

UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE BIOLOGIA



COMUNIDADE DE MORCEGOS EM UMA PAISAGEM
FRAGMENTADA DA MATA ATLÂNTICA DO SUL DA BAHIA,
BRASIL

Este exemplar corresponde à redação final da tese defendida pelo(a) candidato (a) <i>Deborah Maria de Faria</i> e aprovada pela Comissão Julgadora.

DEBORAH MARIA DE FARIA

A handwritten signature in black ink, appearing to read "Wesley R. Silva".

Tese apresentada ao Instituto de
Biologia da Universidade Estadual de
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Orientador: Dr. Wesley Rodrigues Silva

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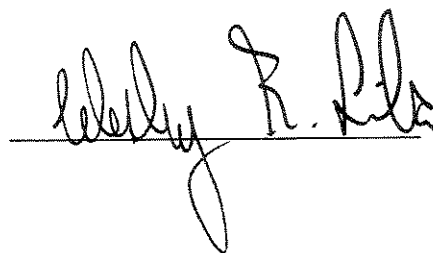
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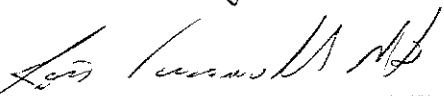
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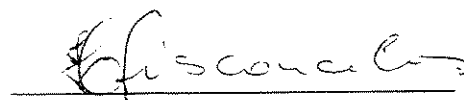
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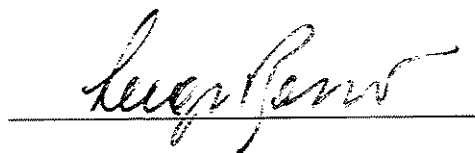
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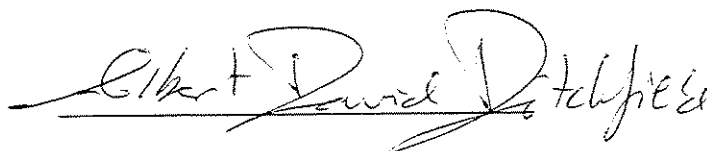
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RESUMO

O processo de conversão de florestas tropicais em paisagens fragmentadas e alteradas é uma das principais causas das elevadas taxas atuais de extinção. Este estudo procurou analisar o impacto da fragmentação e alteração dos ambientes florestais em uma paisagem da Mata Atlântica do sul da Bahia, Brasil. A estrutura da vegetação e da comunidade de morcegos foi investigada em seis categorias de ambientes que compõem a maior parte do mosaico florestal da região de Una: interiores e bordas de floresta contínua (> 1.000 ha) e fragmentos (< 100 ha), plantações sombreadas de cacau (cabruças) e florestas em regeneração inicial (capoeiras). Na região de Una, a fragmentação, regeneração e uso da terra resultam em modificações detectáveis em importantes parâmetros da estrutura da floresta, podendo-se ordenar as categorias ao longo de diferentes gradientes de perturbação. Os padrões de riqueza e abundância total das espécies não foram afetados pela redução da floresta, com fragmentos apresentando a mesma riqueza e frequência de captura que áreas contínuas, embora uma espécie, *Artibeus obscurus*, tenha sido significativamente menos capturada em fragmentos. O principal impacto do processo de fragmentação na comunidade foi a formação de bordas. Nestes ambientes a riqueza de espécies de morcegos foi reduzida pela metade quando comparada com a riqueza obtida em interiores de floresta. As florestas secundárias, que formam a maior parcela da matriz florestal que circunda os remanescentes em Una, se mostraram permeáveis apenas para uma pequena parcela da comunidade de morcegos. Por outro lado, as cabruças apresentaram uma grande riqueza e diversidade de espécies, incluindo várias espécies raras. No entanto, a riqueza e diversidade elevadas nas cabruças de Una parecem estar associadas a proximidade destas áreas com manchas de floresta, pois amostragens em outra região onde cabruças encontram-se distantes de áreas remanescentes mostraram uma comunidade menos rica e diversificada que as cabruças em Una. A resposta dos morcegos às diferentes categorias de floresta é, pelo menos parcialmente, relacionada com as modificações na estrutura florestal destas categorias. As informações geradas neste estudo têm implicações para a conservação da fauna de morcegos nesta região da Mata Atlântica.

ABSTRACT

The process of forest conversion on the tropical fragmented and disturbed landscapes is considered a major cause leading to the present high rates of extinction. The present study attempted to investigate the impact of forest fragmentation in a landscape of the Atlantic forest located in the southern part of the State of Bahia, Northeastern Brazil. Forest structure and the bat community were evaluated in six habitat categories comprising the bulk of the forest mosaic left in the Una region: interiors and edges of continuous forests (>1,000 ha) and fragments (<100 ha), cacao shade plantations (cabruças) and early secondary forests (capoeiras). In the Una region, fragmentation, regeneration and land use have resulted in overall modifications of the original forest structure, and it was possible to order the previously defined forest categories along gradients of structural disturbance. Patterns of bat species richness and abundance were not directly affected by the reduction of forest area, with fragments showing the same diversity, mean species richness and capture frequency as continuous forest tracts, although significant differences were reported to occur in the abundance of a single species, *Artibeus obscurus*, that was less frequent in fragments than continuous areas. The main impact of fragmentation on bats appears to be the formation of edges. Overall, species richness in all forest edge sites was roughly half the number reported to occur for all interior sites. Secondary forests, comprising the bulk of the forest matrix in the Una region, proved to be permeable to only a small fraction of bat species. On the other hand, shade cacao plantations showed a rich and diverse bat assemblage, including rare species. However, this striking richness seem to be closely linked with the presence of forest remnants nearby these plantations, as samples taken from cabruças located at some distance from forest tracts were poorer and less diverse compared with those from Una region. The response of bats to different forest categories seems to be partially associated with some modifications on the original forest structure. This study brings some important information for the conservation of bats in this region of the Atlantic rainforest.

PRÓLOGO

FRAGMENTAÇÃO DE HÁBITAT: O PROBLEMA CENTRAL

A conversão de habitats naturais em fragmentos de diversos tamanhos, graus de conectividade e níveis de perturbação tem se tornado uma das principais ameaças à biodiversidade em todo o mundo (Myers 1980; Shafer 1990). Este processo, conhecido como fragmentação de habitat traz conseqüências teoricamente previsíveis sobre a biodiversidade (Shafer 1990), tornando a dinâmica das comunidades biológicas diferente daquela prevista para sistemas naturais contínuos (Noss & Csuti 1994). Quando um determinado ecossistema é fragmentado, muitas características ecológicas se alteram já que cada porção restante contém apenas uma fração da biota original. Estudos relatam extinções locais, alterações na composição e abundância de espécies e outras formas de empobrecimento e modificação da biota em fragmentos (Willis 1979; Noss 1983; Wilcox & Murphy 1985; Saunders et al. 1991; Bierregaard et al. 1997; Laurance 1997, 1999).

A fragmentação é particularmente preocupante nas florestas tropicais, que juntas abrigam mais da metade do total de espécies de plantas e animais que habitam o globo terrestre (Wilson 1988). Com exceção da Amazônia, a maior parte do que ainda resta encontra-se confinada a fragmentos pequenos e perturbados, geralmente com menos de 100 ha (Turner & Corlett 1996). Esta situação justifica a noção geral de que a fragmentação das florestas tropicais tem sido a principal causa de extinção atual de espécies terrestres em larga escala (Diamond 1989; Shafer 1990). O grande volume de estudos conduzidos nas últimas três décadas resultou no acúmulo de um corpo de conhecimento importante sobre as conseqüências e mecanismos responsáveis pela erosão e alteração da biodiversidade em comunidades fragmentadas (Terborgh 1992; Turner 1996; Laurance 1999).

Parte da erosão biológica que ocorre após a fragmentação deve-se à direta redução do montante total de habitat original. De fato, a existência de uma relação positiva entre a área total e a riqueza local tem sido amplamente observada em inúmeros estudos (Arrhenius 1921; Preston 1962), sendo considerada como uma das regras mais robustas da ecologia (Schoener 1976). Áreas menores teriam uma riqueza de espécies reduzida quando comparadas a grandes extensões devido à menor diversidade ou heterogeneidade de habitats associados (Williams 1943), por representarem apenas uma fração da comunidade originalmente presente em áreas maiores e devido à menor probabilidade de um dado indivíduo encontrar e colonizar uma área menor (Simberloff 1978).

Os primeiros estudos da fragmentação de hábitat tiveram fundamentação na teoria da Biogeografia de Ilhas proposta por MacArthur e Wilson (1967), cuja hipótese central é de que a riqueza de espécies em uma determinada ilha seria resultante do balanço de duas forças opostas: as taxas de extinção e de colonização. Ilhas pequenas teriam populações menores, sendo mais sujeitas a flutuações estocásticas de caráter demográfico, genético e ambiental (Shaffer 1981; Bierregaard et al. 1997), e portanto apresentariam taxas de extinção local mais elevadas do que ilhas grandes. Da mesma forma, taxas de colonização reduzidas seriam esperadas para ilhas mais remotas, distantes de fontes de colonizadores. O número de espécies que determinada ilha poderia suportar, então, seria determinado pelo equilíbrio entre estas duas forças opostas. Assim, ilhas pequenas e isoladas apresentariam um menor número de espécies do que aquelas maiores e próximas a outras ilhas ou continentes (MacArthur & Wilson 1967). Fragmentos de um ecossistema terrestre poderiam ser vistos como ilhas de vegetação distantes e isoladas entre si por estarem circundadas por um mar de ambientes modificados e inóspitos (Preston 1962). Esta semelhança entre sistemas insulares e fragmentos florestais resultou na condução de inúmeros estudos baseados na teoria de MacArthur e Wilson, enfocando o tamanho e distância entre fragmentos como variáveis principais determinantes da composição e riqueza de espécies dos remanescentes florestais (Willis 1979; Diamond 1989; Simberloff 1978).

Durante algum tempo, o modelo de ilhas foi considerado uma ferramenta promissora capaz de auxiliar no embasamento de decisões práticas para a conservação de espécies e ecossistemas, como o desenho de reservas, tamanho mínimo de ecossistema, e planos de manejo de áreas de preservação (p. ex. Preston 1962; Diamond 1975; Wilson & Willis 1975; Whitcomb et al. 1976; Wilcox 1980; Temple 1981; Wright & Hubbel 1983). Alguns pesquisadores foram mais longe, chegando a afirmar que o modelo poderia ser utilizado com eficiência para prever taxas locais de extinção, capacidade de suporte e vulnerabilidade de determinadas espécies em persistir nas comunidades terrestres fragmentadas (Kolata 1974 *apud* Shafer 1990).

No entanto, com o aumento considerável de estudos testando as previsões em fragmentos terrestres, observou-se que nem todos os organismos ou ambientes se comportavam como o previsto em ilhas verdadeiras. A aplicação do modelo para a conservação de sistemas fragmentados recebeu várias críticas (p. ex. Terborgh 1974; Simberloff & Abele 1976). Tornou-se evidente que esta analogia entre sistemas terrestres e insulares era limitada e simplista (Terborgh 1974), pois a água que circunda os arquipélagos é um ambiente capaz de impedir a dispersão da maioria dos organismos terrestres,

virtualmente isolando populações entre diferentes ilhas. Por outro lado, um isolamento completo não ocorre entre diferentes fragmentos florestais. Nos sistemas terrestres, o conjunto de ambientes modificados que envolve os remanescentes, e que são definidos como matriz (Gascon et al. 1999), mostram-se mais complexos e dinâmicos do que ambientes aquáticos. Estas matrizes de diferentes composições e permeabilidade interagem com os fragmentos de forma que a paisagem como um todo exerce influência direta sobre a manutenção das comunidades nos remanescentes (Forman 1995; McIntyre & Barret 1992; Gascon et al. 1999).

A natureza e composição das matrizes, e a tolerância que cada organismo tem em relação a estes ambientes, geram respostas variáveis entre diferentes grupos taxonômicos em áreas fragmentadas (Laurance 1990, 1991a; Malcolm 1997; Gascon et al. 1999). Espécies com maior capacidade de se dispersar e explorar as matrizes podem se manter e até são favorecidas nas áreas fragmentadas, enquanto espécies menos tolerantes tendem a ser mais vulneráveis, mantendo-se isoladas pelos entornos e restringindo seu hábitat apenas aos limites do fragmento (Bierregard et al. 1997; Gascon et al. 1999). Na Amazônia brasileira, as comunidades de pequenos mamíferos terrestres (Malcom 1988, 1997) e de sapos (Tocher et al. 1997) são mais ricas, diversas e abundantes em fragmentos pequenos pois parte das espécies florestais exploram de forma eficiente as áreas secundárias que circundam as matas, ocorrendo também um influxo de espécies destes entornos para dentro dos fragmentos. A capacidade de explorar as matrizes foi a característica ecológica mais importante relacionada a vulnerabilidade de marsupiais em uma região fragmentada da Austrália (Laurance 1991a), determinando também a vulnerabilidade de formigas, aves, pequenos mamíferos e sapos em uma paisagem fragmentada na Amazônia brasileira (Gascon et al. 1999). Por outro lado, Janzen (1983) aponta que a influência destes entornos modificados, como áreas secundárias, torna-se preocupante mesmo quando não acarreta redução direta da riqueza total de espécies em um remanescente. Em alguns casos deve ocorrer uma profunda alteração na representatividade de determinadas espécies, favorecendo aquelas tipicamente associadas a áreas mais perturbadas (Janzen 1983). Espécies pioneiras, generalistas e exóticas freqüentemente invadem ou são favorecidas em remanescentes florestais, alterando a estrutura das comunidades locais, aumentando a vulnerabilidade de espécies restritas a áreas da floresta original.

Uma das consequências diretas da fragmentação é o aumento da quantidade de hábitat de borda em um determinado fragmento (Lovejoy et al. 1986). A borda, definida

como a zona mais externa do remanescente, sofre influência direta dos ambientes do entorno, e nela ocorrem mudanças drásticas de caráter físico e biótico. Estas alterações são particularmente mais acentuadas quando ocorre uma transição abrupta entre a floresta e áreas abertas como pastagens e monoculturas anuais (Mesquita et al. 1999). Nestas faixas de borda ocorre uma maior penetração de luz, uma redução na umidade relativa, uma maior variação da temperatura e um aumento da incidência de ventos, resultando em um microclima distinto das regiões mais interioranas da floresta (Lovejoy et al. 1986; Kapos 1989; Turton & Freiburger 1997; Kapos et al. 1997). De modo geral, estas mudanças afetam as comunidades de animais e plantas que vivem em um fragmento. A maior incidência de luz favorece o estabelecimento de plantas pioneiras e associadas a áreas mais abertas, e um aumento de danos na estrutura da floresta é relacionado com a maior atuação do vento nas bordas (Laurance 1991b, 1997, 1998; Tabarelli et al. 1999; Mesquita et al. 1999). O efeito de borda promove uma alteração geral no hábitat fragmentado, sendo uma das conseqüências mais evidentes e importantes desencadeadas pela fragmentação da floresta (Bierregaard et al. 1997; Davies et al. 2001).

