al, 2007), estrutura social (Yaber e Rabenold, 2002; Le Galliard et al., 2005) e da história de vida (Levin, 1984), bem como fatores ambientais, como clima (Best et al., 2007; Hughes et al., 2007), estrutura da paisagem (Kuch & Idelberger, 2005) e abundância de indivíduos da mesma espécie no local (Fletcher, 2006, 2007).

A heterogeneidade ambiental influencia direta ou indiretamente a distribuição espacial, riqueza e a composição da avifauna, uma vez que para a escolha de um local para viver, uma série de exigências devem ser preenchidas. Tais exigências são influenciadas pela complexa estrutura da floresta, como diversidade, densidade e estrutura da vegetação, tipo de floresta (alta ou baixa), e nível de sucessão ecológica em que se encontra (Hildén, 1965; Orians, 1969; Wiens, 1969; Whitacre et al., 1990; Robinson, 1994; Thiollay; 1996, Amaral, 2007).

A perda de elementos do habitat também tem efeito direto em aves. Alguns componentes estruturais da floresta, como grande número de troncos caídos no chão e áreas com maiores densidades de árvores, promovem diferentes micro-habitats para forrageio e são imprescindíveis para escolha de locais para nidificação (Rodewald e Yahner, 2000; Slaght et al., 2013). Mesmo assim, o efeito da variação espacial dos componentes estruturais da floresta no uso do habitat por aves, têm sido pouco estudado (Enfjäll & Leimar, 2009). Contudo são importantes para entender melhor o funcionamento das interações entre os organismos, a organização e a estrutura de populações e das comunidades ecológicas (Begon, 1986; Ricklefs, 2001). As mudanças na disponibilidade de alimento, de locais para nidificação e abrigo são consequência da variação espacial nas características estruturais dos ambientes muito relevantes para a sobrevivência das aves e cada uma pode influenciar de maneira diferente a estrutura da comunidade (Orians, 1969; Wiens, 1969; Cintra & Naka, 2012).

Diversos estudos já relacionaram fatores componentes de estrutura da floresta à ocorrência e abundância de aves (Borges et al, 2004; Barros & Cintra, 2009; Cintra et al., 2006). Rice et al (1983) sugeriram que a seleção de habitat por aves pode variar sazonalmente de acordo com a disponibilidade de alimento, e que, ...a profundidade... de folhiço também podem ser importantes na escolha de um habitat, por afetar a densidade de presas das aves que forrageiam no chão.

Padrões de distribuição e abundância de aves noturnas foram relacionados com componentes ambientais e sua alimentação (Kavanagh et al., 1995). Segundo Martin (1998) as aves possuem "preferências por micro-habitats", o que reflete a escolha de um local para uso e permanência. Para ambientes de floresta tropical, pouco se sabe da biologia de algumas espécies, bem como das exigências de habitats, estrutura social e outros fatores determinantes de presença e abundância (Thiollay, 2002). Devido a isso, qualquer fator determinante da estrutura da comunidade fica difuso na riqueza, complexidade e heterogeneidade das comunidades de aves tropicais (Cintra & Naka, 2012).

A ecologia de aves de rapina neotropicais é pouco conhecida, em especial as que dependem da estrutura da floresta para escolha de seus habitats ou territórios (Throstom, 2000). As aves noturnas tem sua biologia pouco conhecida, principalmente em relação ao uso do habitat e aos fatores componentes de estrutura da floresta que influenciam diretamente na ocupação e permanência de determinada espécie (Amaral, 2007).

A maioria dos estudos que relaciona componentes da estrutura da floresta à ocorrência de aves predadoras, como corujas, foram realizados no hemisfério norte (p. e. : estudos de La Haye & Gutiérrez com *Strix occidentalis*, e de McCallum com a *Megascops flammeolus*)

No Brasil, em áreas de Mata Atlântica verificou-se diferenças significativas na composição da comunidade de corujas em matas primarias e secundárias (Amaral, 2007). Na floresta amazônica, são escassos os estudos que relacionam a estrutura de habitat com a distribuição, abundância e o comportamento de corujas. Sberze et al. (2010) realizaram um estudo com aves noturnas na Amazônia Brasileira onde analisaram o uso de habitat em Floresta Primária e Secundária por aves noturnas, dentre todas as espécies somente duas corujas foram analisadas, a *Lophostrix cristata* (coruja-de-crista) e *Glaucidium hardyi* (caburé-da-amazônia), cujas ocorrências não foram influenciadas por nenhum dos dois tipos de floresta.

Willis (1977) elaborou uma lista preliminar de aves da Amazônia Central, em trabalho realizado somente na parte leste da Reserva Ducke (RFAD), Manaus; nesta lista constam quatro espécies de corujas com *Megascops choliba* (corujinha-do-mato), registrada em ambientes de borda, de capoeiras e áreas abertas; *Megascops watsonii* (corujinha-orelhuda) em áreas de florestas de Terra firme e com igarapés; *Pulsatrix perspicillata* (murucututu) e *Glaucidium hardyi* (caburé-da-amazônia) em floresta de Terra firme e também bordas, clareiras, plantações altas, nas proximidades de igarapés.

Na RFAD, um estudo recente avaliou os efeitos de componentes estruturais da floresta no uso do habitat por quatro espécies de corujas, e descreveu, de forma geral, a distribuição espacial de seis espécies; a partir de registros em 72 parcelas espaçadas entre si por 1 km, e distribuídas em um grande escala espacial de 64 km^2 (Barros & Cintra, 2009). Os autores mostraram que *Lophostrix cristata* (coruja-de-crista) e *Glaucidium hardyi* (caburé-da-amazônia) apresentaram um padrão de distribuição espacial ao longo do platô central que atravessa a RFAD de norte a sul. *Megascops watsonii* (corujinha-orelhuda) apresentou distribuição concentrada mais a sudeste e as demais corujas (*Strix huhula* (coruja-preta), *Strix virgata* (coruja-do-mato), *Pulsatrix perspicillata* (murucututu)) tiveram baixa frequência de ocorrência, portanto, não entraram nas análises.

Além disso, Barros & Cintra (2009), encontraram um efeito da abundância de troncos mortos, mas ainda eretos na variação da densidade para duas espécies (*Lophostrix cristata* (coruja-de-crita) e *Megascops watsonii* (corujinha-orelhuda)). *Megascops watsonii* (corujinha-orelhuda) foi mais frequente em áreas com grande abundância de árvores. *Glaucidium hardyi* (caburé-da-amazônia), aparentemente prefere usar áreas na floresta próximas a igarapés. Nesse estudo os autores não chegaram a usar a técnica de "*playback*", um método complementar ao ponto de escuta (Granzinolli & Motta-Junior, 2010), a qual ajuda a aumentar detecções e minimizar registros de falsas ausências (Makenzie et al., 2002). Entretanto, mesmo subestimando os números de registros por não usar essa técnica, ainda assim o estudo mostrou padrões bem claros de distribuição espacial e influência da heterogeneidade do ambiente na diferentes espécies de corujas (Barros & Cintra, 2009). Como as espécies têm tamanho do corpo e provavelmente tamanho de área de uso diferente, além de densidades diferentes, seria interessante avaliar em escalas espaciais menores se ocorre similar padrão de distribuição espacial que o encontrado por Barros & Cintra (2009). O diferencial do presente estudo é descrever a distribuição espacial em escala espacial menor (25 km^2) ou cerca de metade do número de parcelas, mas mantendo o mesmo desenho amostral, com o mesmo espaçamento de 1 km entre as parcelas, com o dobro de visitas às parcelas e usando técnicas adicionais de detecção.

Especificamente, o presente estudo analisou como sete componentes de estrutura da floresta: (1) profundidade de folhiço, (2) densidade de árvores vivas, (3) troncos mortos em pé, (4) troncos mortos no chão, (5) abertura de dossel, (6) elevação do terreno e (7) distância do igarapé, influenciam a frequência de uso de habitat (ocorrência e abundância) por corujas em uma floresta de Terra-Firme na Amazônia Central. Teve como espécies focais *Glaucídium hardyi* (caburé-da-amazônia), *Megascops watsonii* (corujinha-orelhuda), *Strix virgata* (coruja-do-mato), *Strix huhula* (coruja-preta), *Lophostrix cristata* (coruja-de-crista) e *Pulsatrix perspicillata* (murucututu), utilizando o método de playback, que além de ser mais acurado, foi pouco testado em corujas de ambientes florestais neotropicais.

A nossa hipótese é de que a variação espacial em componentes de estrutura da floresta influencia de maneira distinta a distribuição espacial e o uso do micro-hábitat pelas espécies de corujas. As previsões são de que a abundância e frequência de ocorrência das espécies de corujas aumenta com a presença de áreas mais planas na floresta, com o aumento na densidade da vegetação, na profundidade da serapilheira, na abundância de troncos mortos no chão e abertura do dossel, e com a proximidade de áreas mais úmidas, ou próximas dos corpos d'água.

Considerando alguns aspectos possivelmente importantes para nossas espécies focais, como por exemplo, hábitos alimentares conhecidos e locais de preferência para abrigo e construção de ninhos, a nossa hipótese prevê: 1) aumento na densidade de *Glaucidium hardyi* (caburé-da-amazônia) com aumento na abertura de dossel; 2) aumento na densidade de *Megascops watsonii* (corujinha-orelhuda) com diminuição da abertura de dossel, e aumento na abundância de árvores, troncos mortos em pé, troncos mortos no chão e profundidade do folhiço; 3) Para *Strix virgata* (coruja-do-mato), a nossa hipótese é de aumento na densidade com diminuição da abertura de dossel e aumento na abundancia de árvores, profundidade do folhiço e troncos mortos em pé e no chão; 4) Para *Strix huhula* (coruja-preta) a nossa hipótese é de aumento na densidade com diminuição na abertura de dossel e aumento nas abundâncias de troncos mortos no chão e em pé; 5) Para as duas espécies maiores, as hipóteses são de aumento na densidade com aumento na abertura de dossel, abundancia de árvores, troncos mortos no chão e em pé no caso de *Lophostrix cristata* (coruja-de-crista)*;* e de diminuição na densidade com aumento na distância do igarapé e na abertura de dossel, e aumento na densidade com aumento na abundância de troncos mortos no chão e em pé, para *Pulsatrix perspicillata* (murucututu) (Sigrist, 2009; van Perlo, 2009; Gwynne et al., 2010; König & Weick, 2008).

OBJETIVOS

Objetivo geral:

Analisar como a heterogeneidade ambiental, determinada pela variação espacial em diversos componentes da estrutura da floresta, influencia no uso do habitat pelas corujas em Floresta de Terra-firme na Amazônia Central.

Objetivos específicos:

1) Avaliar, de maneira independente, como a variação espacial em componentes de estrutura da floresta influencia a frequência de uso de micro-habitat, e a ocorrência e a distribuição espacial de cada uma das cinco espécies de corujas;

2) Discutir as diferenças e as similaridades na ocupação do habitat de cada espécie.

CAPÍTULO 1

Esclarski, P.; Cintra, R. **Effects of Terra-Firme forest structure on habitat use by owls (Aves: Strigiformes) in Central Brazilian Amazonia.**

Submetido para *Neothropical Ornitology*.

EFFECTS OF TERRA-FIRME FOREST STRUCTURE ON HABITAT USE BY OWLS (AVES: STRIGIFORMES) IN CENTRAL BRAZILIAN AMAZONIA.

Priscilla Esclarski[1] & Renato Cintra[2]

[1]Programa de Pós-Graduação em Ecologia, Instituto Nacional de Pesquisas da Amazônia (INPA), CP 478, 69067-375, Manaus, Amazonas, Brasil. E-mail: prisk.esclarski@gmail.com; [2]Coordenação de Biodiversidade, Instituto Nacional de Pesquisas da Amazônia (INPA), CP 478, 69067-375, Manaus, Amazonas, Brasil. E-mail: cintra@inpa.gov.br

Summary – Effects of terra-firme forest structure on habitat use by owls (Aves: Strigiformes) in central Brazilian Amazonia – Owls, despite a well-established role in prey regulation and biological control, are a poorly-studied avian group. For Neotropical species distribution and abundance are especially poorly known. Structural components of forests have been used to explain patterns of owl habitat use and community structure, but such analyses have largely focused on species in the northern hemisphere. The present study examines whether components of forest structure influence habitat use (occurrence and abundance) for six species of owls in an upland forest in central Amazonian Brazil. Between October and November 2012, a playback method was used to sample occurrence and abundance in 30 points, each separated from the next by 1km. Results using multiple linear models revealed relationships between the abundance of four owl species and components of forest structure associated with food availability: *Glaucidium hardyi* (Amazonian Pygmy Owl - distance to nearest creek, p = 0.023), *Megascops watsonii* (Northern Tawny-bellied Screech Owl - leaf litter depth, p = 0.045), *Lophostrix cristata* (Crested Owl - dead fallen trunks on forest floor, p = 0.042), *Pulsatrix perspicillata* (Spectacled Owl - dead fallen trunks on forest floor, p = 0.009). Results of a multiple logistic model also revealed a significant association (p = 0.050) between the occurrence of *Pulsatrix perspicillata* (Spectacled Owl) and dead fallen trunks on forest floor. The influence of the components of forest structure differs according to the owl species, demonstrating interspecific differences in micro-habitat use, and reflecting the importance of food resource availability in owl habitat choice.

Key words: Environmental heterogeneity, owls, *Pulsatrix perspicilata Lophostrix cristata, Megascops watsonii, Glaucidium hardyi,* forest structure, habitat use, birds.

Resumo – Efeitos da estrutura de terra-firme no uso do habitat em corujas (Aves: Strigiformes) na Amazônia Central - As corujas, apesar de atuarem na regulação de presas e controle biológico, representam um grupo ainda pouco estudado quanto à distribuição e abundância, principalmente as espécies neotropicais. Os componentes da estrutura da floresta têm sido usados para explicar padrões de uso de habitat e a estrutura de comunidades, porém, os estudos relacionando tais componentes às corujas concentram-se em espécies do hemisfério norte. O presente estudo analisou se os componentes de estrutura da floresta influenciam o uso de habitat (ocorrência e abundância) por seis espécies de corujas em uma floresta de Terra-Firme na Amazônia Central. Para amostrar ocorrência e abundância foi usado o método playback, em 30 pontos distantes entre si em 1 km, nos meses de outubro e novembro de 2012. Os resultados das análises usando modelos lineares múltiplos mostraram relações significativas entre a abundância de quatro espécies de corujas e componentes da estrutura da floresta associados à disponibilidade de alimento; *Glaucidium hardyi* (caburé-da-amazônia) e distância do igarapé com p=0,023, *Megascops watsonii* (corujinha-orelhuda) e profundidade da serrapilheira com p=0,045, *Lophostrix cristata* (coruja de crista) e troncos mortos no chão com p=0,042, *Pulsatrix perspicillata* (murucututu) e troncos mortos no chão com p=0,009. Já os resultados de modelos logísticos múltiplos houve relação significativa somente entre a ocorrência *Pulsatrix perspicillata* (murucututu) e troncos mortos no chão com p=0,050. Assim, a influência dos componentes da estrutura da floresta difere de acordo com a espécie de coruja, demonstrando as diferenças interespecíficas no uso de micro-habitats, porém, reflete a importância da disponibilidade de recurso alimentar na percepção de habitat ideal pelas corujas.

Palavras-chave: Heterogeneidade ambiental, corujas, *Pulsatrix perspicilata, Lophostrix cristata, Megascops watsonii, Glaucidium hardyi,* estrutura da floresta, uso de habitat, aves.

INTRODUCTION

Heterogeneity is defined as the degree of discontinuity within the environmental conditions of a landscape (Morrison 1998). These conditions may vary according to the composition and forest structure or according to the flow of energy and other resources essential for a given organism. In recent years, based on the concepts of habitat and niche, environmental heterogeneity has been widely used to explain patterns of habitat use and community structure (Day 2000, Gaston 2000, Allen & Gillooly 2006).

Conceptually *habitat* includes where the organism lives, as well as the conditions for the survival of the organism, while *niche* is a description of the conditions of the habitat that meet the minimum requirements of a given species, so that the birth rate is equal to or greater than the rate of mortality considering the impact of environmental conditions on the population (Chase & Leibold 2003).

Knowledge of how organisms are distributed is an essential prerequisite for effective inference of which evolutionary and ecological factors determine patterns of habitat occupation and residence (Ganey & Balda 1994, Ricklefs 2004, Graham et al 2006). The ability to perceive and acquire information about the different features of the environment varies greatly between organisms, but most track changes of the location of suitable dispersal habitat (Enfjäll & Leimar 2009). The perception of ideal habitat depends on a variety of factors, including the morphological characteristics of the species (Srugley & Chai 1990, Hughes et al 2007), social structure (Yaber & Rabenold 2002, Le Galliard et al 2005) and life history (Levin 1984), as well as environmental factors such as climate (Best et al 2007, Hughes et al 2007), landscape structure (Kuch & Idelberger 2005) and abundance of conspecific individuals at the site (Fletcher 2006, 2007).

Environmental heterogeneity influences directly or indirectly the spatial distribution, richness and composition of an area’s avifauna, since individual choices will be influenced by such factors as forest composition and species diversity, vegetation density and structure, and the status of local ecological succession (Hildén 1965, Orians 1969, Wiens 1969, Whitacre et al 1990, Robinson 1994, Thiollay 1996, Amaral 2007).

The loss of habitat elements also has a direct effect on birds. Some structural components of the forest, such as tree density or the abundance of fallen logs, furnish localized micro-habitats for foraging and are known to be prime factors in site selection by nesting birds

(Rodewald & Yahner 2000, Slaght et al 2013). Despite this, the effect of spatial variation in forest structural components on habitat choice by birds has been little studied (Enfjäll & Leimar 2009), even though such factors are important for improved understand of how interactions between organisms operate, and the organization and structure of populations and ecological communities (Begon 1986, Ricklefs 2001). Such changes may impact both survival of individual birds and, when summed, community structure. However, because of species-specific effects neither cause nor effect will be uniform within such a community (Orians 1969, Wiens 1969, Cintra & Naka 2012).

Several studies in central Amazonia have related forest structure components to avian occurrence and abundance (e.g. Borges et al 2004, Barros & Cintra 2009, Cintra et al 2006). Several authors has suggested that habitat selection by birds may vary seasonally according to the availability of food, and that the leaf litter layer may also be sufficiently important in habitat choice as to influence the density of birds-ground and birds-of-prey (Rice et al 1983).

Patterns of distribution and abundance of nocturnal birds are generally related to environmental components, such as forest age, availability of cavities, edge distance, and the spatial and temporal abundance of food. Kavanagh et al (1995) found inverse relationships between generalism as the environment and the food, where generalist species in the environment have been more specific in relation to their prey and the more specific about the environment were more generalist feeding. According to Martin (1998), birds have preferences for micro-habitat which are related to the selection of sites for nesting, feeding and other activities. Such variation can be highly species-specific so that, even when the same substrate is chosen as a nest site, the characteristics of the adjacent vegetation may well be different for each bird species (Martin 1998).

Because tropical bird communities are rich, complex and heterogeneous, factors determining community structure are likely to be diffuse in the way they operate (Cintra & Naka 2012). Consequently, for many species of rainforest bird, little is known about their biology, including such key factors in determining presence and abundance as habitat requirements and social structure, among others (Thiollay 2002).

The ecology of Neotropical raptors is little known, especially in regard to those aspects of forest structure used when choosing their habitats or territories (Throstom 2000). For some diurnal predators, such as *Accipiter nisus* and *Pandion haliaetus*, it is known population density is regulated by availability of prey and of favorable sites for nesting (Newton et al

1977, Van Daele & Van Daele 1982). The situation is currently less certain for nocturnal raptors, especially in the tropics, where species biology is often poorly known, especially in relation to habitat use and which components of forest structure most directly influence occupation and residence (Amaral 2007).

Most studies relating components of forest structure to the occurrence of owls have been conducted in the northern hemisphere. Several authors have suggested that a general preference exists among owls for habitats in mature forests (Zwank et al 1994, Gayne & Balda 1994, Hunter et al 1995, Manzur et al 1998, Peery et al 1999, La Haye & Gutiérrez 1999), and that, within this, difference in structure of preferred habitat vary with owl species body size. Evidence suggests that smaller species may often use more open areas and choose locations with shrubs as nesting sites (McCallum & Gehlbach 1988), while the larger species favor denser canopy and nest in cavities in trunks (Bull et al 1989, Belthoff & Ritchinson 1990).

Dead, broken, but still-standing trunks are often used by nesting owls (Hershey et al 1998), and areas with a greater number of these will have greater owl abundance. Food resource availability has also been related to the occurrence and abundance of owls and indeed some species form pairs according to the abundance cycles of prey (McInvaille & Keith 1974, Ellinson 1980, Smith et al 1981, Village 1982, Smith & Gilbert 1984, Sparks et al., 1994).

Both the presence of fallen logs and great depths of leaf-litter have been shown to provide shelter for owl prey species, such as rodents, lizards, crickets, spiders and beetles, which use leaf-litter for concealment (Kiltie 1981). Such sites can both attract and support more owls, and so increase their local abundance (Smith & Gilbert 1984).

Sometimes similar features combine to influence both food and nest sites. *Bubo blakistoni* is perhaps one of the best-studied owl species, and several studies suggesting that their nests occur in valleys and near to water bodies (Spangenberg 1965, Pukinski 1973, Surmach 1998, Slaght 2011). Nest occurrence is also related to tree trunk diameter, availability of still-standing, but dead trees and fallen logs clogging waterways (the latter being associated with abundance of salmon, an important food: Slaght et al 2013).

Survival and area size usage in *Strix occidentalis caurina* increases with the proportion of available habitat in late successional stages and with the amount of edge habitat, and decreases with the distance from the closest neighbor (Schilling et al 2013), while area used and breeding period expanded in more fragmented habitats. This accords with the suggestion by Filloy & Bellocq (2013) that spatial variation in forest bird species abundance is mainly due to structural components of the forest.

In the Amazon rainforest, there are few studies that relate the habitat structure with the distribution, abundance and behavior of owls. A recent study of nocturnal birds in the Brazilian Amazon analyzed habitat use in primary and secondary forest (Sberze et al 2010), among the species analyzed, only two were owls (*Lophostrix cristata* (Crested Owl) and *Glaucidium hardyi* (Amazonian Pygmy Owl)). Their levels of occurrence did not differ between the two forest types.

Another study in the RFAD evaluated the effects of forest structural components on habitat use by six owl species (Barros & Cintra 2009), describing their general spatial distribution from records in 72 plots spaced from each other for 1 km and distributed in a large spatial scale of 64 km^2. The study showed very clear patterns of spatial distribution and influence of environmental heterogeneity in different species of owls (Barros & Cintra 2009). Dead still-standing trunk abundance was found to explain the variation in density of *Lophostrix cristata* (Crested Owl) and *Megascops watsonii* (Northern Tawny-bellied Screech Owl), with *M. watsonii* (Northern Tawny-bellied Screech Owl) showing more frequent use of areas with high tree abundance. *Glaucidium hardyi* (Amazonian Pygmy Owl) preferred forest areas near streams. In this study, playback was not used as a complimentary technique to compliment listening point use (Granzinolli & Motta-Junior 2010), even though combining the methods increases detections, thus minimizing false absence records (Mackenzie et al. 2002).