A penetração deste efeito de borda varia de acordo com a região e com o tipo de parâmetro considerado. Geralmente modificações microclimáticas ocorrem numa faixa que varia entre 15 e 60 metros do contato do fragmento e o entorno (Kapos 1989; Bierregaard et al. 1997). Em fragmentos florestais na Amazônia, espécies de borboletas associadas a áreas perturbadas podem penetrar mais de 250 metros mata adentro (Lovejoy et al. 1986; Brown & Hutchings 1997). Laurance et al. (1998) mostram uma maior taxa de mortalidade e danos em plantas a até 100 m da borda em fragmentos na Amazônia brasileira, mas em uma floresta tropical australiana este efeito pode ser notado até 500 m mata adentro (Laurance 1991b). Dependendo de características como o formato e tamanho de um dado fragmento (Laurance 1991b) e da natureza da matriz que o envolve, o efeito de borda pode ser tão drástico que todo o remanescente é alterado, ao ponto de não permitir a sobrevivência de espécies mais sensíveis, geralmente restritas a áreas interiores ou nucleares de um fragmento. Determinadas espécies florestais de insetos, aves e pequenos mamíferos evitam bordas, tornando-se raros ou ausentes em uma faixa entre 50 a 100 metros mata adentro (Bierregaard et al. 1997; Didham 1997), necessitando de fragmentos relativamente grandes que comportem áreas nucleares.

Além da tolerância das espécies a habitats modificados, como matrizes e bordas, sabe-se que características ecológicas e naturalísticas das espécies de florestas tropicais as tornam particularmente vulneráveis aos efeitos da fragmentação (Bierregaard et al. 1997).

Fatores como baixa densidade populacional, pequena fecundidade, baixa taxa reprodutiva, raridade natural e pouca plasticidade ecológica tornam certos componentes do ecossistema mais sensíveis à redução e isolamento das áreas naturais do que outros (Laurance 1990, 1991a; Turner 1996). Animais e plantas com grande requerimento de área, como predadores de topo, espécies de grande porte, organismos sedentários ou com pouca capacidade de dispersão tendem a ser negativamente afetados pela fragmentação, assim como organismos sujeitos à caça, coleta e outros tipos de exploração antrópica (Terborgh 1992).

Mais recentemente, os estudos sobre fragmentação começaram a mostrar que características gerais da paisagem, como a distribuição, forma e conectividade entre as porções fragmentadas (Forman 1995), também são fatores-chave que influenciam na dinâmica dos fragmentos florestais. Estes estudos em escala de paisagem, aliados a pesquisas sobre a distribuição e uso de hábitat pela biota, mostraram que, em muitos casos, as espécies utilizam vários ambientes que compõem o mosaico, incluindo os remanescentes florestais e áreas perturbadas e semi-naturais. Tornou-se evidente que, mais do que os próprios hábitats florestais remanescentes, a paisagem como um todo deveria servir de unidade de manejo para permitir a conservação de algumas espécies (Law & Dickman 1998; Gascon et al. 1999).

Apesar dos avanços obtidos nos últimos 30 anos de pesquisa em fragmentação de hábitat, estudos que descrevam a resposta da biota tropical em uma escala de paisagem ainda são raros (ex. Estrada et al. 1993, 1994; Laurance 1990, 1991a; Gascon et al. 1999), e englobam um número limitado de grupos biológicos (Turner 1996). A escassez deste tipo de dado tem limitado a capacidade de prever e diagnosticar com segurança o impacto deste processo em determinadas áreas já fragmentadas ou que estão sujeitas a fragmentação.

A MATA ATLÂNTICA E OS MORCEGOS

Entre as florestas tropicais mais fragmentadas em todo o mundo encontra-se a Mata Atlântica. Calcula-se que, dos quase 1.3 milhões de km² de florestas distribuídas numa faixa de 4.000 km de norte a sul ao longo da costa brasileira em 1500, atualmente restam cerca de 7.6% (Ministério do Meio Ambiente 1999). Esta floresta caracteriza-se por um alto índice de endemismo e riqueza de espécies, abrigando aproximadamente 7% do total de espécies conhecidas em todo o mundo, sendo pelo menos 389 delas endêmicas (Conservation International do Brasil et al. 2001). Estas características colocam a Mata

Atlântica entre as florestas mais ameaçadas em todo o mundo e entre as áreas mais prioritárias dentro de estratégias de conservação em escala nacional e mundial (Myers et al. 2000).

Embora a maior parte dos pesquisadores brasileiros esteja atuando em centros de pesquisa localizados dentro do domínio da Mata Atlântica, a maior parte do conhecimento sobre os efeitos do processo de fragmentação de florestas tropicais ainda advém dos estudos principalmente conduzidos pelo projeto Dinâmica Biológica de Fragmentos Florestais, em Manaus. A dinâmica observada nestes fragmentos da Amazônia, criados há menos de duas décadas e imersos em uma paisagem experimentalmente manipulada, dificilmente pode ser diretamente extrapolada para paisagens mais complexas e há muito fragmentadas (Turner 1996). Dada a grande variação de paisagens, históricos de ocupação, bem como da estrutura das comunidades biológicas, dificilmente todas as florestas tropicais respondem da mesma forma à fragmentação (Turner 1996; Crome 1997). Deste modo, estudos locais e dirigidos a compreender e diagnosticar a resposta da biota em paisagens específicas devem ser considerados de extrema importância.

Das cerca de 250 espécies de mamíferos encontrados na Mata Atlântica, pelo menos 96 são morcegos (Marinho-Filho & Sazima 1998), um grupo de vertebrados bastante diversificado nas florestas tropicais (Findley 1993). Como o único grupo de mamíferos verdadeiramente alado, os morcegos possuem grande mobilidade e capacidade de dispersão, sendo que muitas espécies podem apresentar movimentos e padrões de uso múltiplo de habitat dentro de uma escala de paisagem (Estrada et al. 1993; Walsh & Harris 1996; Law et al. 1999). Por outro lado, fatores como a distância entre áreas remanescentes, a natureza e a configuração dos habitats modificados do entorno, e requerimentos ecológicos específicos tornam determinadas espécies de morcegos particularmente mais vulneráveis a fragmentação (Fenton et al. 1992; Cosson et al. 1999). Apesar da grande riqueza de espécies, do importante papel que morcegos desempenham na funcionalidade das florestas tropicais e da sua estreita relação com os ambientes florestais, pouco se sabe a respeito da resposta deste grupo frente ao processo de fragmentação e alteração de florestas. Esta lacuna no conhecimento é particularmente evidente nas florestas tropicais.

OBJETIVOS

O presente estudo investigou o impacto do processo de fragmentação e alteração de habitats naturais sobre uma comunidade de morcegos em uma paisagem da Mata Atlântica do sudeste do Estado da Bahia, Brasil. Foi considerada a distribuição das espécies de morcegos em áreas de floresta primária e ambientes de entorno, como áreas de plantações sombreadas de cacau e florestas em regeneração inicial. Trata-se do primeiro estudo sobre morcegos conduzido em uma escala de paisagem no Brasil, e um dos únicos para a região tropical (veja Estrada et al. 1993). Esta pesquisa foi parte integrante de um estudo maior e mais abrangente, o Projeto Remanescentes de Floresta da Região de Una – Projeto RestaUna – cujo objetivo central é o de investigar, comparativamente, a resposta de diferentes grupos biológicos frente à fragmentação, regeneração e uso da terra na região de Una.

ORGANIZAÇÃO DO ESTUDO

Esta dissertação encontra-se dividida em quatro capítulos. O capítulo I traz uma breve descrição da região sul da Bahia e da área de estudo, incluindo o desenho experimental básico do projeto RestaUna, que foi seguido para a amostragem da estrutura da vegetação, sendo modificado para as amostragens de morcegos. É dada uma descrição quantitativa e qualitativa da paisagem, incluindo o cálculo da representatividade de várias categorias de ambientes que compõem o mosaico da região. Os três capítulos seguintes trazem os dados biológicos obtidos dentro desta pesquisa e são apresentados no formato de manuscritos científicos independentes, já redigidos na língua inglesa e no formato exigido por periódicos internacionais. O capítulo II investiga quais são as principais alterações da estrutura da floresta em seis diferentes tipos de fisionomias florestais que resultam da fragmentação, regeneração e uso da terra. Considerando-se que tais modificações na estrutura florestal podem influenciar no uso destes ambientes pelos morcegos, este capítulo também serve de base para os resultados apresentados nos dois capítulos seguintes.

Nos capítulos III e IV, o desenho experimental do projeto RestaUna foi ajustado para permitir a avaliação mais precisa de diferentes processos de alteração de habitat sobre a comunidade de morcegos. O capítulo III aborda a resposta da fauna à fragmentação da floresta (insularização e efeito de borda) e à permeabilidade da matriz (capoeiras), e inclui amostragens em bordas e interiores de fragmentos (< 100 ha) e áreas contínuas (> 1000ha),

e em áreas secundárias, que compõem a maior parte do ambiente de entorno. O capítulo IV avalia o papel potencial das plantações sombreadas de cacau (cabruças) para a conservação de morcegos na região sul da Bahia, uma vez que este tipo de fisionomia florestal representa cerca de 40% do que resta de cobertura florestal na região. Neste capítulo foi investigado se as cabruças são capazes de abrigar uma fauna rica e diversa de morcegos e se tal estrutura de comunidade dependeria da proximidade de florestas. Com este objetivo, as amostragens em florestas maduras e cabruças na região de Una, onde as plantações sombreadas são pequenas e sempre próximas a florestas nativas, foram comparadas com aquelas obtidas em cabruças em uma paisagem mais representativa da região cacaueira, composta por extensas plantações distantes de manchas de florestas.

Finalmente, uma discussão geral e as principais conclusões incluindo as implicações práticas dos resultados obtidos neste estudo para a conservação são apresentadas no epílogo deste estudo.

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CAPÍTULO 1

O SUDESTE DA BAHIA, A REGIÃO DE UNA E O PROJETO RESTAUNA

O SUDESTE DA BAHIA, A REGIÃO DE UNA E O PROJETO RESTAUNA

No cenário mundial, o Brasil destaca-se como um país de megadiversidade, e é conhecido por abrigar o maior montante de floresta tropical remanescente no globo terrestre. Duas grandes porções de florestas tropicais cobriam o Brasil na época da chegada dos europeus colonizadores, a floresta Amazônica e a Mata Atlântica. Hoje, 500 anos depois, a Amazônia ainda abriga uma extensão de cerca de 80% da sua cobertura original, e guarda o título de maior e mais preservada floresta tropical do mundo. Por outro lado, a Mata Atlântica, local de entrada e estabelecimento de quase 80% da população brasileira, hoje encontra-se reduzida a menos de 8 % da sua cobertura original, que em 1.500 era estimada em cerca de 1.360.000 km² ou aproximadamente 16% do território brasileiro (Conservation International do Brasil et al. 2001).

A Mata Atlântica encontra-se isolada da Amazônia pelo menos desde o final do período Terciário (Mori et al. 1981), o que resultou em um grande número de espécies endêmicas de animais e plantas. Dentro da Mata Atlântica, pelo menos três regiões distintas são reconhecidas pelos altos níveis de endemismo para vários grupos biológicos tais como borboletas, anfíbios, aves e plantas (Thomas et al. 1998). Um destes bolsões localiza-se na região sudeste, e inclui as matas do litoral sul de São Paulo até o norte do Rio de Janeiro, estendendo-se ainda em parte do extremo sul do estado do Espírito Santo. Outros dois bolsões situam-se na região nordeste, um na região das florestas costeiras dos estados de Pernambuco, Paraíba e Alagoas, que hoje estão restritas às matas de brejo ou de topo de morros, e outro localizado mais ao sul, incluindo as matas costeiras do norte do Espírito Santo e sul da Bahia.

Este último bolsão de endemismo, mais precisamente localizado entre o norte da foz do Rio Doce (ES) e o sudeste da Bahia, forma uma faixa de floresta pluvial do complexo atlântico com características florísticas e faunísticas peculiares, denominada Hiléia Baiana. Além de ser considerada como um centro de endemismo para plantas (Mori et al. 1981, Prance 1982), insetos (Brown 1991), répteis (Jackson 1978), aves (Haffer 1974) e mamíferos (Rylands 1982), essa região também guarda um recorde de riqueza de árvores, com mais de 458 espécies em um único hectare (Carvalho & Thomas 1993; Thomas et al. no prelo). Levantamentos florísticos em duas áreas do sudeste da Bahia mostraram que entre 45 a 48% das espécies de plantas vasculares são endêmicas da Mata Atlântica, cerca de 8% apresentam distribuição disjunta entre este bioma e a Amazônia e aproximadamente 30% são encontradas exclusivamente na faixa da Hiléia Baiana (Thomas et al. 1998). Hoje

esta floresta está praticamente restrita ao sudeste do Estado da Bahia que, embora mantenha apenas 0.4% da cobertura original de floresta (Thomas et al. 1998), ainda abriga os maiores remanescentes de Mata Atlântica do nordeste brasileiro (Figura 1.1a). Esta situação ilustra a grande importância estratégica das florestas remanescentes do sudeste da Bahia para a conservação do bioma Mata Atlântica (Conservation International do Brasil et al. 2001).

Como o restante da Mata Atlântica, o sudeste baiano sofre desmatamento desde o Período Colonial (Dean 1997; Coimbra-Filho & Camara 1996), sendo importante área de extração de pau-brasil e estabelecimento dos primeiros engenhos de cana-de-açúcar no nordeste brasileiro. Madeiras nobres como o jacarandá, jatobá, vinhático, maçaranduba, sempre foram intensamente exploradas na região desde o período colonial até os dias de hoje, apesar da atual proibição desta atividade na Mata Atlântica como um todo.

Comparada ao restante da Mata Atlântica, o sul da Bahia ainda possui várias manchas de floresta, em parte devido às peculiaridades do cultivo do cacau (*Theobroma cacao*), principal produto agrícola local. O cultivo cacaueiro dá-se num sistema conhecido como cabruca, onde ocorre a substituição dos estratos inferiores da floresta por cacau, com a retenção de uma fração do dossel para sombreamento da cultura. Apesar de causar uma profunda alteração na composição florística, parte da estrutura da vegetação é mantida e a plantação se assemelha a uma floresta simplificada (Alves 1990). Comparada a outros usos da terra, como pastagens e monoculturas intensivas, áreas de cabruca são utilizadas por diversos organismos florestais, inclusive espécies de mamíferos e aves (Alves 1990; Moura 1999).

O estabelecimento da cultura cacaueira, no entanto, acompanhou de forma previsível a distribuição dos solos mais férteis da região do sul da Bahia, claramente mais concentrados na região mais a oeste da costa, a pelo menos 20 km do oceano (Figura 1.1b). Sobre estes solos concentra-se a maior parte da área cacaueira, onde predominam extensas plantações que, no total, comportam cerca de 40% do que restou de cobertura florestal na região sul da Bahia (May & Rocha 1996). Por outro lado, a maior parte dos remanescentes florestais encontra-se exatamente na faixa costeira, que pela presença de solos arenosos e pobres foi negligenciada pela cacaucultura (Figura 1.1b). Nesta região litorânea, as cabruças foram estabelecidas apenas em pequenas manchas de solos de maior produtividade, como vales de rios e nos poucos encaves de solos argilosos.