As these species vary in body and home range size, and occur at different densities, it would be instructive to test if similar distribution patterns to those found by Barros & Cintra (2009) occurs at smaller spatial scales.

Accordingly, the aim of the current study was to describe the spatial distribution of 6 species of owl in the RFAD at a smaller spatial scale (25 km^2) than Barros & Cintra (2009), while using the same sample design, and the same 1 km spacing between plots, but with twice as many sample plots and using additional detection techniques.

Specifically, this study examined how seven components of the forest structure influenced habitat use (occurrence and abundance) by owls (*Glaucidium hardyi* (Amazonian Pygmy Owl), *Lophostrix cristata* (Crested Owl), *Megascops watsonii* (Northern Tawny-bellied

Screech Owl), *Pulsatrix perspicillata* (Spectacled Owl), *Strix virgata* (Mottled Owl) and *Strix huhula* (Black-banded Olw)) in a central Amazonian upland forest. The forest structure components were: (1) leaf litter depth, (2) live trees density, (3) standing dead trunk density, (4) fallen dead trunks density, (5) canopy opening, (6) terrain elevation and (7) distance to nearest stream. The presence and the density of the species was estimated using playback - a method previously untested with owls in neotropical forest environments.

Our hypothesis is that the spatial variation in components of forest structure influences the spatial distribution and use of microhabitat by owl, on a species-by-species basis.

We predict that the abundance and frequency of owl species occurrence will increases with (I) the presence of flatter areas in the forest, and (II) with increases in vegetation density, leaf-litter depth, fallen log abundance, the extent of canopy opening, and proximity to more humid areas such as water bodies.

METHODS

Study Areas **-** The study was conducted in the Reserva Florestal Adolfo Ducke (RFAD), located near Manaus, Amazonas State, Brazil (2°55'-03°01'S, 59°53'-59°59'W). Administered by the National Institute of Amazonian Research (INPA), the RFAD covers some 10,000 ha of primary terra firme forest, and is one of the most well studied areas of the Brazilian Amazon (Ribeiro et al 1999, Oliveira et al 2008).

Within the RFAD average annual temperature is 26ºC, and annual rainfall ranges from 1750mm to 2500mm, with a rainy season (November to May) and a dry season (June to October) (Oliveira et al 2008). The dominant vegetation is mature evergreen forest with a canopy between 30-40m, with emergent trees reaching 55m (Ribeiro et al 1999). The local topography is of undulating plateaus with predominantly closed forest canopy and a poorly-lit understory (Oliveira et al 2008), incised by stream-bearing valley bottoms. In the central sector, an elevated plateau area divides the local stream system into two distinct basins. The clear-water streams of the eastern region flow into the Amazon River, while the blackwater creeks on the western side flow into tributaries of the River Negro.

Sample design: - This study involved six species of Strigiformes: *Glaucidium hardyi* (Amazonian Pygmy Owl), *Megascops watsonii* (Northern Tawny-bellied Screech Owl), *Stix virgata* (Mottled Owl), *Strix huhula* (Black-banded Olw), *Lophostrix cristata* (Crested Owl) and *Pulsatrix perspicillata* (Spectacled Owl). Sampling occurred on clear nights with little wind, between 18:00 and 23:00, during the breeding season, because the owls are more sedentary during this period, which guarded against possible double-counting of the same individual in more than one point. Additionally, movements between sampling points were made as quickly as possible, so as to minimize effects of study animal movements between sampling locations. Playback (broadcasting recordings of the spontaneous vocalizations of each species, so that animals respond to these calls: Motta-Junior, Bueno & Braga 2004) was used to test species presence.

The PPBio grid used has 30 plots, with each plot in this study considered as a sampling unit. Each plot on the PPBio grid is 250m in length and each is separated from the next by 1000m. To minimize within-plot variation, each follows the local topographic curve. The center of each plot was used as the listening point, which listening consisted of five minutes auditory attention, used to identify and estimate whether the target owl species was vocalizing within a radius of 125m around the observer (previously determined by experimental simulations evaluating the detection capability of the observer in the field).

Following an initial 5-minute interval, the listener began the sequence of play-backs for the five species, each vocalization being played for three minutes with an interval also three minutes until the playback to the next species, following from the smaller body size (Amazonian Pygmy Owl- *G. hardyi*) to the largest (Spectacled Owl - *P. perspicillata*), to minimize potential effects of dominance rank. A full sampling sequence lasted 35 minutes at each listening point, including the initial playback-free minutes and the playback times. Some 25 minutes were spent commuting between listening points, so that 3-4 plots were sampled per night. Each plot was visited twice.

The following information were recorded for each individual point counts: date and time of registration, species and number of individuals vocalizing. A digital recorder (Panasonic RR-XS4410) with microphone (Yoga EM-9600) and a portable speaker (MaxPrint 2W R.M.S.) were used to broadcast owl calls, always played at the same volume (20) in the four directions (north, south, east, west) from the center point. In case of difficulties in species identification, vocalizations were recorded for later laboratory analysis.

Within each plot from which playback occurred, the following forest structural variables were measured: (1) leaf-litter depth, (2) fallen log density, (3) live tree density with DAP>10cm, (4) standing dead trunks, (5) canopy opening, (6) slope inclination and (7) distance to nearest stream. All these variables had been shown by a previous study in the same area (Barros & Cintra 2009) to be influential in owls micro-habitat use.

Leaf litter depth, fallen dead log and standing dead trunk densities and canopy opening were measured during the same period of field work, to avoid any seasonal variation (Luizão & Schubart 1987, Luizão 1989, Rodeigues et al 2000, Vital et al 2004, Nascimento et al 2006). Five records of leaf litter depth were taken every 5 m within each plot, using a ruler graduated in millimeters. The resulting 51 records-per-plot were then averaged. Fallen logs and standing dead trunks were counted by direct observation for an area within 20m from both sides of the plot center line, along the whole plot length. Canopy cover was measured with a densiospherometer, via four records (north, south, east and west) every 10m along plot central line, and the total of 26 measures averaged for each plot. For the other variables, we used the existing information available on the LTER database (http//peld.inpa.gov.br).

Data analysis -: The correlation between the independent variables (forest structural components) was tested with a Pearson correlation matrix.

To test if forest structural components influence habitat use by the studied owl species, a multiple linear analysis model was performed for the density of each owl species, and a multiple logistic model analysis for occurrence (using as dependent variables the categorical variables presence = 1, absence = 0 : Wilkinson 1998), using the program Systat 13.0. Multiple linear models were assessed with a quantitative response variable and continuous Y for explanatory variables (forest structure components). The general logistic equation is $p = 1/1+e^{-z}$.

A qualitative array was generated with presence/absence and analyzes conducted separately for each owl species.

RESULTS

Per plot forest structure variables showed the following patterns of variation: fallen dead trunk number ranged 9 to 40 and standing dead trunks from 0 to 16; litter depth varied between 2.94 to 5.84 cm, distance to nearest stream from 20 to 493.33 m. Canopy opening varied between 1.29 and 3.94%, density of trees with DBH> 10 cm ranged from 293 to 393 individuals. Terrain elevation ranged from 46 to 105 m.

Of the six owl species that responded playback, *Glaucidium hardyi* (Amazonian Pygmy Owl) and *Lophostrix cristata* (Crested Owl), recorded in 28 of the 30 plots (93.4 % of the sampled area), and were the most abundant species. *Megascops watsonii* (Northern Tawny-bellied Screech Owl) was recorded in 18 plots (60 %), *Pulsatrix perspicillata* (Spectacled Owl) in 13 plots (43.4 %), *Strix virgata* (Mottled Owl) occurred in 7 plots (23.4 %) and *Strix huhula* (Black-banded Olw) in only 3 plots (10 %). The latter two species were excluded from the analysis because of low numbers of records.

Raw densities were converted to a density index by multiplying maximum number of individuals recorded per species recorded by observation time per plot (35 minutes/plot), so that species density ranged from 0 to 0.11. To estimate total density per species for the entire study area, we used the ecological density, given by the number of plots where the species occurred by the total number of plots studied multiplied by the value obtained in May for the density index per sample unit. Densities for studied species in the PPBio grid ranged from 0.002 to 0.102 (Table I). However, the species distribution maps within ADRF were made for the six species (Figure II a, b , c, d, e, f) .

From a test of correlation (Table II), we separate the environmental variables in two models, keeping the variables most strongly and significantly correlated separated in different models. Thus, for each species, the models were constructed Model 1: dead logs on the ground, standing dead trunks, distance from the stream and canopy opening, and Model 2: litter depth, abundance of trees with DBH greater than 10 cm and terrain elevation (Table III a, b, c, d, and IV a, b, c, d).

The results of multiple linear models show that (a) *G. hardyi* (Amazonian Pygmy Owl) density increases with increasing distance from the stream and increase in ground elevation (Table III a, and Figure III), (b) *M. watsonii* (Northern Tawny-bellied Screech Owl) density increases with decreasing depth of litter (Table III b, and Figure IV), (c) the density of *L.*

cristata (Crested Owl) increases with the increase in the abundance of dead tree trunks on the ground (Table III c, and Figure V), (d) the density of *P. perspicillata* (Spectacled Owl) increases with the increase in the abundance of logs dead on the floor (Table III d, and Figure VI). The occurrence of *P. perspicillata* (Spectacled Owl) also increased with the increase in the abundance of dead tree trunks on the ground (Table IV d, and Figure VII).

DISCUSSION

This is the first study that used two simultaneous methods (direct observation by counting points, and playback) to demonstrate how the spatial variation in structure components of a forest upland influence the use of micro-habitats for nocturnal predatory birds. Of key interest from the ecological perspective is that they are of various sizes and in the same family, thus representing a potentially competing array. The results of this study supports existing evidence (e.g. Terborgh 1985, 1990, Barros & Cintra 2009, Cintra & Naka 2012) that, via variation in forest structure components, the heterogeneity of tropical forests influences the spatial distribution of bird species, indicating that such effects have broad impacts throughout bird communities, irrespective if their diet time and time of activity.

Owls, like other predatory birds, select territories according to the potential for breeding and nesting areas (Motta-Junior et al 2004). Cavities for nesting and shelter are rarely constructed, with existing cavities (natural rot holes, holes made by woodpeckers, armadillos and others) exploited opportunistically, sometimes being slightly enlarged or otherwise modified (Glinski et al 1983).

The use of dead and/or broken trunks is common among owls and several studies have demonstrated their importance in owl habitat selection (Form et al 1984, Gutierrez 1985, Carrey 1985, La Haye 1988, Hershey et al 1988, Carrey 1990, Thorstrom 2011, Barros & Cintra 2009, Slaght et al 2013). However, the current study found no relationship between the abundance of standing dead trunks and density of owl occurrence at the micro-habitat level, suggesting the owls are using other forest structure components in the studied habitat. Such factors could include food resource availability.

Food availability is one of many factors limiting habitat use. In owls, low food availability may interfere with reproduction, both extending inter-breeding intervals and reducing clutch size. Additionally, pair formation may be tied to cycles of prey abundance (McInvaille & Keith 1974, Ellinson 1980, Smith et al 1981, Village 1982, Rice et al 1983, Smith & Gilbert 1984, Sparks et al 1994, Motta-Junior et al 2004). In the present study, we used two proxies for food availability - depth of litter and number of fallen dead trunks, and found that this variable significantly influencing the presence of three owl species (*Megascops watsonii* (Northern Tawny-bellied Screech Owl), *Lophostrix cristata* (Crested Owl) *and Pulsatrix perspicillata* (Spectacled Owl)).

For *Lophostrix cristata* (Crested Owl) the frequency of micro-habitat use varied between different areas within the upland forest studied. Though studies were conducted in the same forest type and same location, this result differs from the study of Barros & Cintra (2009) conducted at a greater spatial scale.

The body size is directly related to the species home range size (Schoener, 1968, Holling 1992), which, in turn, reflect differences in how individual of that species fulfill their basic survival requirements, and how individuals perceive differences in distribution of micro-habitats patches (Ziv 2000, Haskell et al 2002). A comparison of owl species occupancy distinguished different species assemblages in secondary and primary terra firme and in seasonally-flooded forest, and proposed that habitat structure differences might be influential (Borges et al 2004). This suggests that the way in which the species involved perceive differences in habitat characteristics may not occur at the level of simple spatial variation, but at a finer scale relating to the structural components if the forest (e.g. Wiens 1976, Kotliar & Wiens 1990, Tews et al 2004). That *Lophostrix* and *Pulsatrix* are larger than *Glaucidium* and *Megascops*, for example, implies higher energy demands in the former pair, and hence more extensive home ranges (Kelt & Vuren 1999, Brown 2007). These size differences explain why *Lophostrix* and *Pulsatrix* explore larger areas, areas which will include a greater variety of microhabitats that those embraced by the smaller species smaller home ranges.

The differences in size of the species apparently did not affect the abundance of individuals found in the points. Possibly because, although larger species occupy a larger territory, the puppies still divided the territories with parents, because even young people who have already left the nest, are still dependent on their parents for food not abandoning the territory to acquire food independence. Thus the great abundance of large species at a point, one can equate both the limit of the territory area, as to a set of individuals belonging to the same family (couple and youngs still dependent)

Unlike the study by Barros & Cintra (2009), where *L. cristata* (Crested Owl) density was related to the abundance of standing dead trunks, the current study found habitat use by *Pulsatrix perspicillata* (Spectacled Owl) and *Lophostrix cristata* (Crested Owl) correlated with an increase in fallen log abundance. As forest floor logs attract such potential owl prey-items as invertebrates and small mammals (Kiltie, 1981), this shows the generality of the positive relationship between log and owl abundance, even when the habitat, prey type and owl size are very different (see Smith & Gilbert 1984).

This suggests that the studied owl species are preferentially using particular areas within the available habitat. Moreover, the different components of forest structure had different effects on use frequency by such smaller species as *Glaucidium hardyi* (Amazonian Pygmy Owl) and *Megascops watsonii* (Northern Tawny-bellied Screech Owl).

It appears that use frequency by *Lophostrix cristata* (Crested Owl) and *Pulsatrix perspicillata* (Spectacled Owl)is higher in areas with greater abundance of fallen logs. Forest floor areas with increased log abundance are widely considered important as places to forage and find potential prey such as rodents, as well as invertebrates within decaying trunks (del Hoyo 1999). Moreover, forest understory environment near such trunks tends to be more humid and this may be important in the dry season, which at RFAD coincides with the nesting season of most species of ground-breeding birds (see appendix Cintra & Naka 2012). Owls at RFAD are likely to more readily find food items when visiting areas with higher than those with lower abundance of fallen logs. However, areas with these characteristics can increase the risk of exposure of individuals to potential predators, like snakes (which use such locations as refuges and to breed), and hunting wild cats (ocelots and jaguars) that use them for concealment. Therefore owls visiting such sites must balance visit length and frequency in order to reduce vulnerability to predators while visiting these more profitable foraging sites (e.g. Lima & Dill 1990, Masse et al 2013).

We had expected that *Lophostrix cristata* (Crested Owl) occurrence would be positively related to elevation, as a previous study (Barros & Cintra 2009) had demonstrated a strong association of this large owl with higher altitude, probably because in such areas the forest tends to be more open. However, the current study recorded that *L. cristata* (Crested Owl) also uses low-lying and sloped areas, a novelty for the biology of this species, previously believed to use only flat area of plateaus.

Arthropod abundance increases with litter depth, which, in turn, influences the occurrence of understory-living species of insectivorous birds (tropics: Pearson 1977, Pearson & Derr 1986 – RFAD: Cintra & Cancelli 2008, Cintra & Naka 2012). Confirming results from a study conducted within the reserve, but at a larger spatial scale (Barros & Cintra 2009), our results show that *Megascops watsonii* (Northern Tawny-bellied Screech Owl) preferentially uses forest environments with shallower leaf-litter layers. Though specialists exist, many owl species are opportunistic and have a generalist diet (Schubart et al 1965, Sick 1997). *Megascops watsonii* (Northern Tawny-bellied Screech Owl) eats small rodents, birds and invertebrates, so the fact that it most frequently uses places with little leaf-litter may be due to the ease with which such prey is both seen and captured in such places. Such foraging may be energetically effective since, according to Amaral (2007), the use of sites with less litter increases predation success rates, while economizing on time and energy spent.

Glaucidium hardyi (Amazonian Pygmy Owl) had a higher density closer to creeks. This was also found by Barros & Cintra (2009), who believe this may be explained by the more open canopy and understory close to streams, which increase visibility, and the range of small animals (lizards, frogs, small mammals) that frequent such areas. In a study of screech owls, Gilberd & Smith (1984) found that they used different habitats in and outside the breeding season, using more open areas, which provided a more successful predation.

The other owl focal species (*Strix virgata* (Mottled Owl) and *Strix huhula* (Black-banded Olw)), were excluded from statistical analyzes because they showed low sample numbers. Three species were not considered by a previous study (Barros & Cintra 2009) for a similar reason. However, the playback method used here allowed inclusion of *Pulsatrix perspicillata* (Spectacled Owl), which Barros & Cintra (2009) had excluded because of low detectability.

All species in the study were detected in at least 3 sampling plots (10%) in each field visit. In 7 plots of the PPBio grid *Strix virgata* (Mottled Owl), a species not included in the study, responded to playbacks of the other owl species.

Lophostrix cristata (Crested Owl) and *Glaucidium hardyi* (Amazonian Pygmy Owl) were the commonest owl species, being absent from only 2 sampled plots, and abundant in the remaining 28. Given their spatial overlaps, these species probably do not compete, and so can coexist in the same habitat. The current study found *Lophostrix cristata* (Crested Owl) to be uniformly distributed within the study area. This runs counter to the results of Barros & Cintra (2009) who found its abundance clumped on the RFAD central plateau.

The current study found that *Megascops watsoni* was abundantly and widely distributed across the study grid. This is in contrast to the findings of Barros & Cintra (2009) who found *M. watsoni* to be restricted to an area, Ipiranga in the southwestern part of the RFAD that the current study did not work in. Thus, the observed pattern might be linked to methodological differences or to a recent expansion and colonization of new areas by this owl.

According to maps generated by the study, *Pulsatrix perspicillata* (Spectacled Owl) occurs in areas close to streams below 100 m elevation. This may relate to a diet that includes small mammals, birds, large spiders, insects and freshwater crabs (Sick 1997, Sigrist 2009). Similar results have been recorded for other owl species: in a study of the diet of *Strix uralensis*, Korpimaki & Sulkava (1987) found a relationship between the proportion of water bodies and increased predation on rodents, possibly because prey animals are more vulnerable to the predation nearby in water bodies. The frequency which *Pulsatrix perspicillata* (Spectacled Owl) was recorded in the sampled area corroborates the view of Stotz (1997), that the species is common in areas of central Amazonian terra firme forest, a fact that is still is no consensus among researchers. It also confirms hitherto untested occasional observations, that the species preferred areas closer to water bodies (Sick 1997).

Strix huhula (Black-banded Olw) was recorded in only three plots, all in a single hydrological micro-basin, while *Strix virgata* (Mottled Owl) was present only in plots with minimal canopy opening.

Overall this study has demonstrated that six species of owls at RFAD use different microhabitats. The current study covered only one breeding season. Comparing our results with those from Barros & Cintra (2009) indicate that, above and beyond differences that might result from different methodologies, there may be substantial inter-year variation in apparent habitat preferences. Consequently, we would recommend a multi-year monitoring program that includes habitat use and movement of individuals, so that it may be determined if presence of individuals of various species in an area are related to the influence of vegetation structure or a result of expansion and occupation of the species over multiple breeding seasons.

ACKNOWLDGMENTS

PE thanks the following: to the Instituto Nacional de Pesquisas da Amazônia (INPA) for logistic help during this study; to the Programa de Pesquisa em Biodiversidade, Programa de Pesquisas Ecológicas de Longa Duração, and the Conselho Nacional de Desenvolvimento Científico e Tecnológico (PPBio/PELD/CNPq), for the study grant and the project financing; to Rafael S. Guerta, for help at all stages of the research; to my friends Glauco Kohler, Matheus Montefusco and Raiclicia Morais for their company and help in the field, and especially the field-guides Sr. Ayres and Srta. Ivanery, without whom it would have been impossible to collect the data required for this study. Adrian Barnett helped with the English.

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TABLES

Table I. Densities for studied species of owls in the PPBio grid. Reserva Ducke, central Amazonia

Species	**Density per plot**	**Density by area**
G. hardyi	0 – 0,11	0,102
M. watsonii	0 – 0,08	0,048
S. huhula	0 – 0,02	0,002
S. virgata	0 – 0,02	0,004
L. cristata	0 – 0,11	0,102
P. perspicillata	0 – 0,05	0,021

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Table II. Pearson Correlation Matrixde for Forest Structural Components recorded in 30 plots in the Reserva Ducke, central Amazonia

	Logs	**Litter**	**Snags**	**Distance to stream**	**Canopy opening**	**Tree abundance**	**Altitude**
Logs	1,000						
Litter	0,172	1,000					
Snags	0,061	0,029	1,000				
Distance to stream	-0,030	-0,253	0,089	1,000			
Canopy opening	-0,208	0,339	0,092	0,017	1,000		
Tree abundance	-0,243	-0,369	0,118	0,359	0,246	1,000	
Altitude	-0,135	-0,381	0,180	0,757	-0,087	0,410	1,000

Table III (a) Results of Multiple Linear Models analysis of variation of *G. hardyi* abundance in relation to Forest Structure Components (Model 1 and 2) recorded in 30 plots of Reserva Ducke, central Amazonia.

Effect	**Coefficient**	**Standard Error**	**Std. Coefficient**	**Tolerance**	**t**	**Significance (p-value)**
Model 1						
Constant	2,254	1,004	0,000	.	2,246	0,034
Logs	-0,032	0,023	-0,248	0,949	-1,402	0,173
Snags	-0,033	0,052	-0,110	0,977	-0,631	0,534
Distance to stream	0,003	0,001	0,420	0,991	2,424	0,023
Canopy opening	0,049	0,258	0,034	0,946	0,191	0,850

Model 2						
Constant	0,854	2,588	0,000	.	0,330	0,744
Litter	-0,335	0,238	-0,252	0,800	-1,404	0,172
Tree abundance	0,003	0,006	0,100	0,779	0,552	0,586
Altitude	0,018	0,009	0,370	0,771	2,024	0,053

Table IV (a) Results of Multiple Logistic Models analysis of variation of *G. hardyi* occurrence in relation to Forest Structure Components (Model 1 and 2) recorded in 30 plots of Reserva Ducke, central Amazonia.