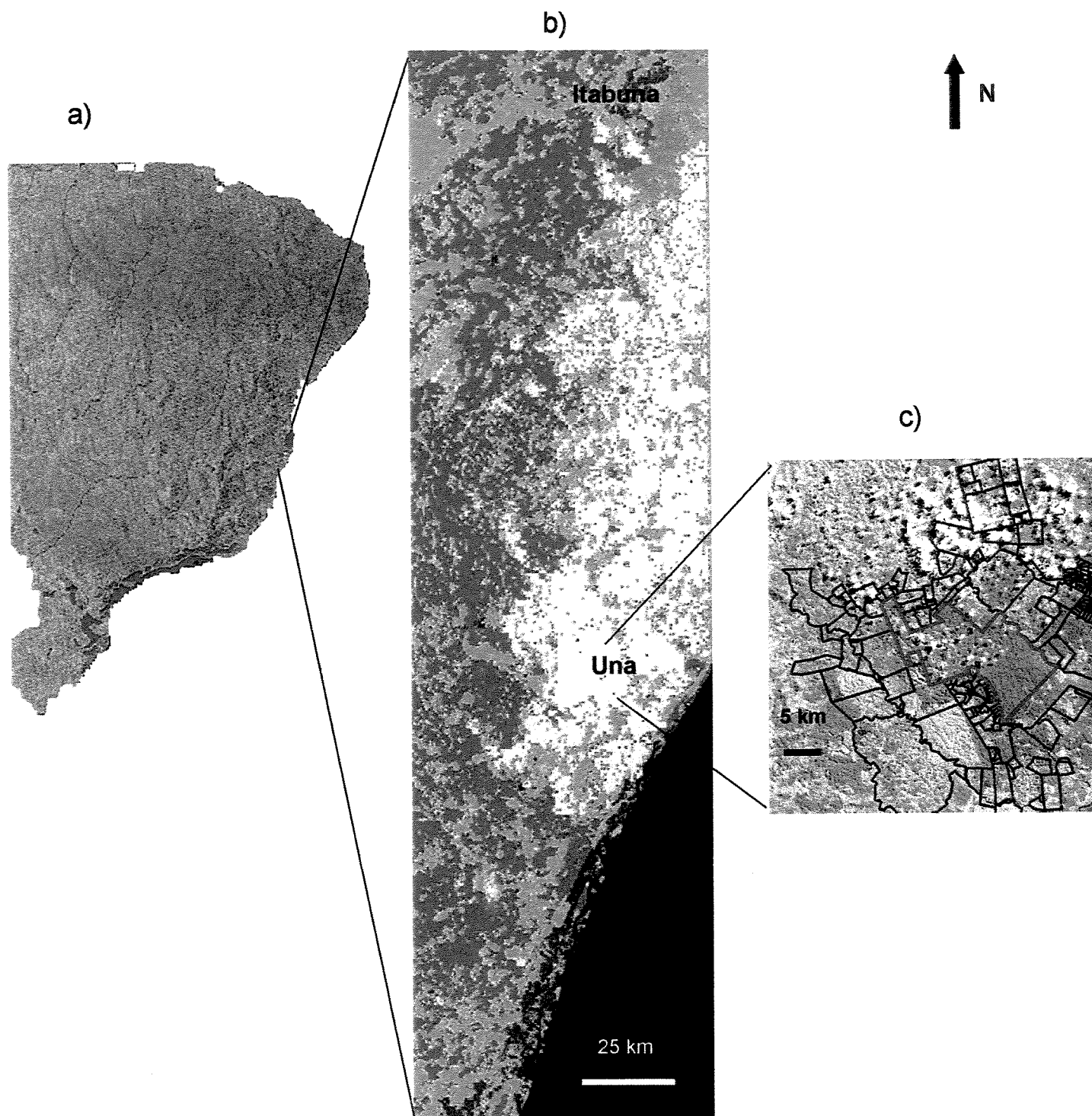


Figura 1.1. (a) Mapa do Brasil mostrando, em vermelho, a distribuição dos remanescentes de Mata Atlântica e, em destaque, a região sul da Bahia (Fonte: Revista Veja, 1999); (b) Imagem de radar da região sudeste da Bahia, mostrando a concentração das cabruças (laranja) na porção interiorana e as florestas (amarelo) no litoral (Saatchi et al. 2001); (c) os limites da Reserva Biológica de Una, em contorno vermelho, e o mapeamento de propriedades localizadas no entorno da reserva (Fonte: IESB).

Nas últimas duas décadas, dois fatores principais levaram à decadência da lavoura cacaueteira, resultando em uma considerável redução da cobertura florestal nesta região. Após a entrada maciça de produtores asiáticos e africanos no mercado mundial, o preço do cacau despencou para cerca da metade do valor necessário para a manutenção das lavouras (Alger 1998). A situação agravou-se ainda mais com a introdução e expansão do fungo vassoura-de-bruxa (*Crinipellis pernicioso*), doença que dizimou grande parte da lavoura acarretando uma brusca queda de produtividade dos cacauais brasileiros. Endividados e sem perspectivas, os proprietários das grandes fazendas da região começaram a explorar a madeira das cabruças e fragmentos florestais remanescentes, substituindo as lavouras sombreadas por outros tipos de cultivo e pastagens para garantir melhor retorno financeiro. Além disso, assentamentos agrícolas e invasões em áreas de solos de menor produtividade, impõem pressões aos remanescentes florestais da região, acelerando o processo de fragmentação das florestas como um todo.

A REGIÃO DE UNA

Pela predominância dos remanescentes na faixa ao longo da costa, e dada a necessidade de preservar trechos contínuos da Hiléia Baiana, o IBAMA decretou, em 1980, a Reserva Biológica de Una – RebioUna (Figura 1.1c), localizada no município de Una a 40 km ao sul da cidade de Ilhéus (15°10'S, 39°03'W). Porém, dos 11.400 ha contemplados pelo Decreto 85.463, apenas 7.022 ha foram legalmente adquiridos, sendo que o restante ainda hoje encontra-se ocupado por posseiros (Araújo et al. 1998). Somente 5.500 ha da área total adquirida são compostos por florestas maduras, sendo que o restante é representado por florestas secundárias, áreas abertas e plantações abandonadas.

A maior parte das manchas de floresta na região de Una ainda pertence a particulares. Um estudo contemplando a área implementada da RebioUna, dentro da zona tampão, mostra a existência de uma área de floresta no entorno pelo menos três vezes maior do que a área existente no interior da reserva (Araújo et al. 1998). Mesmo quando se tratam de manchas de tamanho reduzido, estas áreas servem de habitat para inúmeras espécies de animais e plantas, inclusive algumas ameaçadas de extinção. É o caso do primata endêmico, o mico-leão-da-cara-dourada (*Leontopithecus chrysomelas*), cuja população, estimada em 300 indivíduos na Reserva de Una, pode passar de 6.000 nos remanescentes da região (Alger & Caldas 1996).

Os remanescentes de floresta da região de Una formam uma das maiores porções contínuas de floresta ainda existentes em todo o nordeste brasileiro, e a região é hoje considerada como uma das áreas prioritárias para conservação (Ministério do Meio Ambiente 1999). Enquanto outras florestas de baixada estavam sendo intensamente destruídas, até 1945 cerca de 77,6% da região era coberta por florestas (Mendonça et al. 1993). Esta situação começou a mudar drasticamente após 1975 com a construção da rodovia BR 101, que abriu uma nova frente de colonização e exploração destas florestas, levando ao desmatamento de cerca de 42.700 ha. Nesta década de 70, a região de Una, como outras áreas do sul da Bahia, firmou-se como um importante polo madeireiro, abastecendo os mercados do sul do país após o esgotamento das madeiras nobres da faixa de Hiléia Baiana do Espírito Santo.

Análises de fotos aéreas mostram que em 1994 as florestas já ocupavam apenas 33,77% da região de Una, e até 1995 existiam pelo menos 19 serrarias estabelecidas na cidade e na zona rural do município de Una (Mesquita 1996). Hoje a extração de madeira de remanescentes florestais da Mata Atlântica está oficialmente proibida, mas grandes quantidades de toras ainda é extraída de cabruças, que estão sendo rapidamente substituídas por outros cultivos e atividades econômicas, como a pecuária e a cafeicultura.

É clara a urgência de um plano de ação para frear a perturbação que a área vem sofrendo, e recuperar alguns trechos já degradados. No entanto, qualquer iniciativa dessa natureza necessita de um maior volume de informações - de caráter qualitativo e quantitativo - a respeito da estrutura da biota local, cujo conhecimento atual é restrito a poucos grupos taxonômicos (p. ex. primatas e plantas). Além disso, torna-se premente um levantamento da quantidade e qualidade dos remanescentes florestais próximos à Reserva Biológica de Una, caso haja a necessidade de se escolher e priorizar áreas adicionais para preservação.

A REGIÃO DE UNA E O PROJETO RESTAUNA

Com o objetivo principal de estudar comparativamente a resposta de diferentes grupos taxonômicos frente ao processo de fragmentação de hábitat, e delinear uma estratégia de conservação para a região de Una, em 1997 foi criado o projeto Remanescentes de Floresta da região de Una – projeto RestaUna (<http://www.restauna.org.br>). O projeto foi elaborado por um grupo de estudantes de pós-graduação da Universidade Estadual de Campinas (UNICAMP) e da Universidade de São

Paulo (USP), e vinculado ao Núcleo de Estudos da Mata Atlântica (NEMA) da Universidade Estadual de Santa Cruz (UESC), em Ilhéus, Bahia. As atividades do projeto foram concentradas nas áreas do entorno da RebioUna, inventariando e mapeando a distribuição da fauna da região em diferentes tipos de ambientes que formam o mosaico florestal da região.

Dentro do seu objetivo principal, o Projeto RestaUna contempla quatro linhas principais de pesquisa:

- 1) levantamentos quantitativos da fauna e da flora nos principais tipos de fisionomias do mosaico ambiental na região da Reserva Biológica de Una, incluindo os seguintes grupos biológicos: bromélias, samambaias, espécies arbóreas, artrópodes do folhicho, besouros, borboletas, sapos, lagartos, aves, mamíferos terrestres e morcegos.
- 2) estudo da estrutura da vegetação dos principais tipos de ambiente da região.
- 3) estudo do efeito de borda no microclima.
- 4) estudo do impacto da caça no entorno da Reserva Biológica de Una.

A PAISAGEM DE UNA:

O primeiro passo para o estabelecimento do desenho experimental foi a condução de um estudo detalhado sobre a paisagem da região. Após 18 meses, que incluíram uma série de vistas em campo, análise de fotos aéreas e sobrevôos, foi possível mapear e definir a distribuição de todos os tipos de ambientes que compõem a paisagem da região de Una, passo fundamental para o planejamento das amostragens.

A análise da paisagem foi conduzida através do mapeamento de três blocos de amostragem, de aproximadamente 5 x 5 km, que foram escolhidos de forma a conter pelo menos parte de áreas contínuas de floresta (> 1.000 ha) para permitir a avaliação dos efeitos da fragmentação através do contraste de diferentes tratamentos com estas áreas controle (Figura 1.2). A partir de fotos aéreas da região de 1997, que foram cedidas pelo Instituto de Estudos Sócio Ambientais do Sul da Bahia – IESB, a Dra. Susan Laurance (INPA – Projeto Dinâmica Biológica de Fragmentos Florestais) realizou a interpretação pelo método de estereoscopia, gerando mapas temáticos sobre a distribuição do mosaico de ambientes em cada bloco de amostragem. Estes mapas foram checados em sucessivas excursões ao campo e, posteriormente, foram realizados mais dois sobrevôos nas áreas de estudo para corrigir erros e dúvidas existentes. Os mapas foram digitalizados e

georeferenciados para permitir a tomada de medidas importantes que descrevem a paisagem. Finalmente, a análise de importantes parâmetros qualitativos e quantitativos da paisagem foi conduzida pelo Prof. Dr. Jean Paul Metzger, do Laboratório de Ecologia de Paisagem da USP, um dos colaboradores do projeto RestaUna.

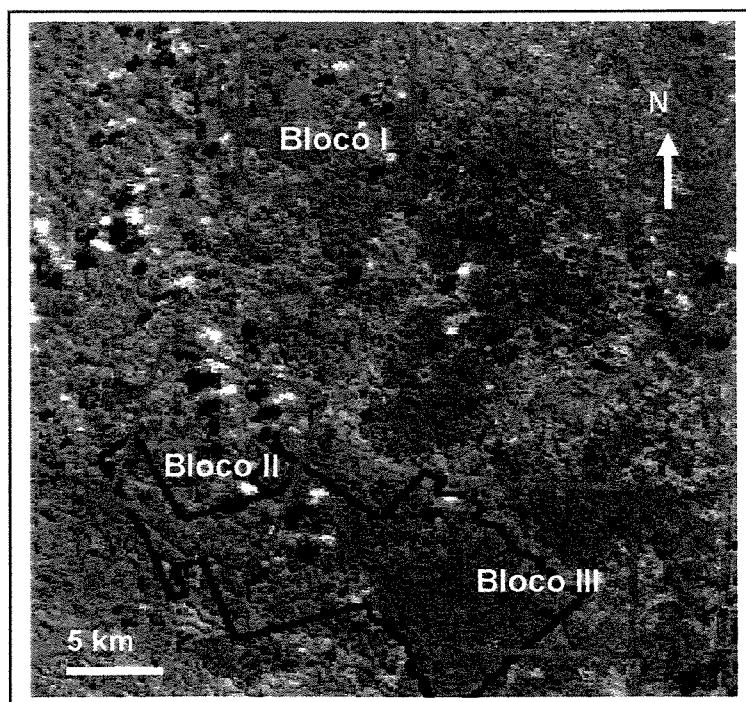


Figura 1.2. Imagem georeferenciada de satélite mostrando o contorno da Reserva Biológica de Una (preto) e dos três blocos de amostragem (azul). As áreas alaranjadas representam florestas.

No total, a área compreendida entre os três blocos soma 14.319,70 ha. Observa-se que a paisagem da região de Una é formada por um mosaico ambiental onde os remanescentes florestais, preservados ou perturbados em diferentes graus, estão inseridos numa matriz complexa. Entre os principais tipos de ambientes modificados encontram-se, além das áreas abertas, fisionomias florestais como as capoeiras (16,17%), ou florestas secundárias em estágio inicial de regeneração, cabucas (5,9%) e seringais (2%). Outros cultivos menos disseminados também são encontrados em menor escala, como plantações de piaçava, pupunha, dendê, coco, banana, maracujá, mamão e pimenta (Araújo et al. 1998), que junto com pastagens e outras áreas abertas formam cerca de 27% da área mapeada neste estudo (Figura 1.3).

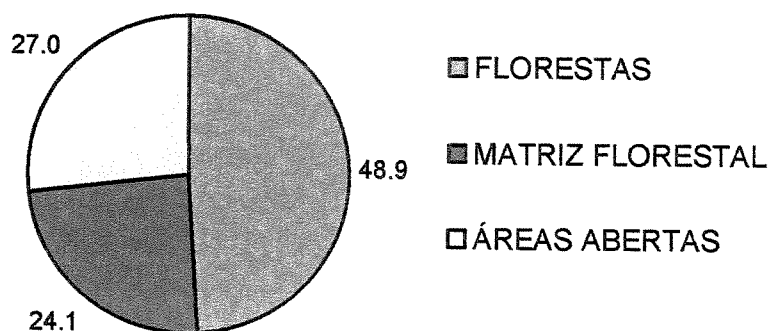


Figura 1.3. Porcentagem de cobertura de cada tipo de ambiente na soma dos três blocos de amostragem na região de Una, sul da Bahia. Florestas são definidas como remanescentes de Mata Atlântica nativa madura; matriz florestal inclui capoeiras, cabruças e seringais, e áreas abertas são formadas por pastagens, campo sujo, áreas de agricultura, corpos d'água.