Parameter	**Estimate**	**Standard Error**	**Z**	**p-value**	**95% Confidence Interval**	
					Lower	**Upper**
Model 1						
Constant	-340,279	1,231E+010	0,000	1,000	-2,412E+010	2,412E+010
Logs	18,217	5,150E+008	0,000	1,000	-1,009E+009	1,009E+009
Snags	-27,408	8,119E+008	0,000	1,000	-1,591E+009	1,591E+009
Distance to stream	-7,672	1,660E+008	0,000	1,000	-3,254E+008	3,254E+008
Canopy opening	112,312	3,103E+009	0,000	1,000	-6,082E+009	6,082E+009
Model 2						
Constant	395,751	9,124E+011	0,000	1,000	-1,788E+012	1,788E+012
Litter	114,462	3,159E+010	0,000	1,000	-6,192E+010	6,192E+010
Tree abundance	1,566	2,384E+009	0,000	1,000	-4,673E+009	4,673E+009
Altitude	-13,524	1,160E+009	0,000	1,000	-2,274E+009	2,274E+009

Table III (b). Results of Multiple Linear Models analysis of variation of *M. watsonii* abundance in relation to Forest Structure Components (Model 1 and 2) recorded in 30 areas of Reserva Ducke, central Amazônia.

Effect	**Coefficient**	**Standard Error**	**Std. Coefficient**	**Tolerance**	**t**	**Significance (p-value)**
Model 1						
Constant	1,648	0,954	0,000	.	1,728	0,096
Logs	-0,001	0,022	-0,012	0,949	-0,060	0,953
Snags	-0,054	0,049	-0,211	0,977	-1,097	0,283
Distance to stream	0,001	0,001	0,118	0,991	0,618	0,542
Canopy opening	-0,235	0,246	-0,187	0,946	-0,956	0,348
Model 2						
Constant	5,328	2,488	0,000	.	2,141	0,042
Litter	-0,482	0,229	-0,421	0,800	-2,103	0,045
Tree abundance	-0,007	0,006	-0,254	0,779	-1,253	0,221
Altitude	0,001	0,008	0,029	0,771	0,142	0,888

Table IV (b). Results of Multiple Logistic Models analysis of variation of *M. watsonii* occurrence in relation to Forest Structure Components (Model 1 and 2) recorded in 30 areas of Reserva Ducke, central Amazônia.

Parameter	**Estimate**	**Standard Error**	**Z**	**p-value**	**95% Confidence Interval**	
					Lower	**Upper**
Model 1						
Constant	-4,308	2,515	-1,713	0,087	-9,237	0,620
Logs	0,054	0,056	0,976	0,329	-0,055	0,163
Snags	0,132	0,128	1,032	0,302	-0,119	0,383
Distance to stream	0,000	0,003	-0,149	0,882	-0,005	0,005
Canopy opening	0,717	0,611	1,173	0,241	-0,481	1,915
Model 2						
Constant	-12,687	7,340	-1,728	0,084	-27,074	1,699
Litter	0,667	0,611	1,092	0,275	-0,530	1,865
Tree abundance	0,029	0,018	1,622	0,105	-0,006	0,064
Altitude	-0,010	0,023	-0,430	0,667	-0,056	0,036

Table III (c). Results of Multiple Linear Models analysis of variation of *L. cristata* abundance in relation to Forest Structure Components (Model 1 and 2) recorded in 30 plots of Reserva Ducke, central Amazonia.

Effect	**Coefficient**	**Standard Error**	**Std. Coefficient**	**Tolerance**	**t**	**Significance (p-value)**
Model 1						
Constant	1,437	1,102	0,000	.	1,305	0,204
Logs	0,054	0,025	0,389	0,949	2,146	0,042
Snags	-0,042	0,057	-0,131	0,977	-0,731	0,471
Distance to stream	0,000	0,001	0,058	0,991	0,327	0,746
Canopy opening	-0,254	0,284	-0,162	0,946	-0,894	0,380
Model 2						
Constant	0,276	3,329	0,000	.	0,083	0,935
Litter	0,272	0,307	0,191	0,800	0,887	0,383
Tree abundance	0,000	0,008	-0,008	0,779	-0,035	0,972
Altitude	0,007	0,011	0,135	0,771	0,617	0,542

Table IV (c). Results of Multiple Logistic Models analysis of variation of *L. cristata* occurrence in relation to Forest Structure Components (Model 1 and 2) recorded in 30 plots of Reserva Ducke, central Amazonia.

Parameter	**Estimate**	**Standard Error**	**Z**	**p-Value**	**95%Confidence Interval**	
					Lower	**Upper**
Model 1						
Constant	592,839	6,142E+010	0,000	1,000	-1,204E+011	1,204E+011
Logs	-26,981	2,227E+009	0,000	1,000	-4,366E+009	4,366E+009
Snags	-18,768	5,505E+009	0,000	1,000	-1,079E+010	1,079E+010
Distance to stream	-0,425	74.595.600,49	0,000	1,000	-1,462E+008	1,462E+008
Canopy opening	-20,149	2,967E+010	0,000	1,000	-5,816E+010	5,816E+010

Model 2						
Constant	1.000,619	8,193E+010	0,000	1,000	-1,606E+011	1,606E+011
Litter	-144,626	1,157E+010	0,000	1,000	-2,268E+010	2,268E+010
Tree abundance	2,330	1,495E+008	0,000	1,000	-2,930E+008	2,930E+008
Altitude	-22,375	1,091E+009	0,000	1,000	-2,137E+009	2,137E+009

Table III (d). Results of Multiple Linear Models analysis of variation of *P. perspicillata abundance* in relation to Forest Structure Components (Model 1 and 2) recorded in 30 plots of Reserva Ducke, central Amazonia.

Effect	Coefficient	Standard Error	Std. Coefficient	Tolerance	t	Significance (p value)
Model 1						
Constant	-0,883	0,616	0,000	.	-1,433	0,164
Logs	0,040	0,014	0,479	0,949	2,822	0,009
Snags	0,049	0,032	0,260	0,977	1,554	0,133
Distance to stream	0,000	0,001	-0,111	0,991	-0,669	0,509
Canopy opening	0,099	0,159	0,107	0,946	0,627	0,536
R^2 = 0.317						
Modelo 2						
Constant	-0,754	1,952	0,000	.	-0,386	0,702
Litter	0,219	0,180	0,257	0,800	1,216	0,235
Tree abundance	0,001	0,005	0,066	0,779	0,306	0,762
Altitude	-0,002	0,007	-0,068	0,771	-0,314	0,756
R^2 = 0.072						

Table IV (d). Results of Multiple Logistic Models analysis of variation of *P. perspicillata* occurrence in relation to Forest Structure Components (Model 1 and 2) recorded in 30 plots of Reserva Ducke, central Amazonia.

Parameter	**Estimate**	**Standard Error**	**Z**	**p-Value**	**95%Confidence Interval**	
					Lower	**Upper**
Model 1						
Constant	6,656	3,385	1,967	0,049	0,023	13,290
Logs	-0,151	0,077	-1,963	0,050	-0,302	0,0001
Snags	-0,348	0,204	-1,706	0,088	-0,747	0,052
Distance to stream	0,001	0,003	0,345	0,730	-0,005	0,007
Canopy opening	-0,433	0,640	-0,677	0,499	-1,687	0,821
Model 2						
Constant	8,668	6,711	1,292	0,196	-4,485	21,820
Litter	-0,920	0,625	-1,472	0,141	-2,145	0,305
Tree abundance	-0,014	0,016	-0,900	0,368	-0,045	0,017
Altitude	0,006	0,022	0,271	0,787	-0,037	0,048

FIGURE LEGENDS

Figura I. RFAD – Trail grid and plots used during the study (http://ppbio.inpa.gov.br/repositorio/imagens)

Figure II. Species distributions **a)** *Glaucidium hardyi*, **b)** *Megascops watsonii*, **c)** *Strix huhula*, **d)** *Strix virgata*, **e)** *Lophostrix cristata*, **f)** *Pulsatrix perspicillata* in the PPBio plots at RFAD.

Figure III - Results of multiple linear models of variation in *Glaucidium hardyi* density in relation to forest structure components (Model 1 and 2). Some numbers of the axes are negative because the partial relationships deviation of the expected results as all the other variables are maintained constant with their observed means.

Figure IV. Results of multiple linear models of variation in *Megascops watsonii* density in relation to forest structure components (Model 1 and 2).

Figure V - Results of multiple linear models of variation in *Lophostrix cristata* density in relation to forest structure components (Model 1 and 2).

Figure VI - Results of multiple linear models of variation in *Pulsatrix perspicillata* density in relation to forest structure components (Model 1 and 2).

Figure VII - Results of multiple linear models of variation in *Pulsatrix perspicillata* density in relation to abundance of fallen logs.

FIGURES

Figure I.

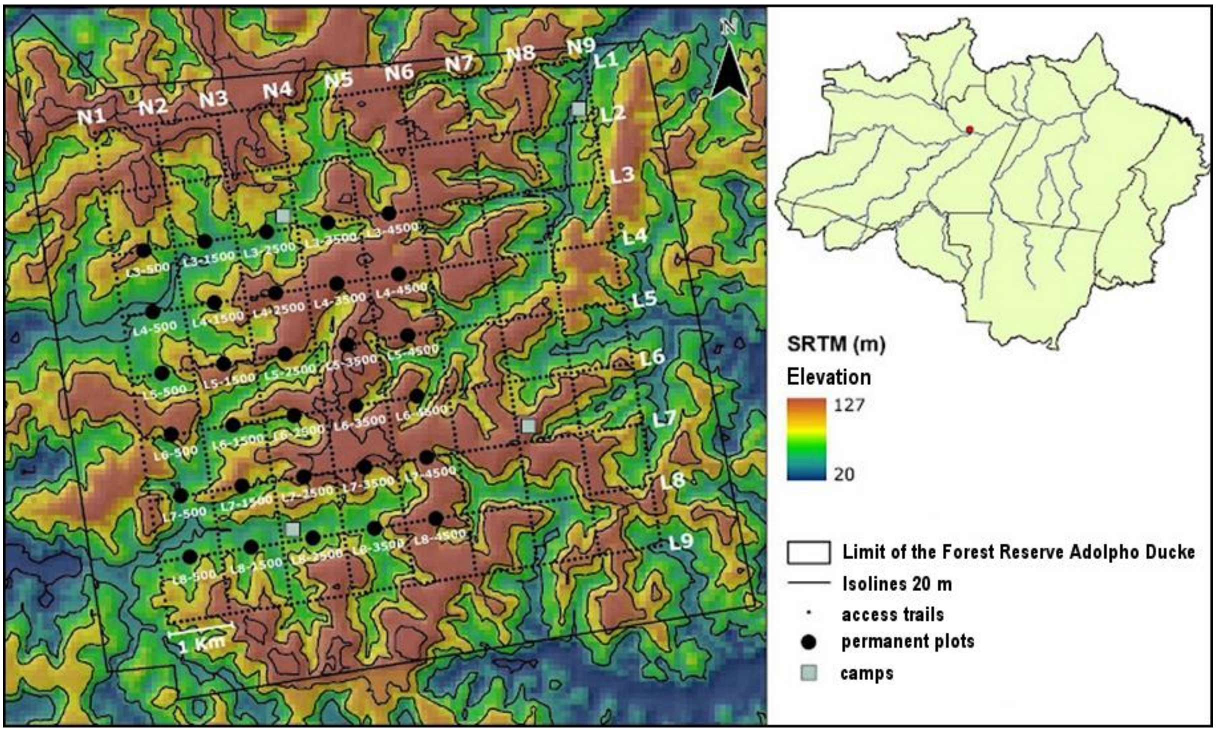


Figure II.