Embora a região de Una ainda apresente a maior parte da paisagem composta por remanescentes florestais maduros (Figura 1.3), pelo menos 1/3 desta floresta encontra-se a menos de 75 m da borda, ou da zona de contato entre a floresta e outro ambiente modificado. Uma análise visual dos mapas mostra que o processo de fragmentação florestal ainda não levou ao isolamento completo da maioria dos remanescentes da região (Figura 1.4). Na fase atual, o principal componente desse processo é o aumento das bordas da floresta pelo implemento de atividades agrícolas, que termina por moldar feições dendríticas, apresentando elevada razão perímetro/área nas matas afetadas.

A quantidade de cada tipo de ambiente variou em cada bloco analisado, sendo que cada bloco representou, em média, uma área de 4.773,23 ha ($\pm 576,30$) (Figura 1.4). Nota-se um aumento de área de floresta madura do bloco I para o II e III e, nesta mesma sequência, uma diminuição da representatividade de áreas abertas. Nos blocos I e III as capoeiras compõem a maior parcela da matriz florestal, enquanto que as cabruças são mais representaivas no bloco II, permeando grandes extensões da floresta madura.

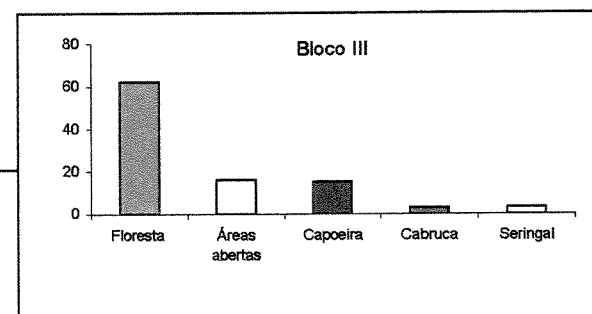
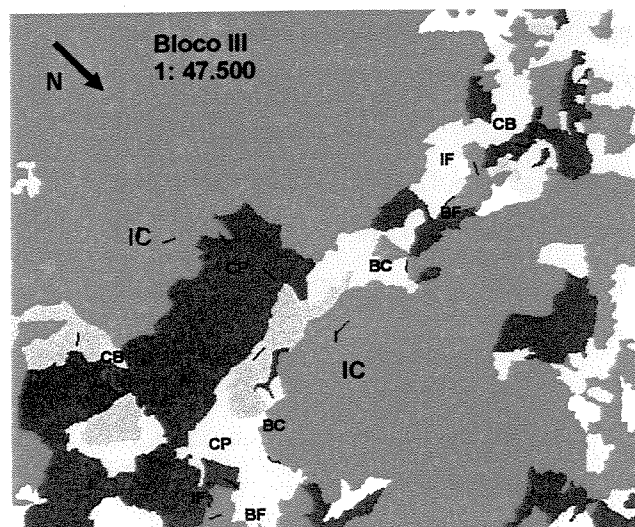
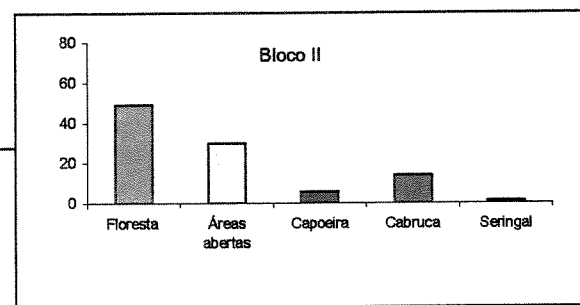
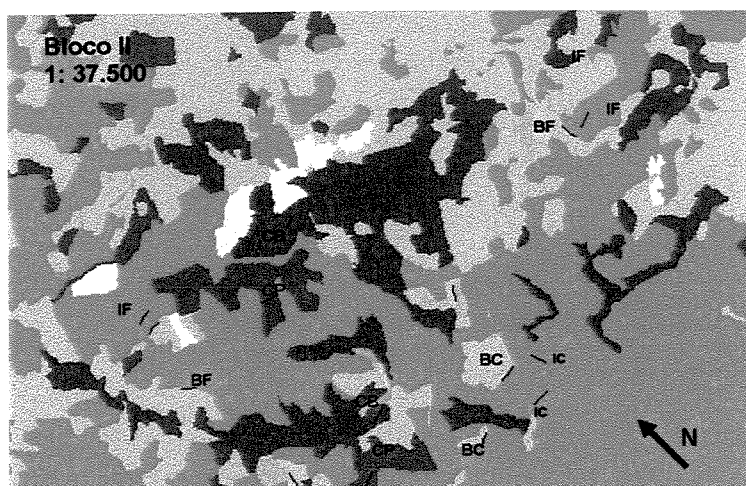
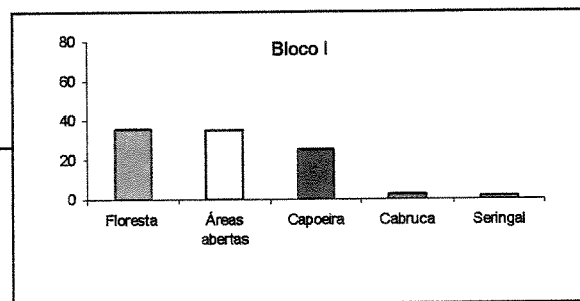
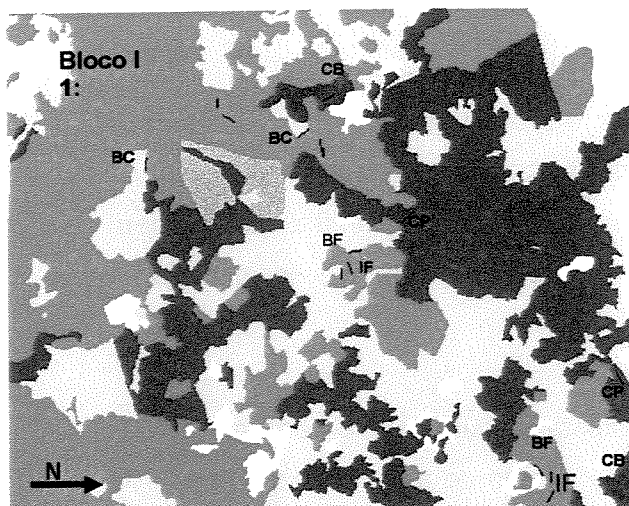


Figura 1.4. Mapas digitalizados e georeferenciados dos três blocos de amostragem, mostrando ambientes de floresta madura (verde), áreas abertas (amarelo), capoeiras (marrom), cabruças (azul) e seringais (cinza). Cada bloco também traz a localização de cada transecto de amostragem nas categorias da paisagem, identificadas como: IC: interior de controle; IF: Interior de fragmento; BC: borda de controle; BF: borda de fragmento; CP: capoeira e CB: cabruca. Ao lado de cada bloco segue uma representação gráfica da % de cada tipo de ambiente para cada bloco.

O DESENHO EXPERIMENTAL

Com base nesta visão geral da paisagem de Una, o projeto estabeleceu amostragens contemplando os seis tipos de ambientes que incluíram, além dos remanescentes de floresta madura, os tipos de ambientes florestais mais significativos da matriz e que teriam um maior potencial para a conservação da região. Desta forma, foram selecionadas as seguintes categorias de paisagem:

- ♦ **interior de floresta contínua:** em uma área de floresta madura, pouco perturbada, com no mínimo 1000 ha de área, os interiores formam a porção de mata a pelo menos 100 metros de distância de qualquer área aberta;
- ♦ **borda de floresta contínua:** faixa distante de 15 a 20 m do contato com pastagens, localizada em remanescente de floresta madura maior que 1000 ha;
- ♦ **interior de fragmento:** em uma área de floresta madura, menor que 100 ha de área, os interiores formam a porção de mata a pelo menos 100 metros de distância de qualquer área aberta;
- ♦ **borda de fragmento:** faixa distante de 15 a 20 m do contato com pastagens, localizada em remanescente de floresta madura com área inferior a 100 ha;
- ♦ **cabruca:** áreas de plantações sombreadas de cacau;
- ♦ **capoeira:** formada por vegetação florestal secundária em estágio sucessional inicial, resultante da recolonização por espécies florestais de áreas de floresta que sofreram derrubada total e foram abandonadas há menos de 20 anos.

Em cada bloco de amostragem foram selecionadas duas réplicas de cada categoria, totalizando 36 áreas, seis para cada categoria. Em cada réplica foi estabelecido um transecto de cerca de 200 m de comprimento, no qual todos os grupos taxonômicos abordados dentro do RestaUna foram amostrados (Figura 1.4).

Além das coletas de animais e plantas o projeto ainda abrangeu amostragens da estrutura da vegetação e da abundância de artrópodes associados ao estrato de subosque. Todos estes dados foram coletados e analisados por pesquisadores que colaboraram e/ou foram contratados pelo projeto RestaUna, fazendo parte do banco de dados do projeto.

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CAPÍTULO 2

ESTRUTURA DE FLORESTAS EM UMA PAISAGEM DA MATA ATLÂNTICA: EFEITO DA FRAGMENTAÇÃO, DA REGENERAÇÃO E DO USO DA TERRA.

RESUMO

Diferentes processos associados a perturbação antrópica, como a fragmentação, regeneração e o uso da terra criaram um complexo mosaico de florestas na região de Una, sudeste da Bahia, Brasil. Nós investigamos se as principais categorias de paisagem da região podem ser discriminadas por descritores de estrutura da vegetação normalmente utilizados na literatura como indicadores de perturbação. Os ambientes estudados foram: floresta contínua (fragmentos de mata primária com mais de 1.000 ha); borda de floresta contínua (fragmentos com mais de 1.000 ha e a menos de 20 metros de qualquer área aberta); interior de fragmento (floresta com menos de 100 ha); borda de fragmento (fragmentos com menos de 100 ha e a pelo menos 20 metros de uma área aberta); floresta secundária (fragmentos que foram totalmente desmatados e deixados regenerar há pelo menos 20 anos); cabruca ou áreas de plantação de cacau (*Theobroma cacao*) onde o subosque é substituído por cacau e árvores grandes são deixadas para sombrear a cultura. Para discriminar entre os ambientes nós utilizamos os seguintes descritores: presença de lianas lenhosas; presença de lianas herbáceas; números de árvores mortas; número de troncos caídos; altura do folhio; estrutura vertical dos ambientes medido pela densidade de folhagem; estrutura horizontal avaliada pela distribuição de diâmetro à altura do peito. A análise discriminante mostrou que a presença de lianas lenhosas foi a principal variável para discriminar os três grupos de ambientes: cabruças; florestas secundárias; florestas primárias, indicando que o manejo de agro-culturas e a sucessão secundária estão alterando drasticamente a estrutura das florestas na região. Um segundo gradiente determinado principalmente pela densidade de folhagem entre 20 - 25 m de altura separa florestas secundárias dos outros ambientes, sendo possível detectar um *continuum* que vai desde o interior de floresta contínua até a borda de fragmentos pequenos. Isto mostra um aumento do efeito de borda em pequenos tratos de florestas. Os resultados gerais mostram que a análise de descritores individuais de estrutura de vegetação podem ocultar gradientes em ambientes complexos como das florestas tropicais.

Palavras-chave: estrutura da vegetação, fragmentação de florestas, efeito de borda, regeneração de florestas.

Forest structure in an Atlantic rainforest landscape: fragmentation, regeneration and land use effect.

ABSTRACT

Different disturbances such as fragmentation, regeneration and land use, have resulted in a complex landscape mosaic in the Una region, Southeastern State of Bahia, Northeastern Brazil. We investigated whether the main forest categories that comprised the bulk of what is left in the regional landscape could be discriminated by vegetational structural descriptors commonly used as indicators of disturbance. We assessed the forest structure in six habitat categories previously defined as: interiors and edges of continuous mature forests (>1,000 ha), interiors and edges of mature forest fragments (<100 ha), early secondary forests (capoeiras) and areas of shade cacao plantation, where the cacao shrub (*Theobroma cacao*) is grown under the shade of few remnant trees. Forest descriptors used here were: infestation of herbaceous lianas and woody climbers, number of dead trees, number of fallen trunks, litter depth, vertical stratification profile and trees in different diameter at breast height (d.b.h.) classes. Discriminant analysis revealed that woody lianas infestation discriminated three different categories: shade cacao plantations, secondary forests and mature forest sites, indicating disturbances driven by this specific management system and forest regeneration. A second gradient was mainly determined by the foliage densities of the forest stratum at 20 to 25 m height, separating early secondary forest from the remaining categories. Along this same gradient it is possible to detect a *continuum* of disturbance ordering interiors of continuous forests as the most preserved sites and edges of fragments at the other extreme. This shows more pronounced edge effect in fragments compared with continuous forests. This paper reveals that the use of single descriptors of forest structure can hide gradients in complex habitats such as tropical forests.

Keywords: forest structure, forest fragmentation, edge effect, forest regeneration.

INTRODUCTION

At an alarming annual rate of 150,000 km² (Myers 1984; Whitmore 1990), most of the tropical forests have been converted into man-made landscapes (Myers 1980). A straightforward result of this massive deforestation is the direct reduction on the amount of forest available and the isolation of most patches.

The southern part of the State of Bahia, Brazil, harbors one of the last remnants of the Atlantic forest that is characterized by high levels of species richness and endemism (Mori et al. 1983). However, this remaining forested area does not represent a homogeneous canopy cover. Rather, it consists of a mosaic of different forest physiognomies varying in the degree and nature of structural changes. As the core region for the national cocoa production, nearly 40% of the forest left in southern Bahia comprises shade cacao plantations, where the crop is grown under a rustic system locally known as *cabruca* (May & Rocha 1996). By thinning the canopy layer and replacing the native understory by cacao (*Theobroma cacao* - Sterculiaceae), cabruças are highly modified habitats, though still a multilayered forest, which some organisms tend to exploit (Alves 1990; Dietz et al. 1996).

The remaining native forest in southern Bahia is confined to a few large blocks of primary forest, concentrated mainly in the coastal region, and a constellation of small scattered fragments. As expected, the forest structure in these remnants is likely to suffer further modifications by human direct intervention (i.e. logging, palm heart poaching, firewood extraction) and disturbances after its isolation and exposure to new, modified surrounding habitats. Forest edges face higher rates of tree damage and mortality, climatic fluctuations and increased plant species turnover, leading to overall alterations in forest structure on edges relative to interior (Lovejoy et al. 1986; Kapos 1989; Saunders et al. 1991; Matlak 1993, 1994; Murcia 1995; Laurance 1997; Laurance et al. 1998; Stevens & Husband 1998; Laurance et al. 2001). This group of phenomena is known as “edge effects”. Also, a considerable proportion of the forest left in southern Bahia, as well as in all areas along the Atlantic forest domain, is represented by patches of secondary forest in several successional stages.