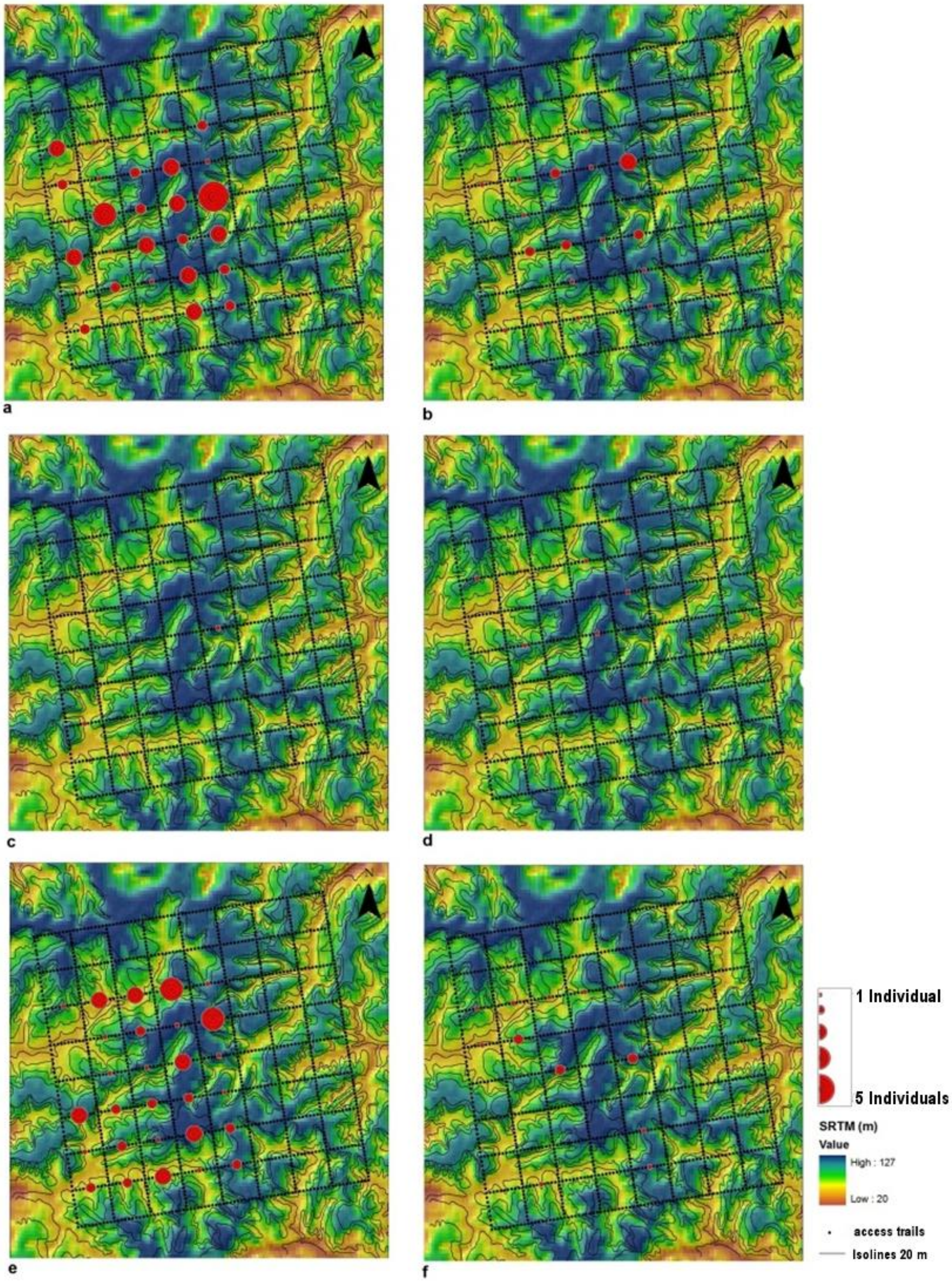
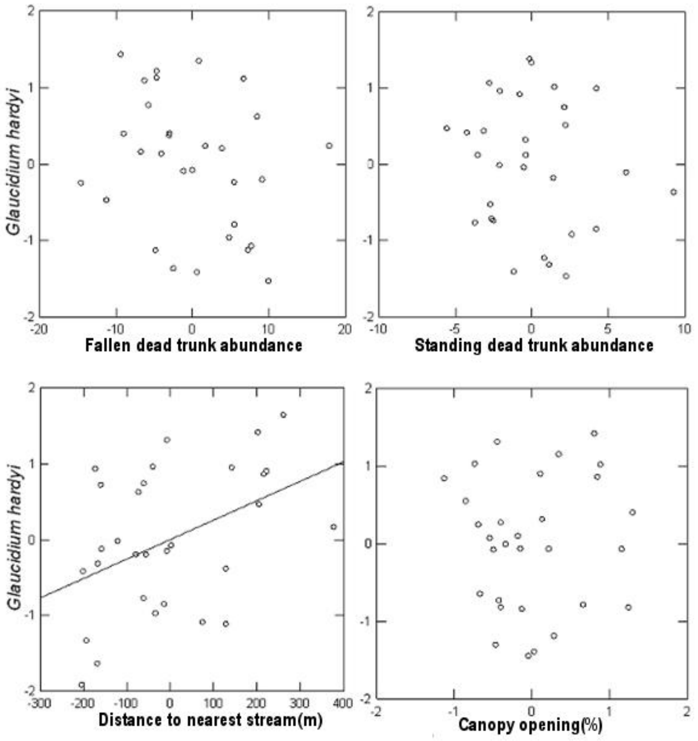

N
a
b
c
d
e
f
1 Individual
5 Individuals
SRTM (m)
Value
High : 127
Low : 20
access trails
Isolines 20 m

Figure III.

Modelo 1



Modelo 2

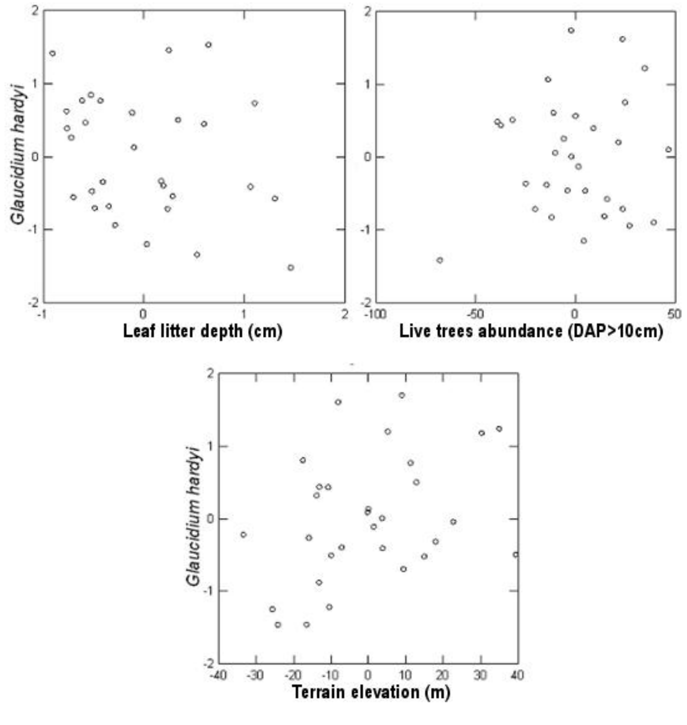
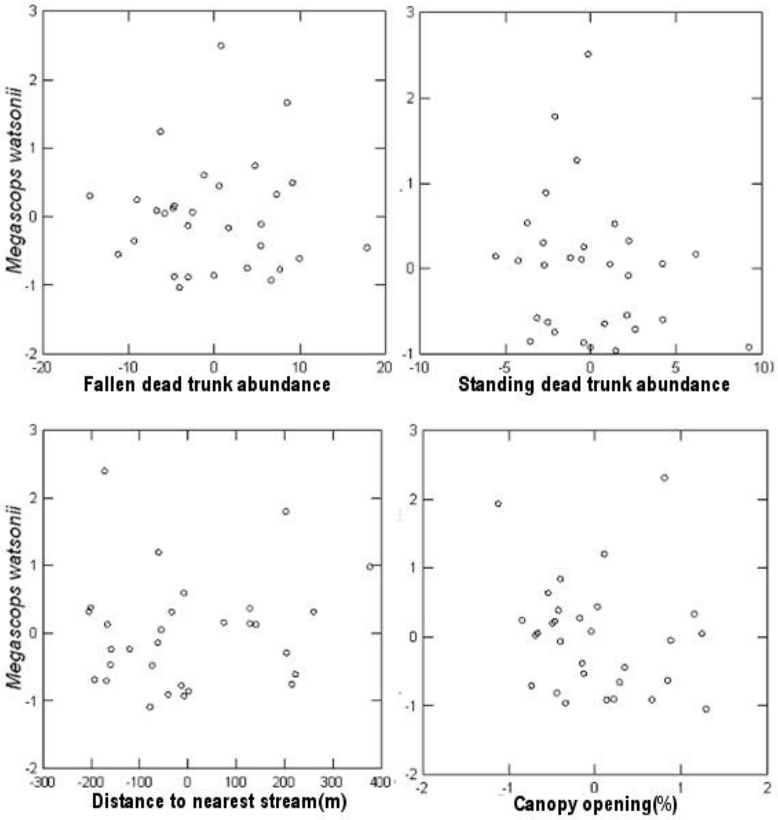


Figure IV.

Modelo 1



Modelo 2

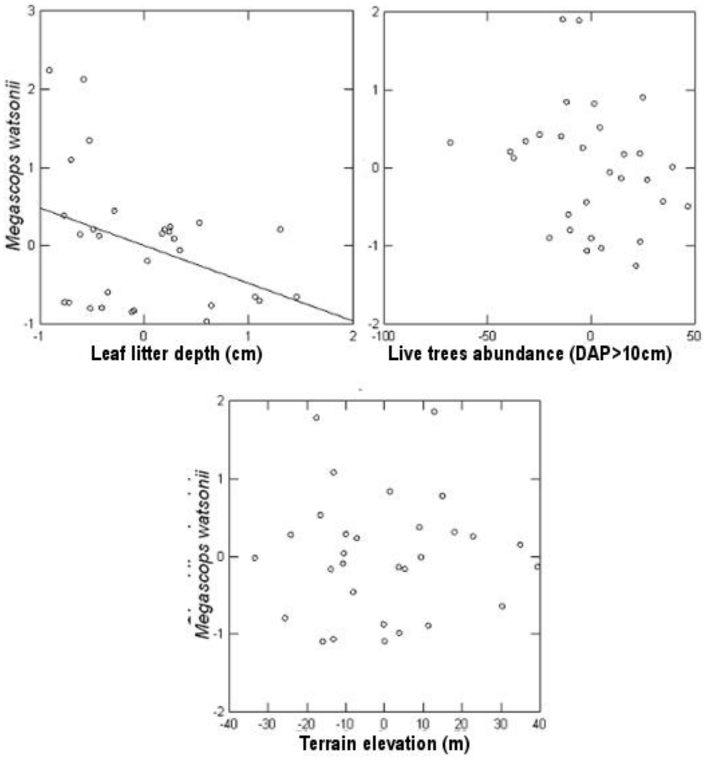
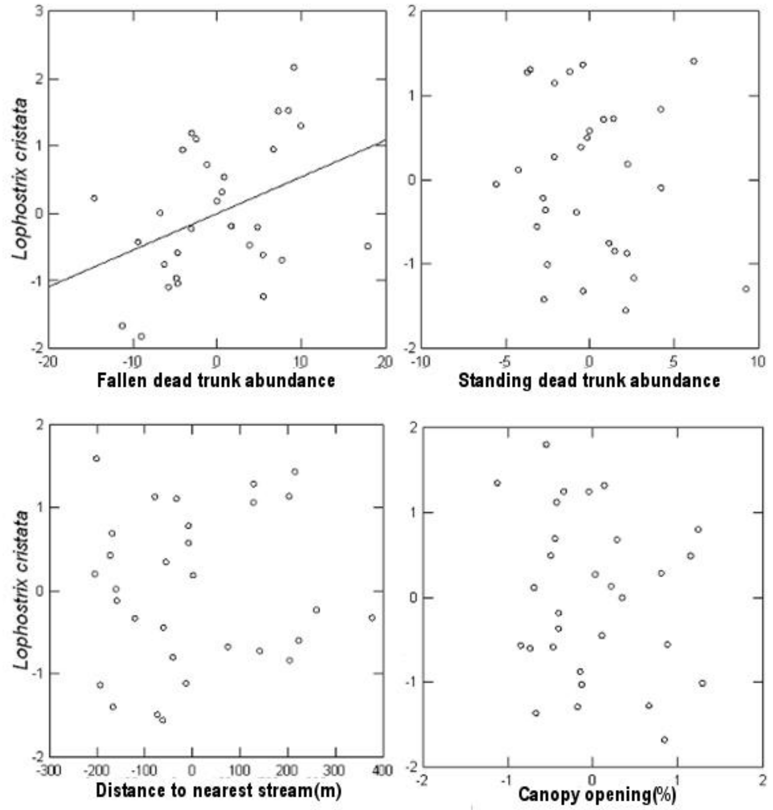


Figure V.