For conservation purposes, understanding to what extent the forest structure has been modified among different forest physiognomies is of paramount importance, as it may underlie the extent to which the local biota exploits and is distributed in the landscape. To address these concerns, this paper attempts to investigate the effect of forest fragmentation, regeneration and the specific land use of shade cacao plantations on the forest structure of

native remnants in an area of southeastern Bahia. Here we analyze the relationship of the vegetation structure among the different forest physiognomies that comprise the mosaic of forest left, searching for potential discriminant features.

MATERIAL & METHODS

STUDY AREA

Una, located in the southern part of the state of Bahia, Brazil, comprises one of the last remnants of what is left from the Atlantic Forest in northeastern Brazil. This forest can be classified as southern Bahian wet forest (Gouvêa et al. 1976) or, after the recent classification proposed by Oliveira-Filho and Fontes (2000), as a tropical lowland rainforest, harboring a tall vegetation characterized by its stratification in lower, canopy and emergent layers, abundant in epiphytes, ferns, bromeliads and lianas (Thomas et al. 1998). Average rainfall for Una town is 1918 mm yr⁻¹ (from 1965 to 1973; Mori et al. 1983), and annual temperature mean 24°C.

Although logging was always a common practice along the entire Atlantic Forest since the 1500s, the heavy deforestation around the Una region took place only after the construction of the BR 101 highway in 1975. It is estimated that the forest remnants comprise only 3-5% of the original extension (Thomas et al. 1998). As a result of both national and international pressures, in 1980 the Brazilian government established the only federally protected area for the region. Although the Una Biological Reserve is a forest remnant of only 7.500 ha, in the area a considerable amount of forest is private owned. Today other smaller private owned forest reserves are also established in the region, though the Biological Reserve is still the largest, continuous block of protected forest.

SAMPLE SITES

We undertook this study at the Una Biological Reserve and the surrounding areas, located in municipality of Una, Bahia, Brazil (15°10' S, 39°03' W). To determine the most representative habitats comprising the forest mosaic in the Una region, we carried out a survey using satellite imagery, aerial photos and an intensive ground-truthing. After 18 months of landscape analysis it became clear that fragmentation and land use have resulted in a complex landscape in which the remaining forest is composed mostly of primary stands of continuous forests (>1000 ha) and fragments (30 to 100 ha) with several levels of

disturbance. A matrix including pastures, annual crops, rubber tree plantations, early growth forests and areas of shade cacao plantations surrounds these remnants.

After the landscape characterization, we chose to sample six forest categories previously defined as: IC: *interior of continuous mature forests* (> 1000 ha); IF: *interior of mature forest fragments* (<100 ha); EC: *edges of continuous mature forests* (sites of continuous forests located 20 m from pastures); EF: *edges of mature forest fragments* (sites of forest fragments located 20m from pastures); SF: *early growth forest sites* (where the regeneration followed a total clear cut at least 20 years ago; herein secondary forests); SC: *shade cacao plantation* (under the traditional system of cabruças). These categories make up the bulk of the forest habitats left in Una region (see chapter 1).

We selected six samples of each forest category making a total of 36 sampling sites. These sites were distributed along three blocks of 5 km X 5 km, each block encompassing 12 sites representing two replicates of each forest category per block (Figure 1.4). In each sampling site we established two parallel 2 m x 200 m plots and estimated variables which included those usually associated with disturbance and others describing both the horizontal and vertical forest structure, as follows:

Variables associated with disturbance:

- ◆ number of trees with woody lianas larger than 1.8 cm at 1.5 m height;
- ◆ number of trees with herbaceous lianas;
- ◆ number of standing dead trees;
- ◆ number of fallen trunks (> 20 cm in diameter);
- ◆ mean litter depth: for each plot we measured 41 points spaced at 5 m intervals, resulting in 82 measurements for each sampling site.

Vertical structure descriptors

- ◆ We also assessed the foliage profile in each transect with 12 points 15 m apart, resulting in 24 points in each sampling site. These measurements were taken in twelve points regularly spaced along each transect, and the mean values for each stratum used for the analysis. Foliage profile was recorded following a modification of the Hubbell and Foster's method (1986) described in Malcolm (1995a). Using a 3 m pole to allow a vertical sighting, we estimated the intervals occupied by foliage (e.g. estimation of the foliage intervals hitting this vertical imaginary line) in eight forest vertical strata: 0-1m; 1-5m; 5-10m; 10-15m; 15-20m; 20-25 m; 25-30 m and 30-35 m (Figure 2.1).

Horizontal forest structure descriptors:

- ◆ Diameter at breast height (d.b.h.) classes: along both plots, we checked all woody trees and assigned each individual to the following d.b.h. classes: 5-10cm, 10-15cm, 15-25cm, 25-35cm and > 35cm

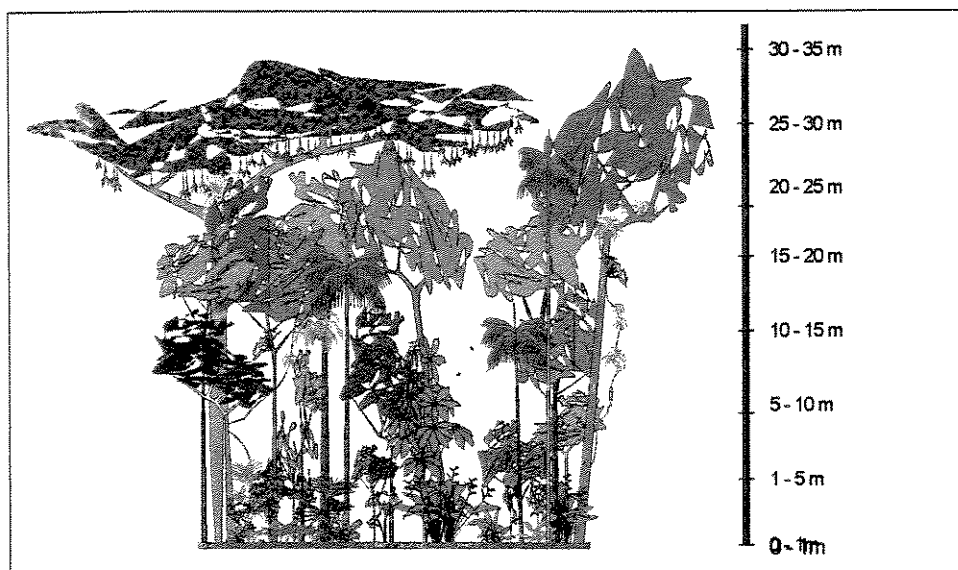


Figure 2.1. Graphical representation showing the vertical profile of a rainforest area. Scale represents eight vertical foliage strata intervals (heights in meters) assessed on the present study. Drawn by Gustavo Accacio.

DATA ANALYSIS

Differences in the mean values of the first five vegetation descriptors were investigated among the six forest categories with one-way Analysis of Variance. Using the Dunnett's *a posteriori* test, we contrasted each forest descriptor variable found in controls (transects of interior of continuous forest) to those present in the remaining forest categories. The null hypothesis was rejected with a p-associated value lower than 0.05 (Zar 1999).

D.b.h. distribution and the foliage height profile are two important set of descriptors widely used to assess habitat complexity and heterogeneity (August 1973), and many studies have demonstrated that biological groups are influenced by these ecological factors. Herein, we investigated the presence of forest structural gradients by performing two Principal Component Analyses (PCA), one for each set of descriptors. Site scores of the two

first axes from each PCA were attached to the original data matrix representing linear combinations of the original data, and were used as single variables describing ecological gradients thereafter, instead of the entire original set of data.

We performed a Stepwise Canonical Discriminant Analysis (SCDA) procedure as a parsimonious method for describing differences among groups (McGarigal et al. 2000), eliminating variables that otherwise would add noise to the data structure. SCDA was based on Wilk's lambda statistic, which considers differences among groups and the cohesiveness within groups. In each step of analysis F-statistics are calculated measuring the changes on Wilk's lambda statistics. Variables increasing cohesiveness without changing separation among group centroids were selected over those variables increasing group separation without changing cohesiveness (McGarigal et al. 2000). Finally, the accuracy of our *a priori* site classification was evaluated. The percentage of sites correctly classified was calculated by building new discriminant functions excluding the site under analysis. This new function was then applied to the site, one-by-one, knowing where it should be classified (McGarigal et al. 2000); the percentage of groups correctly classified gives an overview of the consistency level of the analysis.

We investigated potential violations of assumptions of multi-collinearity, multinormality and covariance relationships by inspection of Product-moment Pearson correlation matrix, Kolmogorov-Smirnov tests and bivariate scatter plots. The analysis was performed using the SPSS package (SPSS 1998), following further default criteria.

RESULTS

The analysis of the vegetation descriptors showed few significant differences among interiors of controls and all the remaining forest categories. Regarding the set of variables associated with forest disturbance, only the number of trees with woody lianas showed significant differences from interiors of control sites (Figure 2.2), with shade cacao plantation sites showing much lower densities (Dunnett *a posteriori* test, $p = 0.000$). However, it is possible to notice a tendency of edges, both from controls and fragments) to present higher concentrations of litter depth, fallen trunks, woody lianas and dead trees than interior sites.

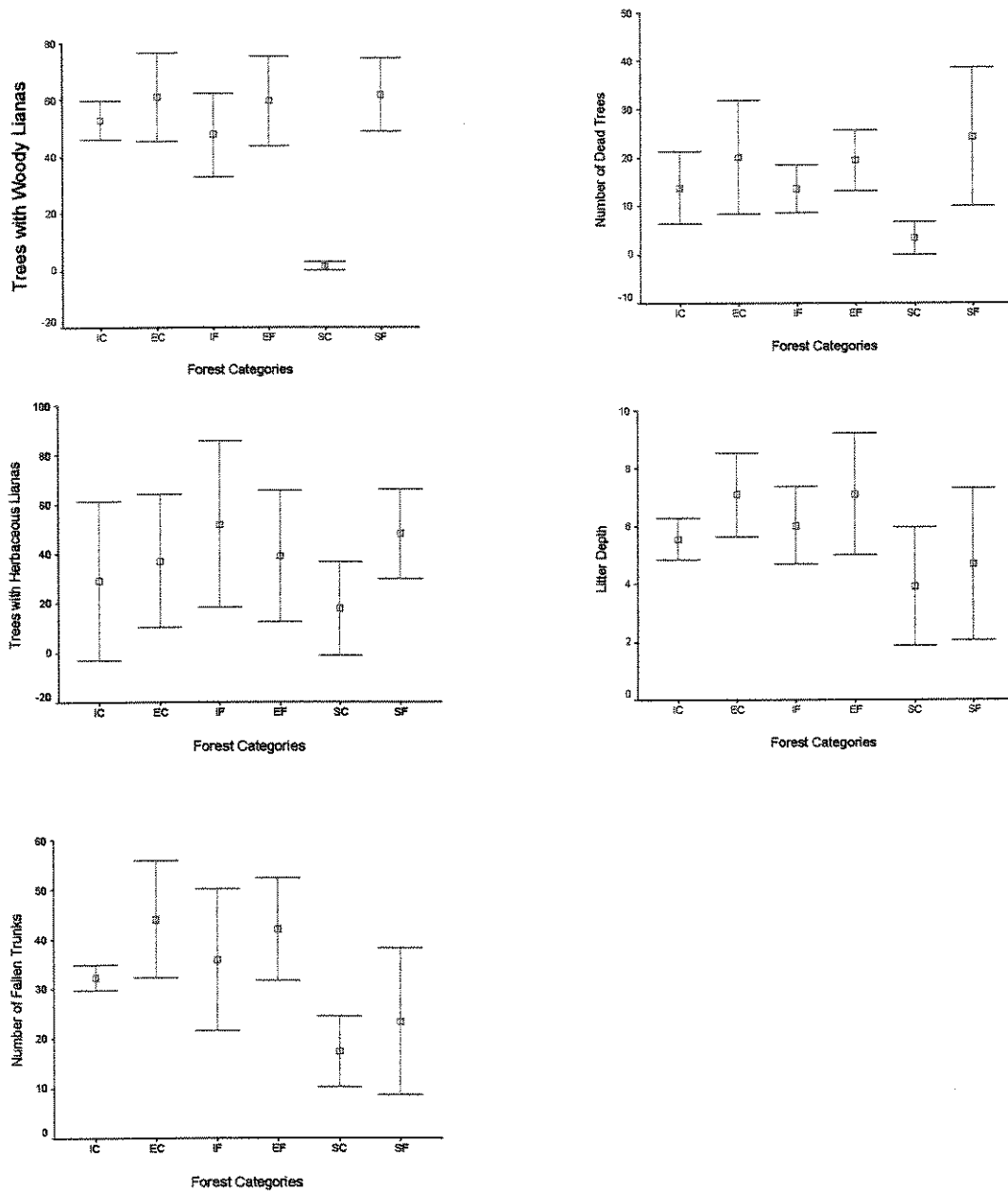


Figure 2.2: Mean values of five structural variables reported in six forest categories in an area of Atlantic Forest sites at Northeastern Brazil. IC: interior of continuous forest; IF: interior fragments; EC: edges of continuous forests; EF: edges of fragments; SC: shade cacao plantation; SF: secondary forests.

Vertical Structure: foliage stratification profile

Few significant differences of foliage density were detected comparing interiors of control sites with the remaining forest categories. As expected, shade cacao plantations depicted significant lower densities of foliage right above the cacao shrubs (5–10 m), whereas secondary forests were characterized by a lack of higher foliage strata (>15 m) forming a thick single forest strata from 1 up to 10 m high (Figure 2.3). Compared with interiors of control forests, edges of fragments showed significant higher concentration of foliage on the forest understory (1–5 m), though more foliage from 15–20 m.

Although a few significant differences were detected on stratum-by-stratum comparisons, the overall pattern arises by examining the PCA outputs. The first two axes of PCA with the foliage density data accounted for 76% of data variation. The intervals occupied by foliage at 20–25 m and at 10–15 m height were the most important variables (higher absolute loading values) on the first and second axis, respectively (Figure 2.4a). Differences among more disturbed sites are emphasized, with fragment edges and secondary forests showing lower foliage values above 15 m high (Figure 2.4b) and cabrucas a rarefied stratum at 5–10m high.

Horizontal structure: d.b.h. classes

Thin trees (5–10 cm) accounted for more than 50% of all trees reported in interiors of control forests, although this density was significantly higher when compared with cabrucas, as this size class of trees in cabrucas encompasses the cacao shrubs. These shade cacao plantations also showed lower densities of trees ranging from 15 to 35 cm d.b.h. than interiors of control forests (Figure 2.5). On the other hand, larger trees were found in significantly lower densities in early secondary sites than interiors of control sites. Similar to the results reported for vertical stratification, both secondary forests and edges of fragments had lower mean numbers of medium to large sized trees (15–35 cm d.b.h.) (Figure 2.5).

The two first PCA axes with d.b.h. classes, together explaining 91% of total variation, showed a tendency of more disturbed sites to occupy the ordination extremes, while relatively undisturbed sites occupied intermediate values. The number of thin trees (5–10 cm DBH) mostly determines this arrangement (Figure 2.6a). The lower densities of thin trees (5–10 cm) from shade cacao placed this forest category sites on an extreme of the gradient of variation, with edges of fragments and secondary forest sites on the other extreme with lower densities of larger trees (15–25 cm) (Figure 2.6b).

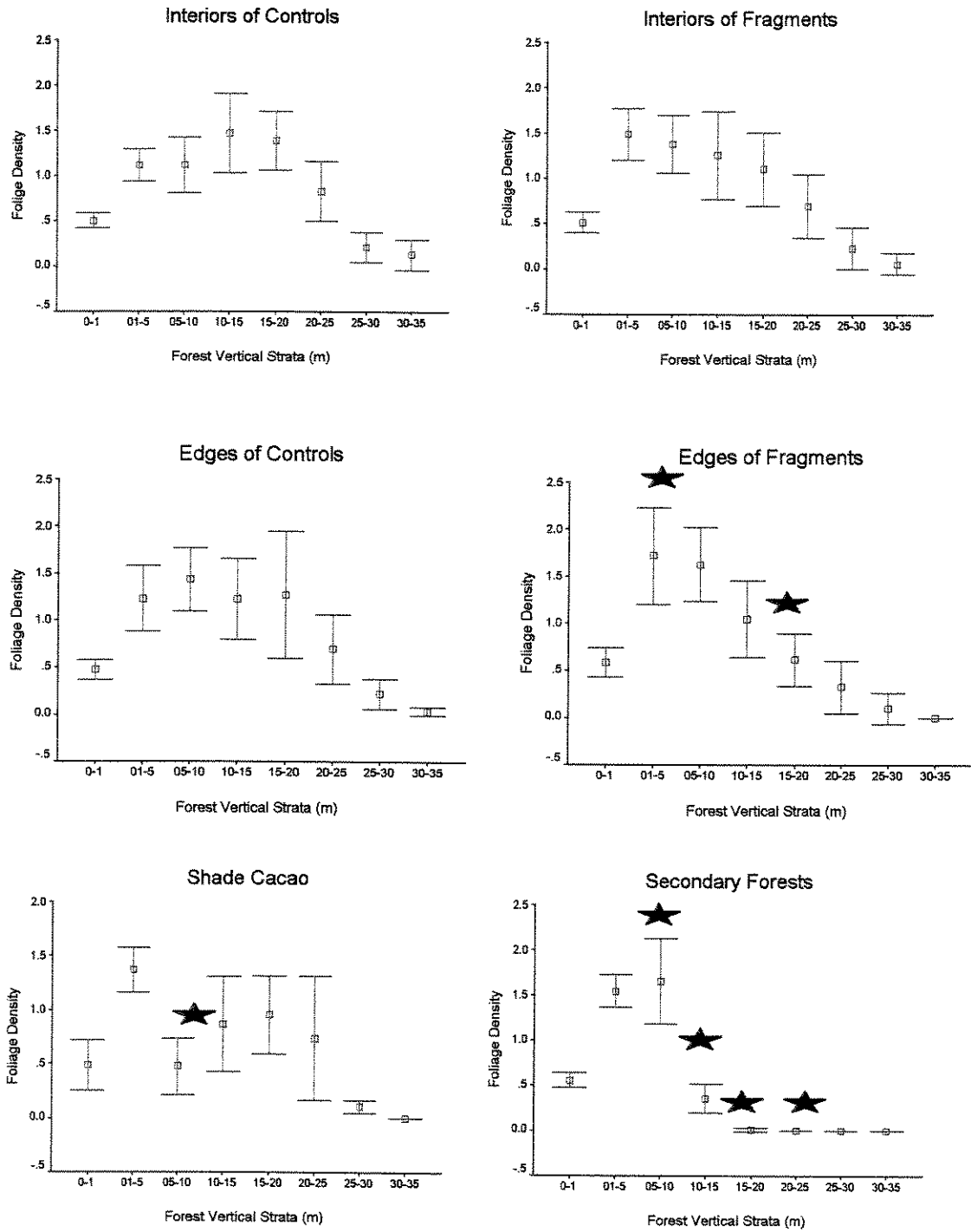


Figure 2.3: Mean values of foliage height in eight forest strata of six forest categories in an area of Atlantic forest in Northeastern Brazil. Shaded bars indicates Dunnet's test significant differences ($p < 0.05$) from interiors of control forests.

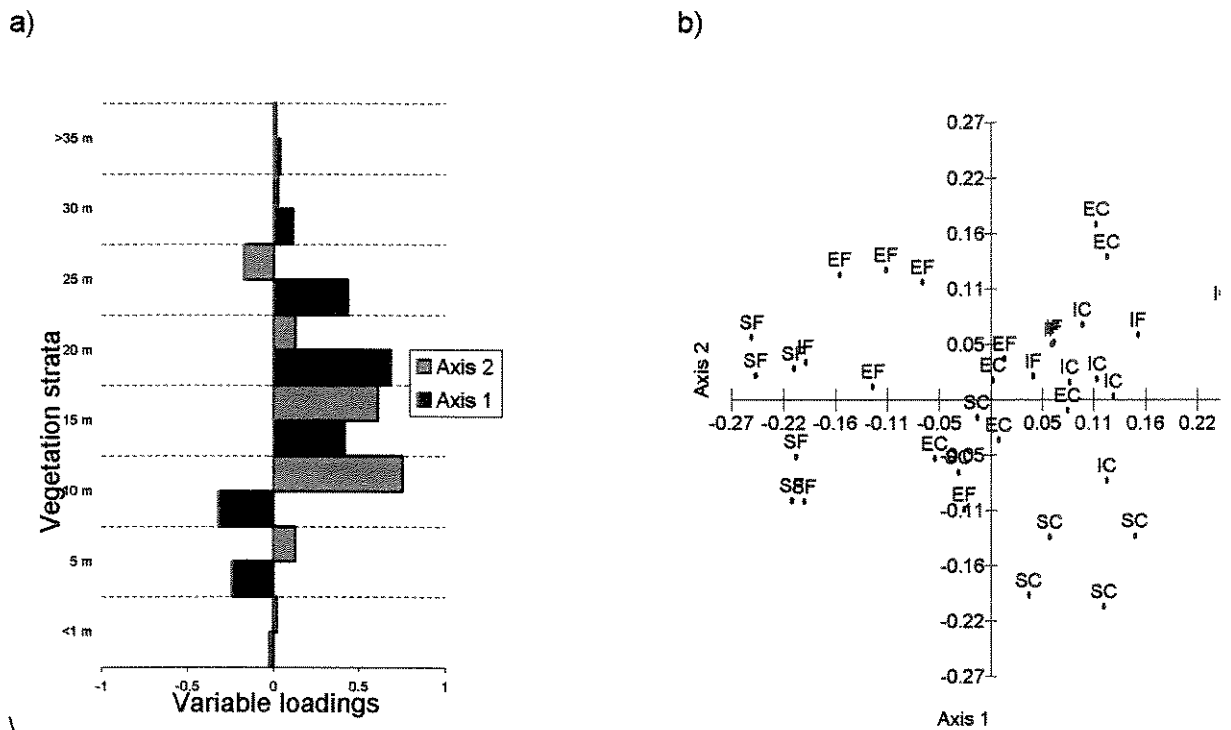


Figure 2.4: (a) Factor loadings of PCA axis I and II explaining, respectively, 54% and 22.1% of total variance and the graphical re and sites ordination (b) with data of density from eight foliage vertical strata in 36 sites of six forest categories in an area of the Atlantic forest from Northeastern Brazil. IC: interior of continuous forest; IF: interior fragments; EC: edges of continuous forests; EF: edges of fragments; SC: shade cacao plantation; SF: secondary forests.

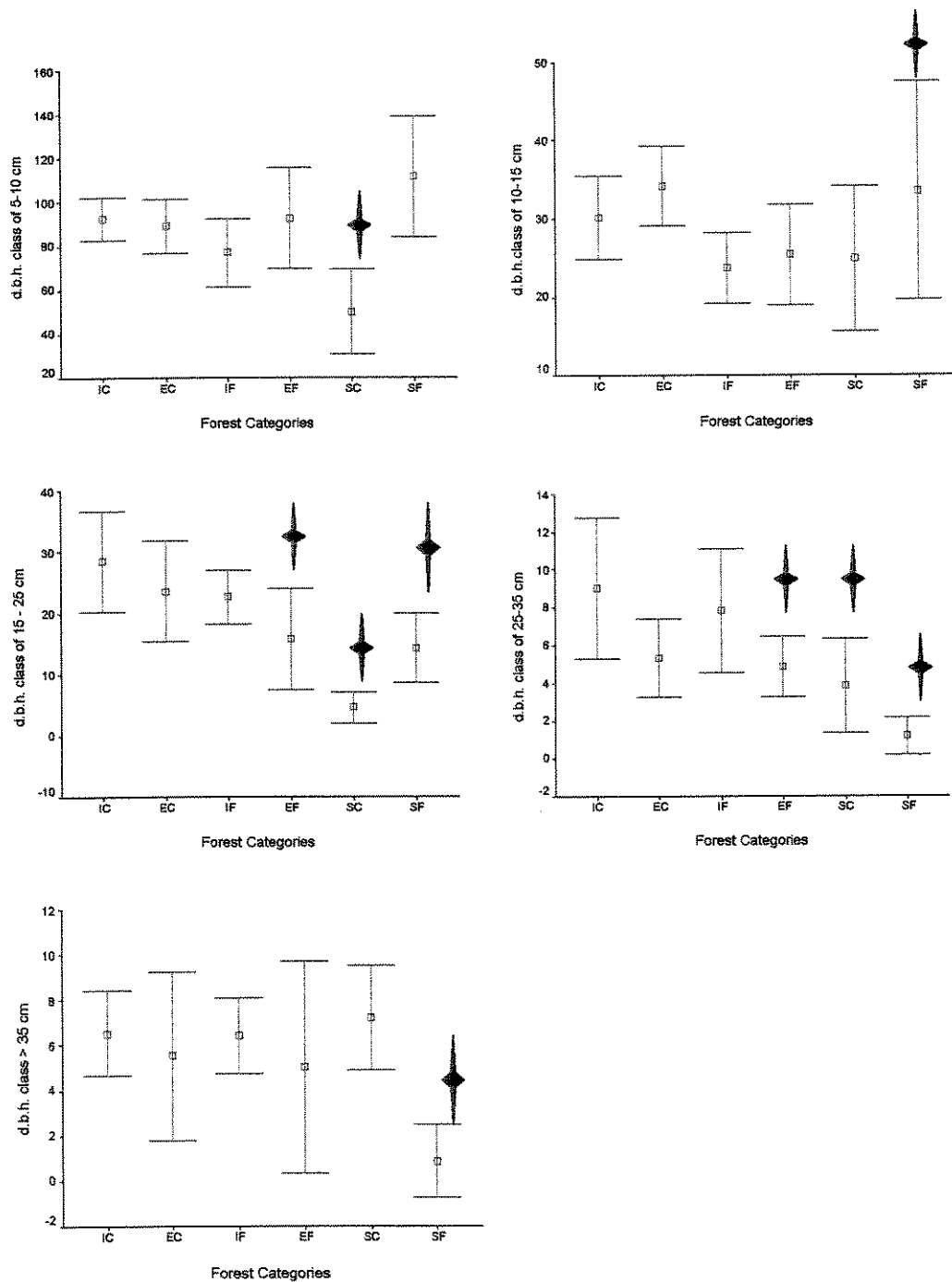


Figure 2.5: Distribution of the number of trees in five classes of d.h.b. in six forest categories in southern State of Bahia, Brazil. Forest categories are: IC: interior of continuous forest; IF: interior fragments; EC: edges of continuous forests; EF: edges of fragments; SC: shade cacao plantation; SF: secondary forests. Black markers indicate significant differences from interior of continuous forest by the Dunnett *a posteriori* test ($p < 0.05$).

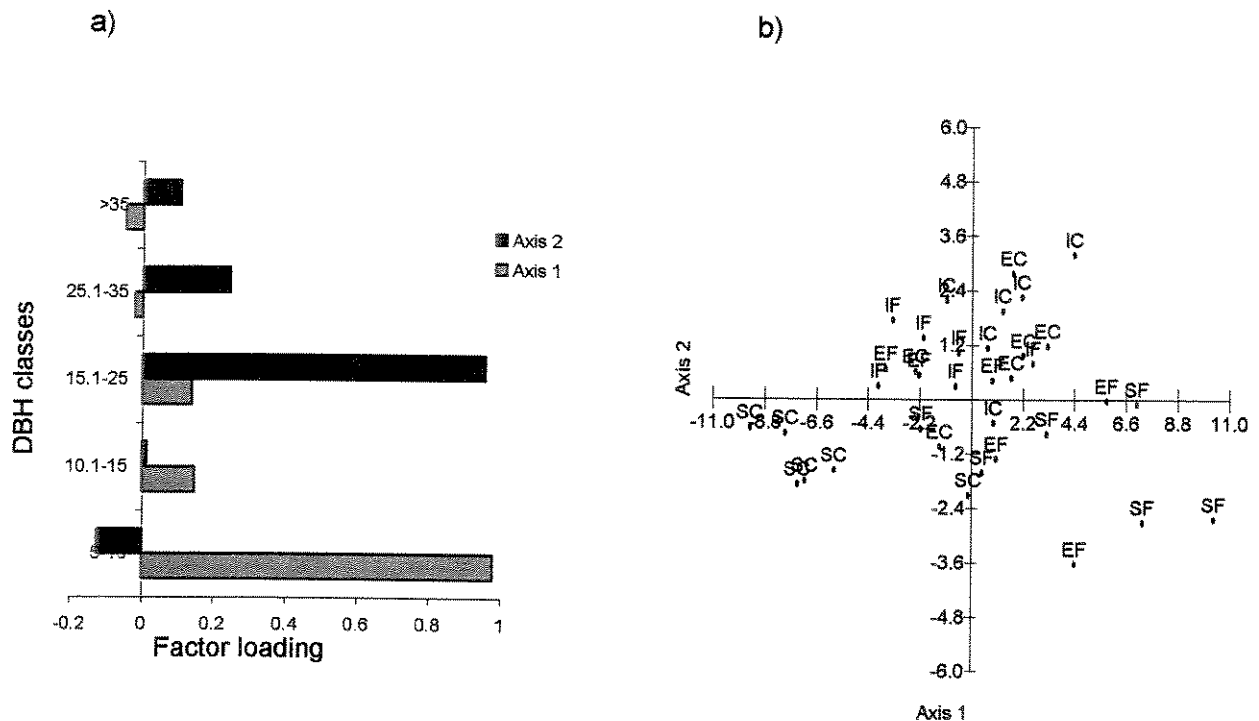


Figure 2.6: Factor loadings (a) and sites ordination (a) of PCA comprising the number of trees in five classes of d.b.h. in 36 sites in six vegetation categories in a Atlantic Forest in Northeastern of Brazil. Legends depicted: IC: interior of continuous forest; IF: interior fragments; EC: edges of continuous forests; EF: edges of fragments; SC: shade cacao plantation; SF: secondary forests.

Relationships among forest categories: the Discriminant Analysis

All the variables met the main assumptions required by SCDA except for homocedasticity of variance-covariance matrix (Box's M test = 118.57; approximate $F=1.51$; $p= 0.013$). Despite this fact, statistical inferences based on linear canonical functions with such bias are still considered robust (McGarigal et. al 2000). A high degree of consistency was reported on the classification scheme as 72% of our sites were correctly classified (Table 2.1). All cabruca sites were correctly classified as cabruças, and a high consistency was also found on transects of interiors of controls and secondary forests, representing extremes along a disturbance gradient.