Modelo 1



Modelo 2

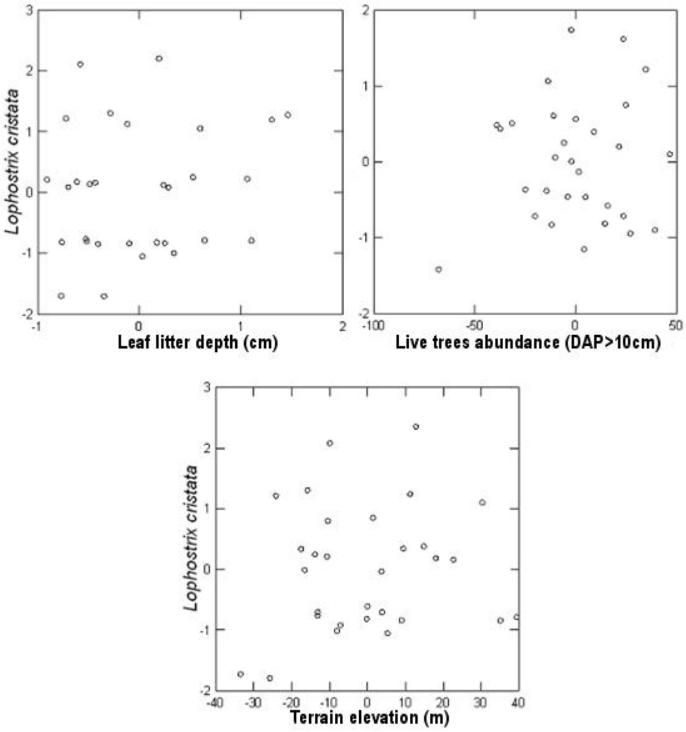
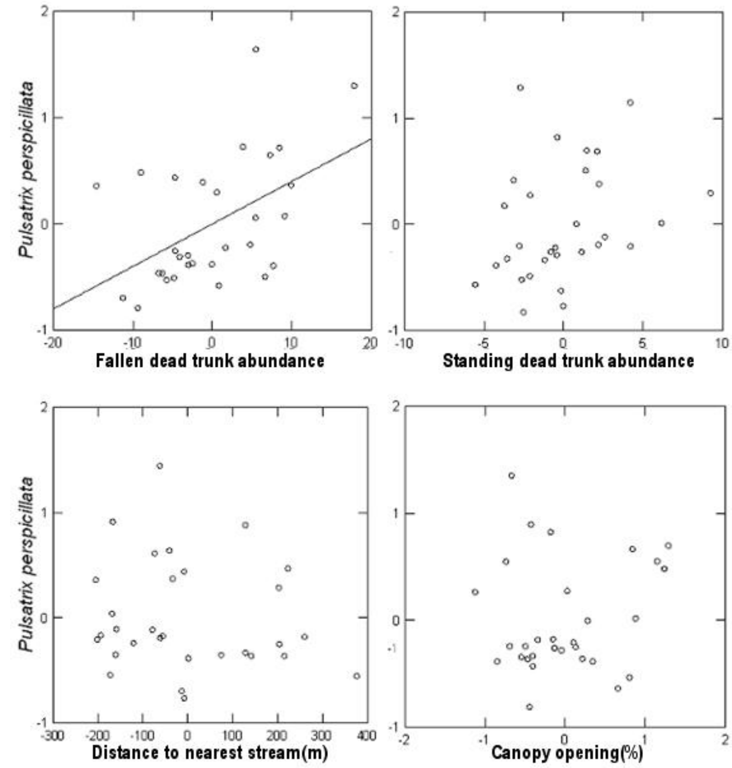
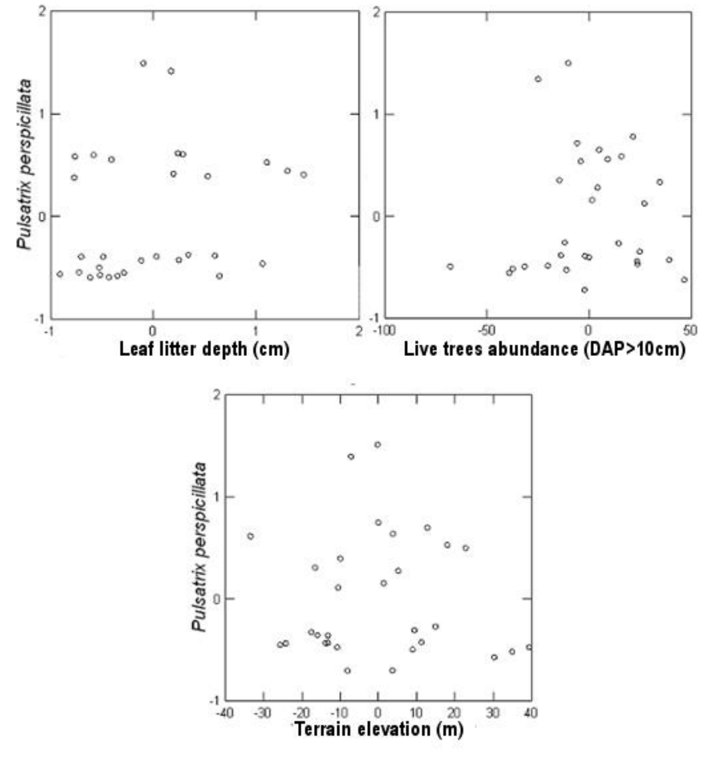


Figure VI.

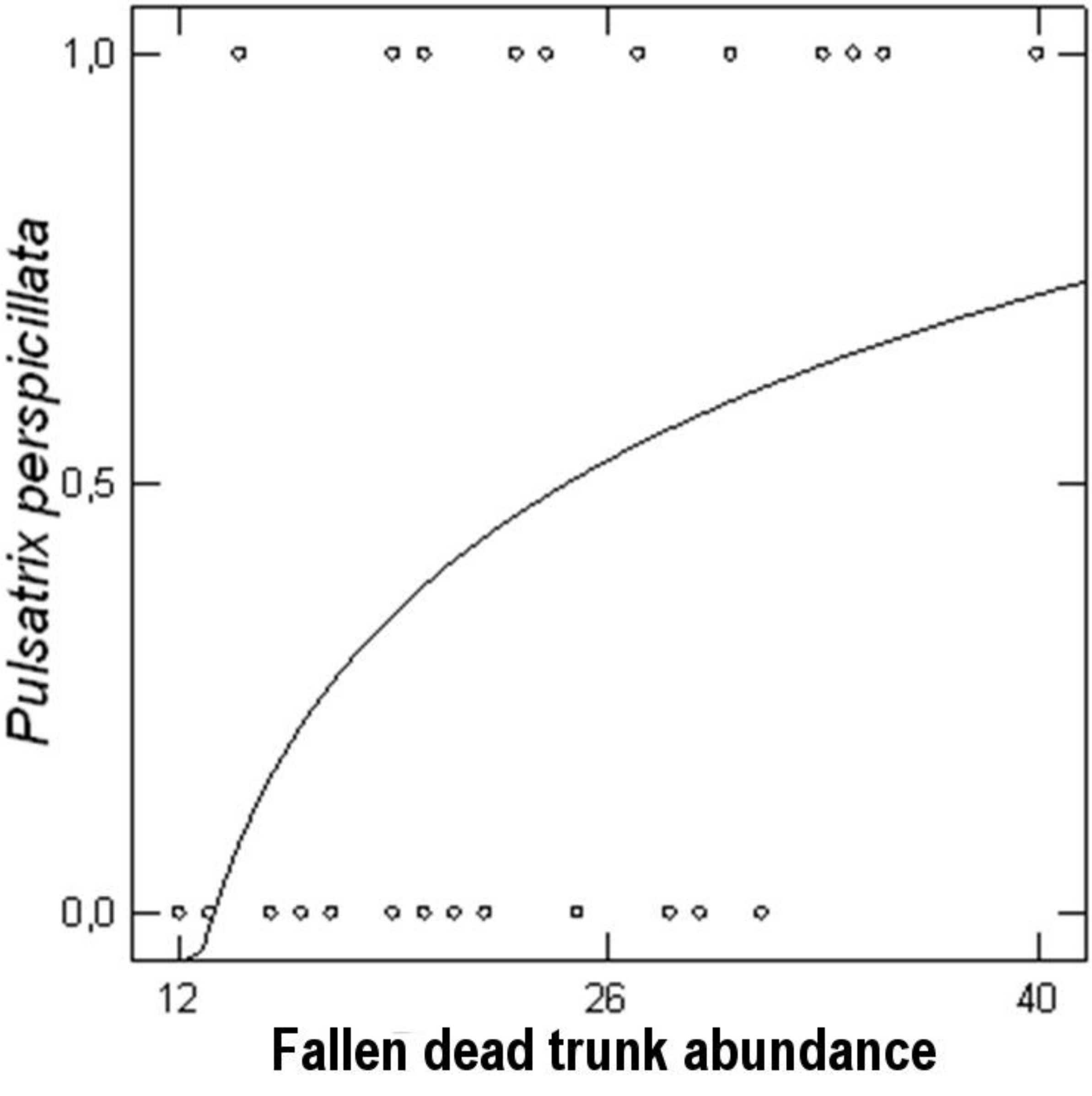


Modelo 1



Modelo 2

Figure VII.


1,0
0,5
0,0
12
26
40
Fallen dead trunk abundance
Pulsatrix perspicillata

CONCLUSÃO

O presente estudo conclui que as corujas usam diferentes micro-habitats, são dissimilares de acordo com o tamanho corpóreo assim como nos seus requerimentos de habitat, alimentar, reprodutivos e comportamentos interespecíficos.

A menor espécie estudada *Glaucidium hardyi* (caburé-da-amazônia) aparentemente é uma espécie dominante, pois se mostrou extremamente agressiva mesmo às reproduções do playback de espécies com o triplo de seu tamanho.

De acordo com as relações estabelecidas entre os componentes da estrutura da floresta e sua importância para a espécie, os componentes relacionados à disponibilidade de recursos alimentares foram os que estiveram relacionados significativamente com a ocorrência e densidade das espécies de corujas. Isso foi observado, possivelmente, pelo fato de já terem filhotes nos ninhos, o que torna os recursos alimentares extremamente importantes, já que os pais, além de buscarem alimento para si, têm de alimentar sua prole.

Mais estudos ainda são necessários e por vários anos, principalmente quanto ao uso de habitat e movimentação de indivíduos, a fim de verificar se o padrão encontrado está, de fato, relacionado à influencia da estrutura da vegetação ou se é resultado da expansão e ocupação da espécie ao longo de vários períodos reprodutivos.

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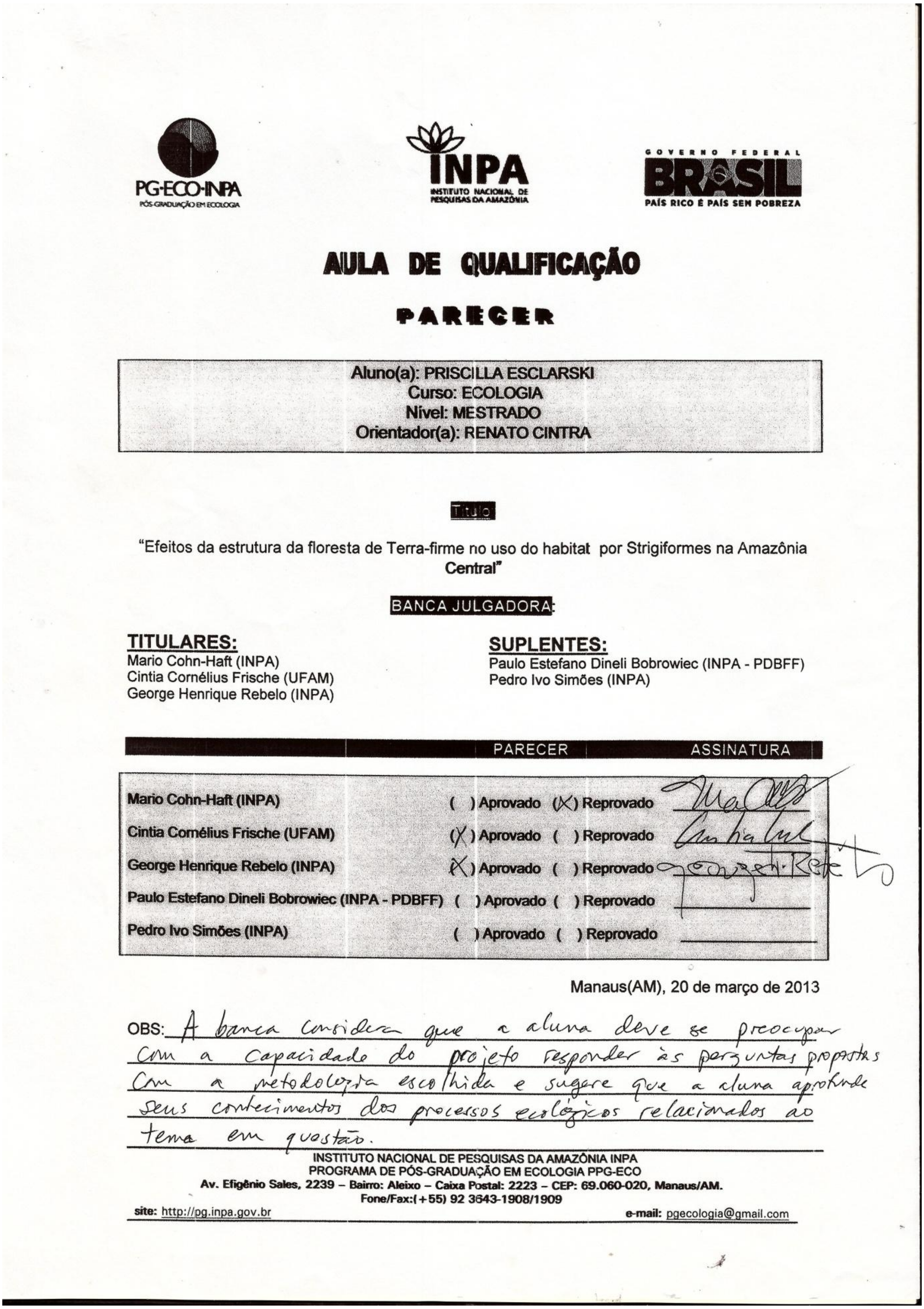
APÊNDICES

Ata da Aula de Qualificação



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INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

GOVERNO FEDERAL
BRASIL
PAÍS RICO É PAÍS SEM POBREZA

AULA DE QUALIFICAÇÃO

PARECER

Aluno(a): PRISCILLA ESCLARSKI
Curso: ECOLOGIA
Nível: MESTRADO
Orientador(a): RENATO CINTRA

Título

"Efeitos da estrutura da floresta de Terra-firme no uso do habitat por Strigiformes na Amazônia **Central**"

BANCA JULGADORA:

TITULARES:
Mario Cohn-Haft (INPA)
Cintia Cornélius Frische (UFAM)
George Henrique Rebelo (INPA)

SUPLENTES:
Paulo Estefano Dineli Bobrowiec (INPA - PDBFF)
Pedro Ivo Simões (INPA)

	PARECER	ASSINATURA
Mario Cohn-Haft (INPA)	( ) Aprovado (X) Reprovado	
Cintia Cornélius Frische (UFAM)	(X) Aprovado ( ) Reprovado	
George Henrique Rebelo (INPA)	(X) Aprovado ( ) Reprovado	George H. Rebelo
Paulo Estefano Dineli Bobrowiec (INPA - PDBFF)	( ) Aprovado ( ) Reprovado	
Pedro Ivo Simões (INPA)	( ) Aprovado ( ) Reprovado	

Manaus(AM), 20 de março de 2013

OBS: A banca considera que a aluna deve se preocupar com a capacidade do projeto responder às perguntas propostas com a metodologia escolhida e sugere que a aluna aprofunde seus conhecimentos dos processos ecológicos relacionados ao tema em questão.

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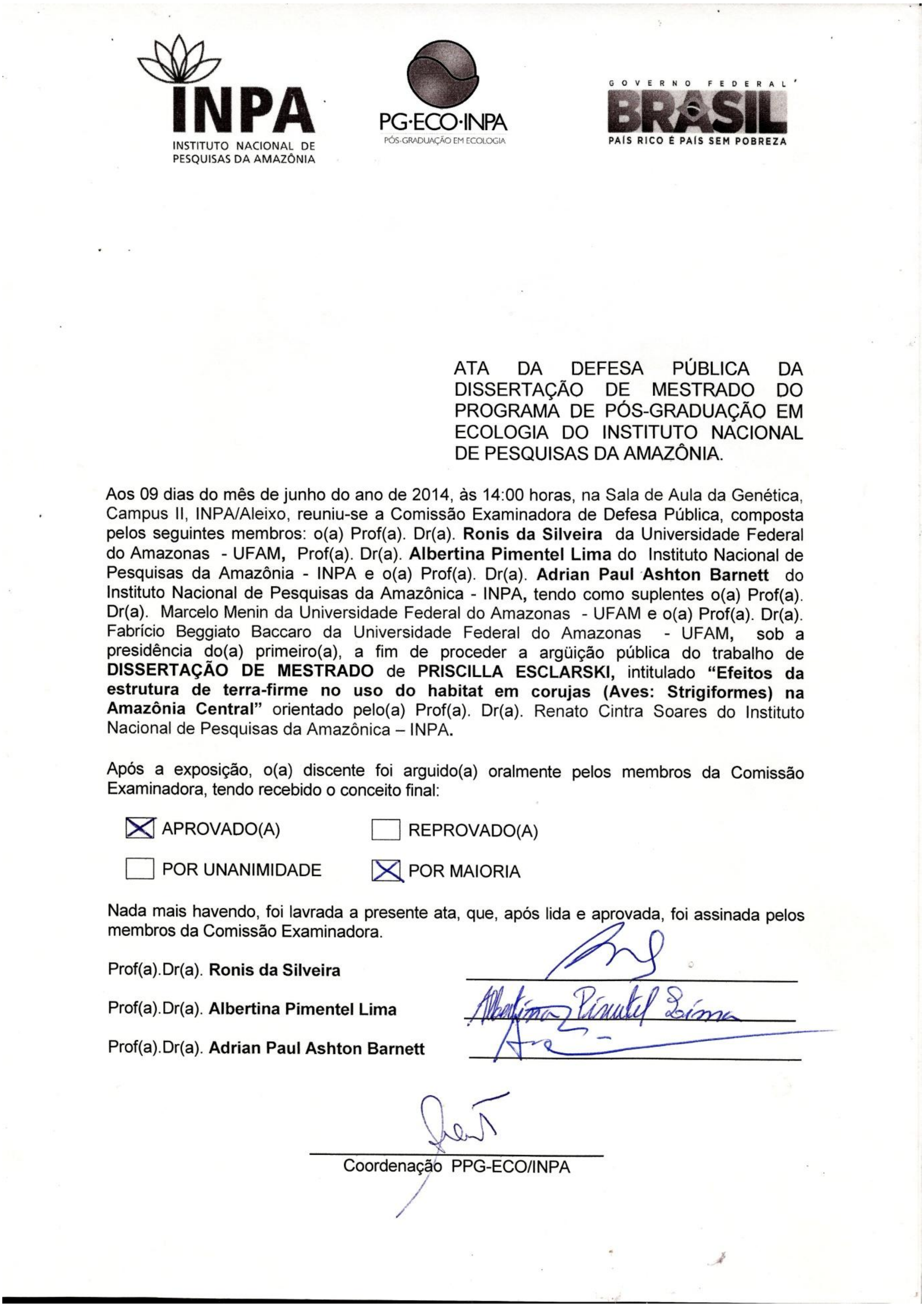
PROGRAMA DE PÓS-GRADUAÇÃO EM ECOLOGIA PPG-ECO
Av. Efigênio Sales, 2239 – Bairro: Aleixo – Caixa Postal: 2223 – CEP: 69.060-020, Manaus/AM.
Fone/Fax:(+55) 92 3643-1908/1909
site: http://pg.inpa.gov.br **e-mail:** pgecologia@gmail.com



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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 09 dias do mês de junho do ano de 2014, às 14:00 horas, na Sala de Aula da Genética, Campus II, INPA/Aleixo, reuniu-se a Comissão Examinadora de Defesa Pública, composta pelos seguintes membros: o(a) Prof(a). Dr(a). **Ronis da Silveira** da Universidade Federal do Amazonas - UFAM, Prof(a). Dr(a). **Albertina Pimentel Lima** do Instituto Nacional de Pesquisas da Amazônia - INPA e o(a) Prof(a). Dr(a). **Adrian Paul Ashton Barnett** do Instituto Nacional de Pesquisas da Amazônica - INPA, tendo como suplentes o(a) Prof(a). Dr(a). Marcelo Menin da Universidade Federal do Amazonas - UFAM e o(a) Prof(a). Dr(a). Fabrício Beggiato Baccaro da Universidade Federal do Amazonas - UFAM, sob a presidência do(a) primeiro(a), a fim de proceder a argüição pública do trabalho de **DISSERTAÇÃO DE MESTRADO** de **PRISCILLA ESCLARSKI,** intitulado **"Efeitos da estrutura de terra-firme no uso do habitat em corujas (Aves: Strigiformes) na Amazônia Central"** orientado pelo(a) Prof(a). Dr(a). Renato Cintra Soares do Instituto Nacional de Pesquisas da Amazônica – INPA.

Após a exposição, o(a) discente foi arguido(a) oralmente pelos membros da Comissão Examinadora, tendo recebido o conceito final:

☒ APROVADO(A) ☐ REPROVADO(A)

☐ POR UNANIMIDADE ☒ POR MAIORIA

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

Prof(a).Dr(a). **Ronis da Silveira** ______________________

Prof(a).Dr(a). **Albertina Pimentel Lima** Albertina Pimentel Lima ______________________

Prof(a).Dr(a). **Adrian Paul Ashton Barnett** ______________________

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Coordenação PPG-ECO/INPA