Four out of nine variables (Table 2.2) were sufficient to highlight differences among forest categories. These variables were grouped in two statistical significant functions with a good agreement of functions and groups of original variables by high canonical correlations

with original variables (Table 2.2). The highest values of canonical coefficients in the first function was the number of trees with woody lianas, while the second function was mostly discriminated by the first axis from the PCA of foliage stratification, which described a gradient on increasing foliage density on 20-25 m high.

The first SCDA function displayed three distinct groups: mature forests (interior and edges of both controls and fragments); secondary forests and cabruças (Table 2.3; Figure 2.7), showing a high number of trees with woody lianas in former and its scarcity in cabruças. Conversely, the second function placed mature forests and shade cacao sites as a group apart from early secondary forests. Absence of foliage on forest higher strata on secondary forest drives this pattern.

Taking into account the mature forest sites, we notice a gradient from edges of fragments to interiors of controls, with these extremes centroids being statistically different. The remaining two forest categories comprising intermediate centroid values were statistically similar to both extremes. This pattern is, however, a spurious result influenced by a given site that was originally classified as an interior of fragment, which is clearly an outlier (Figure 2.7). From a new discriminant analysis now excluding this outlier, it was possible to note that edges of fragments are indeed a distinct group from the remaining primary forest categories (Interiors and edges of control and interiors of fragment sites).

Table 2.1: Classification results based on original and predict group cases. The table entries are number of cases correctly back-classified by the discriminant functions. (72.2% of cases were correctly classified).

Forest Category	Interior Controls of	Edges Controls of	Interiors of Fragments	Edges of Fragments	Shade Cacao	Secondary forest
Interior controls of	<u>5</u>		1			
Edges controls of	1	<u>4</u>	1			
Interiors fragments of	1	1	<u>3</u>	1		
Edges fragments of		1	1	<u>3</u>		1
Shade Cacao					<u>6</u>	
Secondary forests				1		<u>5</u>

Table 2.2: Standardized canonical discriminant coefficients and stepwise canonical discriminant statistics that identify significant functions separating six forest categories in an area of Atlantic forest in northeastern Brazil.

Discriminant variables	Canonical coefficients	
	Function 1	Function 2
No. of trees with woody lianas	0.92	-0.21
Foliage profile PCA II (10.1-15 m)	0.71	-0.04
Number of fallen trunks	0.49	0.18
Foliage profile PCA I (20.1-25 m)	0.52	0.91
Discriminant statistics		
Eigenvalues	6.60	2.42
Cumulative variance explained	70.9	96.9
Canonical correlation	0.93	0.84

Table 2.3: Centroids of forest category scores from canonical discriminant functions. Categories in the same group showed no statistical differences in the HSD Tukey test.

Vegetation categories	Homogeneous Groups from Canonical Discriminant					
	Function 1			Function 2		
	Group 1	Group 2	Group 3	Group 1	Group 2	Group 3
Cabruças	-4.77					1.15
Secondary forests		-1.09		-2.73		
Edges of fragments			1.21		-0.91	
Interiors of fragments			1.29		0.69	0.69
Edges of controls			2.04		0.46	0.46
Interiors of controls			1.32			1.34
Uniformity within groups ¹ .	1.00	1.00	0.71	1.00	.09	0.65

1. Significance by HSD Tukey test within groups, giving a measure of homogeneity within each group.

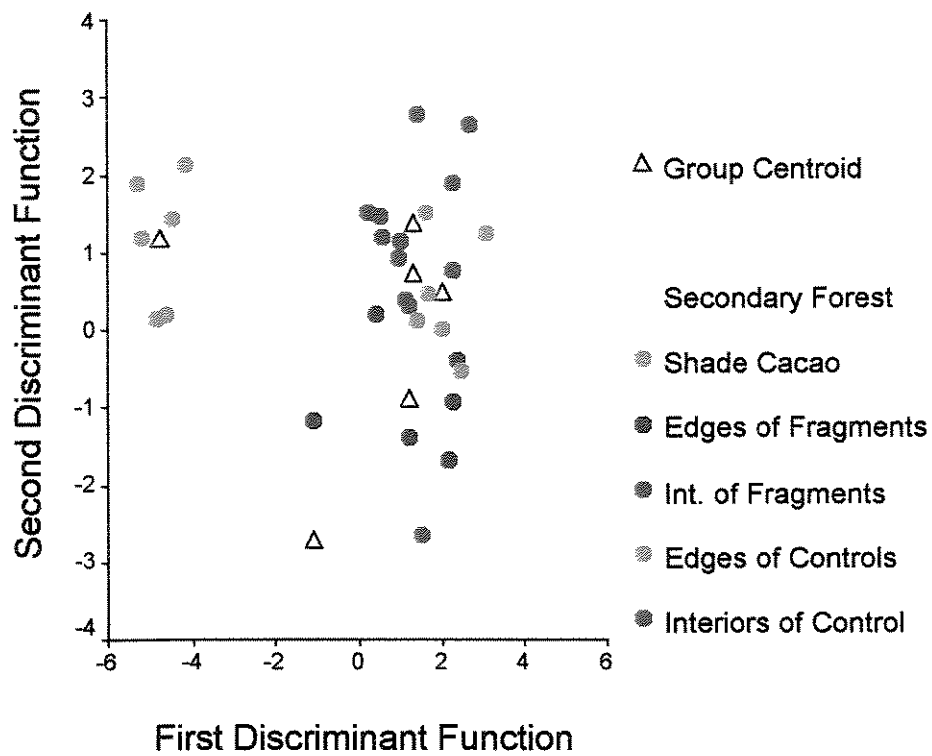


Figure 2.7. Scatter plot of canonical discriminant scores for 36 sites in six vegetation categories in Atlantic Forest in Brazil. Group centroids are: (1) Interiors of controls; (2) Edges of controls; (3) Interiors of fragments; (4) Edges of fragments; (5) Shade cacao plantation; (6) Secondary forests.

DISCUSSION

Natural processes are often influenced by a multitude of causes, and univariate approaches are likely to fail in revealing natural variation gradients. Our sites represented parts of a continuum of forest structural alterations related to fragmentation, forest regeneration and a specific land use, shade cacao plantation. Overall, it seems that our six previously defined forest categories are indeed entities differing in some features of forest structure. Although no single feature was able to describe the whole gradient, it was possible to note both significant differences as well as subtle trends in structural modifications from interiors of continuous forests, representing the most well preserved sites, to the remaining forest categories. Markedly, shade cacao plantations depicted a clear trend to show lower values for all descriptors such as dead trees, fallen trunks, litter depth, herbaceous vines, and a statistically significant lower density of liana infestation when compared with interiors of controls. These results are consistent with earlier findings (Alves 1990), and are a direct result of the forest thinning and pruning processes used for the establishment and maintenance of the cocoa crop.

Edges (of fragments and continuous forests) and secondary forest sites showed a weak tendency to have higher densities of all variables, which is consistent with the overall results from other studies indicating that these features are commonly associated with edges and other disturbed areas (Oliveira-Filho et al. 1997; Tabanez et al. 1997; Viana et al. 1997; Mesquita et al. 1999). Forest edges showed a trend to higher concentration of dead trees, herbaceous vines and woody lianas, fallen trunks and litter depth when compared with interior sites. Secondary forests also present a tendency of an increased number of dead trees but a lower concentration of fallen trunks, probably as a result of low density of large trees in these secondary forests or higher rates of decomposition (Brown & Lugo 1990).

Actually, thin trees predominate in all forest sites except in the cabruças, where the cacao shrubs that replace the native understory are grown at lower densities and regularly spaced. Mori et al. (1983) observed the same pattern when sampling an area located close to our study sites, and suggested that edaphic factors could explain these features. They also called attention for the fact that, as in other areas along the Bahia coast, Una was intensively exploited by the logging industry. The authors observed a low concentration of large, timber-producing hardwood species from the families Lauraceae and Sapotaceae, which is probably a direct result of this kind of disturbance. Signs of recent logging activity were also observed in all sampling sites in the present study at Una, regardless of forest

category previously defined (Eduardo Mariano – Projeto RestaUna – personal communication).

Changes in forest horizontal and vertical structure (d.b.h. and foliage profile) highlighted differences among vegetation categories, but ordination procedures revealed clear gradients related to structural disturbances. Vertical stratification showed that edges and secondary sites presented a clear tendency to have increased densities of understory foliage with a concomitant decrease in the higher foliage strata. In fact, a single, thick foliage stratum up to 10 m high characterized secondary forests, representing short forests, with a low canopy and no emergent trees (higher than 15 m). These changes in the vertical forest structure near edges are strong patterns reported to occur for other tropical forests (Williams-Linera 1990; Malcolm 1994; Oosterhoom & Kappelle 2000), probably as a result of increased tree mortality and light incidence, triggering overall changes on microclimate (Kapos 1989; Murcia 1995; Didham & Lawton 1999). This situation can lead to heavier leaf flushing in lower strata. These significant modifications of forest stratification are strong predictors of diversity of some fauna groups (e.g. Malcolm 1988; Pardini 2001 for small mammals).

Discriminant analysis highlighted major suites of forest disturbance revealing a gradient along which the forest categories could be ordered. The first discriminant function revealed a clear disturbance gradient mainly determined by an increased infestation of woody lianas, depicting three major groups: cabruças, secondary forests and mature forest sites.

Lianas are important components of tropical forests, comprising 45% of all woody species larger than 10 m high at Barro Colorado, Panama (Croat 1978). Nearly 37% of all woody in other tropical sites of eastern Brazil were infested by lianas (Mori et al. 1983). They are thought to represent important food resources for the local faunas, especially in forest fragments where they proliferate due to further disturbance (Emmons & Gentry 1983; Gentry 1991). In fact, significant proliferation of light-demanding liana species represents a striking feature associated with disturbance, particularly on forest edges (Chiarello 1997; Laurance 1997; Oliveira-Filho et al. 1997; Tabanez 1997; Viana et al. 1997; Tabarelli et al. 1999; Dewalt et al. 2000; Gillespie et al. 2000; Laurance et al. 2001). Again, two different causes can be evoked for reduced incidence of woody lianas in shade cacao plantations and secondary forests. The cabruca management system significantly reduces lianas as a result of the forest thinning and annual pruning, to avoid competition and prevent the death of cacao shrubs by tree-falls (Alves 1990). On the other hand, intermediate densities of liana

infestation in early secondary forests appear to be a result of the absence of large, tall trees to support these species (Dewalt et al. 2000).

Similarly, another gradient clearly related with structural disturbance can also be noticed along the second discriminant function, where the main feature is largely determined by a decrease of the density of the upper forest strata (20.1-25 meters high) in more disturbed sites. Along this gradient, sites were arranged sequentially from less to more disturbed sites: interior of controls, interior of fragments; edges of controls; edges of fragments; secondary forest. In this function, shade cacao was grouped together with mature forests, as this management system keeps some components of upper canopy strata. Secondary forest included short forests not often exceeding 10 meters high with no canopy or emergent trees that characterize mature tropical forests.

This second function also depicted an important gradient ordering the mature forest sites. Among the mature forest categories, we noticed a gradient of increasing structural disturbance following this sequence: interiors of continuous forests, interiors of fragments, edges of continuous forests and edges of fragments. However, significant differences were only noticed between the two extremes of the gradient, and the second function comprised at least two groups of forest categories. Together with the shade cacao, sites from interiors of continuous forests were significantly different from edges of fragments. This result highlights a relationship between the size of a given forest and the effect of the surroundings on its edge.

Didham & Lawton (1999) reported the same relationship pattern for differences in microclimatic variables in forest remnants from central Amazonian. The authors suggested that the higher levels of disturbance on fragment edges could be attributed to multiple edges in smaller fragments as a result of additive edge effects (Malcolm 1994). Here we suggest an alternative explanation. We propose that a more pronounced edge effect in forest fragments may be related with further sources of disturbance inside the fragment itself. For instance, the presence of tree-fall gaps and the buffer potential from large forest tracts behind the edge zone may also be important features influencing edge effect. Compared with larger, continuous forest tracts, small fragments have proportionally larger areas covered by tree-fall gaps per unit of area, increasingly the probability of gap formation near edges. In tropical forest fragments, edge zones have higher tree mortality and damage (Ferreira & Laurance 1997; Laurance et al. 1998) wind turbulence (Laurance 1997) and altered microclimate conditions (Didham & Lawton 1999). All these features are thought to be a direct result of the influence of fragment surroundings.

On the other hand, tree-fall gaps, either resulting from natural processes or man-made clearings induced by logging activities (Thiollay 1997), are likely to represent additional open, disturbed areas inside the fragments. While mature forest acts like a physical barrier to edge effects penetration, internal gaps may reduce the forest buffer capacity. It is known that gaps greatly elevate the total amount of sunlight reaching the lower forest strata. This situation favors the proliferation of light-demanding species, triggering overall major changes on the local forest structure (Putz 1984; Denslow 1987; Clark 1990). Tree-fall gaps also generate expressive numbers of thin trees in other sites of the southeast Brazilian Atlantic forest (Chiarello 1997). The intense logging activity in the Una forests is likely to be a strong source of forest gaps, allowing effects from the exterior to penetrate further from edge zones. Our findings point to the need of a new approach for forest edge effect studies that embrace the internal role of vegetation structure as a safeguard of edge effects in intact forest or amplifier in disturbed forest sites.

CONCLUSIONS

Our analysis has shown that our previously defined forest categories showed differences in the forest structural features. At least two distinct ecological gradients are related to disturbance. Mature forests, shade cacao and secondary forest sites can be classified as different forest categories when features such as the presence of woody lianas and the foliage density of the superior forest strata is taken into account. On the other hand, subtle changes lead to the separation among mature forest sites, with disturbance being related mainly with a decrease in the densities of the upper forest strata. Our study showed that processes such as fragmentation, forest regeneration and the establishment of shade cacao plantations are important sources of structural modification on the remaining forest cover in Una landscape.

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CAPÍTULO 3

FRAGMENTAÇÃO DE HÁBITAT, ESTRUTURA DA FLORESTA E UMA COMUNIDADE DE MORCEGOS NA MATA ATLÂNTICA DA REGIÃO DE UNA, BRASIL.

RESUMO

Entre as áreas tropicais mais ameaçadas do mundo destaca-se a floresta atlântica brasileira, hoje restrita a menos de 8% da sua extensão original, e representada por fragmentos florestais de diferentes tamanhos, grau de conectividade e perturbação. Este estudo objetivou avaliar o impacto do processo de fragmentação e alteração de habitats naturais sobre as comunidades de morcegos que habitam uma das regiões mais ricas da floresta atlântica, o sul da Bahia. Comparei a estrutura de comunidade de morcegos em 30 transectos em cinco categorias de ambientes, incluindo interiores e bordas de florestas contínuas (>1000 ha) e fragmentos (< 100 ha), e a matriz de entorno formada predominantemente por florestas secundárias em estágio inicial de regeneração. No total, registrei 30 espécies de morcegos de um total de 1.268 capturas em redes de neblina. A comunidade de morcegos mostrou-se rica e diversa tanto em fragmentos quanto em áreas contínuas de floresta, incluindo várias espécies usualmente associadas a ambientes pouco perturbados. Este resultado indica que tais parâmetros como composição, riqueza de espécies e abundância de indivíduos não foram afetados diretamente pelo tamanho total área de floresta em um dado remanescente. Bordas, uma consequência direta da fragmentação, e o estabelecimento de uma matriz de crescimento secundário no entorno dos remanescentes, tem um impacto negativo na comunidade de morcegos, pois nos dois ambientes a assembléia de espécies se mostrou um subconjunto da comunidade encontrada em interiores de fragmentos e florestas contínuas. Esta resposta é consistente com as alterações gerais da estrutura da vegetação em áreas perturbadas, que resultou em um gradiente de aumento da densidade foliar do subosque e diminuição no número de árvores grossas de interiores para bordas e capoeiras. Os morcegos parecem perceber estas alterações estruturais, pois a riqueza de espécies, frequência de captura e diversidade, assim como a frequência de captura de dois frugívoros dominantes foi negativamente associada a este gradiente de perturbação, enquanto os morcegos da sub-família Phyllostominae foram quase exclusivamente restritos às áreas menos perturbadas, representadas pelos interiores de floresta. Discuto algumas possíveis explicações para a estreita associação entre morcegos e este gradiente de perturbação determinado pela fragmentação e pelo uso da terra na região de Una.

Palavras-chave: morcegos, Mata Atlântica, fragmentação de habitat, conservação.

HABITAT FRAGMENTATION, FOREST STRUCTURE AND A BAT COMMUNITY IN THE ATLANTIC RAINFOREST IN THE UNA REGION, BRAZIL.

ABSTRACT

There is an immediate need to prevent local biodiversity loss caused by habitat fragmentation and its associated processes. As one of the most threatened ecosystems in the world, the Brazilian Atlantic Rainforest has been reduced to less than 8% of its original cover, and the conservation of its rich biota requires urgent decisions. This study focuses on the effects of habitat fragmentation upon the bat community from one of the few regions that concentrates remnants of northeastern Brazilian Atlantic Rainforest. I compared the bat community structure in 30 transects encompassing five different habitat categories: interiors and edges of both continuous forest (>1000 ha) and fragments (< 100 ha), and the surrounding matrix of second growth forests. I reported a total of thirty bat species from 1,268 captures in mist nets. Bat communities were rich and frequent in both fragments and continuous forest tracts. Also, small stands showed bats usually associated with less disturbed forests, indicating that community properties like composition, richness and total capture were not directly affected by forest size *per se*. Edges and secondary forests had a negative impact on bat communities. In these habitats the bat assemblage was a subset of the interior of both fragments and continuous forests. This bat response is consistent with the overall modification of forest structure in disturbed habitats (edges and secondary forests), which consists of a gradient of increasing understory foliage density and decreasing number of thick trees from interiors to edges and secondary forests. Bats seem to perceive these forest structural modifications, as the total species richness, capture frequency and diversity, as well as the frequency of two common frugivorous species were negatively associated with this disturbance gradient, whereas the rare phyllostomines were almost exclusively restricted to less disturbed areas represented by forest interiors. I discuss some possible explanations for the close association between bats and this disturbance gradient triggered by fragmentation of forest in the Una landscape.

Keywords: Bats, Atlantic Forest, habitat fragmentation, conservation.

INTRODUCTION

The massive conversion of natural habitats into small and isolated patches has concerned conservationists worldwide. The ultimate consequence of this process, namely habitat fragmentation, is the local extirpation and the global species extirpation (Shafer 1990). Habitat destruction accounts for nearly half of the recent disappearance of continental bird species (Diamond 1989) and is considered a main factor that affects modern extinction rates of the land biota (Shafer 1990).

The current knowledge of the consequences of habitat fragmentation on biological communities has been based on a large body of research, with a particular bias towards bird studies (Turner 1996). In comparison, other biological groups such as plants, invertebrates and the remaining vertebrates have received less attention. Results from bird studies may have only a limited applicability on management strategies designed to ameliorate the effects of habitat fragmentation on the entire biota, as they may show different responses compared with other biological groups. Therefore, studies focusing other target taxa should be encouraged.

Bats should be considered as an important group to conduct fragmentation studies for several reasons. Bats represent more than 980 species worldwide and they are especially diversified in Neotropical regions where in some areas they comprise nearly half of all mammal species reported locally (Fleming et al. 1972; Bonaccorso 1979). Bats are also considered the most ecologically diverse mammals in Neotropical ecosystems (Kalko 1996; Altringham 1996), and forage on a variety of food items, with carnivorous, insectivorous, sanguinivorous, piscivorous, nectarivorous and frugivorous species (Hill & Smith 1984). As most bat species are closely associated with forest habitats, bats may be potentially vulnerable to the increased deforestation process taking place in tropical areas.

Despite the characteristics of bats cited above, our current knowledge about the response of this group to habitat loss and fragmentation is rudimentary. Although there are no conclusive statements, there seems to be a simplification of the bat community structure towards disturbed areas (Aguiar 1994; Reis & Muller 1995), especially in the family Phyllostomidae, the most trophically diverse of New World bats (Fenton et al. 1992). Moreover, some bat species may be restricted to continuous and less disturbed forest tracts, which suggests they are vulnerable to deforestation (Fenton et al. 1992; Estrada et al. 1993; Reis & Muller 1995; Brosset et al. 1996; Kalko et al. 1999), as may be the case of most Phyllostomidae bats, particularly the sub-family Phyllostominae. However, it is still unclear if

there is a relationship between species richness and the total forested area (Pedro 1998). Furthermore, isolation distance between forest patches may play an important role influencing the resilience of bat communities, as well as the tolerance of some species to the modified habitats that surround forest remnants (Estrada et al. 1993; Cosson et al. 1999). However, the extent to which bats respond to direct modifications in habitat, such as edge induced changes in forest structure or changes in the surrounding matrix, has rarely been addressed for tropical regions (Estrada et al. 1993; Medellín et al. 2000).

To provide data in this direction, I sampled bats in an area of the Atlantic rainforest in Northeastern Brazil, a forest that has been subject to severe habitat fragmentation and human exploitation. Based on an experimental design, my study examined bat community attributes (species richness and diversity), species-levels response (abundance) and the distribution of Phyllostominae species, a guild of gleaning bats that includes insectivorous, carnivorous and omnivorous species, in five habitat categories comprising the bulk of the forest mosaic remaining in the study area. These habitats included large and small patches of primary forests, and the surrounding matrix of second growth vegetation, called capoeiras. I used data on vegetation structure and, for the particular set of Phyllostominae species, the abundance of insect prey as predictors to bat response to forest categories. I concentrated on three specific questions concerning the effect of habitat fragmentation upon bat communities: (1) are bats affected by actual forest reduction, showing differences between small and continuous forest patches in the attributes investigated? (2) is the surrounding matrix of secondary forest permeable to bats? (3) are bats sensitive to general disturbance of forest structure derived from fragmentation such as edge formation?

METHODS

♦ STUDY AREA

This study was carried out in the Una region, located in the southern part of the state of Bahia, northeastern Brazil at 39°04'W and 15°17'S (Figure 1.1). The dominant vegetation physiognomy was technically classified as southern Bahian wet forest (Mata Higrófila Sul-Baiana) by Gouvêa et al. 1976. Mean annual temperature is 24°C and the rainfall averages 1,500 mm/year, with no defined seasonality although a rainless period of 1-3 months may occur from December to March (Mori et al. 1983). Although human occupation in Southern Bahia dates back to the European colonization 500 years ago, the Una region has been largely deforested only in the last 40 years with the establishment of the BR 101 highway in

1945 (Mendonça et al. 1993). This road has opened the frontier for intensive logging activities and by 1994, satellite images revealed that only 34,8% of the original forest remained. Today timber exploitation is still a major threat to the forest, but land squatters, cattle raising and sun-coffee plantations are also other agents of deforestation at a regional scale.

This area comprises one of the last remnants of the Atlantic Forest left in Northeastern Brazil and is considered as a *hot spot* of biodiversity due to high levels of endemism and species richness (Thomas et al. *in press*). It is the home of several endemic primates (e.g. *Leontopithecus chrysomelas*, *Cebus apella xanthostemos*), and a high percentage of endemism for tree species is found (Thomas et al. 1998). Despite its striking importance, only 7.000 ha are effectively protected by federal law within the Una Biological Reserve, municipality of Una while the bulk of the remaining forest is privately owned.

♦ STUDY DESIGN

As part of a major project (Projeto RestaUna - www.restauna.org.br) designed to comparatively investigate the response of biological communities facing habitat fragmentation bats were sampled following a previously established experimental design. Through satellite images, aerial surveys, photo interpretation and intensive ground-truthing, it became clear that the landscape in the Una region comprises a mosaic of forest habitats, including mature, disturbed and second growth forest, and farms of shade cacao plantations. Therefore, the fragmentation process in the Una region, although very intense, has not led to the complete isolation of most forest tracts, as might be expected in the “classic” picture of forest islands immersed in a matrix of pastures. Most of the forest patches in Una are physically connected by some forested physiognomy such as shade cacao plantations, second growth vegetation or by narrow strips of mature forests. In this landscape the remaining forest is mostly represented by areas larger than 1,000 ha or by fragments smaller than 100 ha. Most patches are irregularly shaped and have many constrictions, resulting in a high proportion of edge habitats. In this shredded forest (Feinsinger 1994), the proportion of edges rather than the isolation of patches seems to be the most striking feature directly related to the fragmentation process (see chapter I).

In this scenario I considered a fragment as a mature forest patch smaller than 100 ha, completely isolated from another similar area or connected to it by uncleared land such as second growth forests, shade plantations or by narrow strips of mature forest, while forests larger than 1.000 ha were considered as continuous or “control” forests.

After the characterization of the overall pattern of the local landscape, I chose to sample the bat community along transects in five different habitat categories encompassing both mature forests and the surrounding matrix. These categories include interiors and edges of continuous forest (more than 1,000 ha), interiors and edges of forest fragments (<100ha), and areas of early secondary forest called capoeiras. By definition, a capoeira results from a vegetation succession in an area that was clear cut less than 20 years ago. Edges are considered as the interface between forest and pasture physiognomies. Edge sites were established inside the forest areas, in a parallel transect 20 meters inside the forest, while interiors were sites located at least 75 meters within the forest.

The sampling design encompasses six samples in each forest category. These replicates are spatially distributed in three blocks of 5km X 5km, each block comprising two replicates of each habitat category (Figure 1.4). In each sample I set up a 100m long transect where bats were sampled, resulting in a total of 30 transects considered in my study. This sampling design aimed to capture a considerable portion of the landscape heterogeneity, to test whether the possible differences found within treatments (each forest category) are affected by their spatial distribution in the landscape.

♦ FOREST STRUCTURE

I relied on the data bank of the RestaUna project to obtain data on forest structure. These data were collected by technicians hired by the project coordination during the time period I sampled bats. Forest structure in each habitat category was assessed by measuring two descriptors: the density of woody trees of different diameter-classes at breast height (dbh) and the foliage density in different height classes.

In each transect two 2 m X 200 m plots were established and all the woody trees were assigned to the following dbh classes: 5-10cm, 10-15cm, 15-25cm, 25-35cm and > 35cm. Foliage profile was recorded following a modification of the Hubbell and Foster's method (1986) described in Malcolm (1995). Using a 3m pole to allow a vertical sighting, the intervals occupied by foliage (e.g. estimation of the foliage intervals hitting this vertical imaginary line) were recorded for each height in the forest vertical stratum: 0-1 m; 1-5 m; 5-10 m; 10-15 m; 15-20 m; 20-25 m; 25-30 m and 30-35 m (Figure 2.1). These measurements were taken in twelve points regularly spaced along each transect, and the mean values for each stratum used for the analysis.

♦ ARTHROPOD ABUNDANCE

I measured the insect abundance for gleaning insectivorous bats, here encompassing all the Phyllostominae. As gleaners, these bats catch arthropod prey from surfaces such as the ground, branches, tree trunks or foliage. I used a standard method to sample arthropods from the forest understory (Davies 1986). The insects were collected using a wooden cross-shaped structure, covered with a white cotton cloth to allow the visual sighting of the animals. This structure is used as a tray, placed under a branch or small bush which is then beaten with a small wooden stake. Only the arthropods that fall into the tray were collected and fixed in ethanol (70%) for further identification. Along each of the 36 transects, 20 understory branches were randomly selected for arthropod sampling.

I used only data on the beetles as they are thought to be one of the main food sources for insectivorous Phyllostominae (Humphrey et al. 1983; Fenton et al. 1999) and also because they were abundant enough in my study to perform statistical tests. I used the total captures of all beetles for each transect as replicates for each habitat category. Sampling was carried out by the RestaUna team in 10 days during November 2000. A more detailed description of the method and general results of that study can be found in Brescovit et al. (in press).

• BAT SAMPLING PROCEDURE

Bats were mist-netted following a standardized sampling unit, consisting of a set of eight mist nets (or 69 net-meters), placed along each 100m transect. Each transect was sampled for four non-consecutive nights, resulting in a total sampling effort of 120 nights. The nets were opened from 6 PM to 11 PM, the most active period for bats (Fleming 1988). In order to minimize possible influences from other factors, I did not sample on nights with heavy rain for more than 30 consecutive minutes nor with full moon. As I relied on a single sampling method, I am aware that these estimates represent an incomplete picture of the overall bat assemblage in Una region, as it under-represents, for instance, bats not readily caught in mist nets, such as most aerial insectivorous or non-*phyllostomidae* bats. However, as mist nets are by far the most common and effective sampling method for on bat studies in the Neotropical region, it allows for comparisons among most of the studies.

Nets were checked every 20-30 minutes and when bats were caught, they were kept inside cloth bags to permit feces sampling, after which they were released by the end of each sampling night. Feces were collected and analysed on the laboratory for a further study of bat feeding habits.

Bats were identified following the few available identification keys (Vizotto & Taddei 1973; Simmons & Voss 1998), visits to the National Museum of Natural History (Washington, DC) and the American Museum of Natural History (New York, USA). Most identifications were confirmed by Dr. Charles Handley, Dr. Nancy Simmons and Dr. Valdir Taddei.

♦ DATA ANALYSIS

I used a two-way ANOVA, with treatments (habitat categories) and blocks as factors to test differences in the bat parameters (capture frequency, species richness and diversity) among the treatments and blocks, and also to investigate possible interactions between the factors. Raw data for each transect included the sum of species richness and capture frequency from the four sampling nights, which probably included recaptures. Data were tested for normality (Kolmogorov-Smirnov test) and homogeneity of variances (Levene test), both important assumptions of parametric ANOVA model (Zar 1999). When required, data were rank-transformed to better meet normality and homocedasticity of variances among groups. Differences were considered to be statistically significant at 0.05. Prior to the data analysis, I searched for potential ANOVA comparisons (n treatments minus 1) that could be run in order to avoid an increase of type I error, by planning the orthogonal contrasts procedure (Montgomery 2001). The comparisons took into account the main questions considered in the current study and were as follows:

1) The effect of forest reduction (area):

interiors + edges of controls X interiors + edges of fragments

interiors of control forests X interiors of fragments

2) The permeability of the matrix:

secondary forests (capoeiras) X primary forest categories (interiors and edges of fragments + interiors and edges of controls)

3) edge effect:

interiors of controls + interiors of fragments X edges of controls + edges of fragments

I used the Shannon-Wiener diversity index, and I also calculated the beta-diversity (turnover of species among sites) by using the Jaccard similarity index and then running a one-way ANOVA to verify differences in the mean values. Rarefaction procedure (Krebs 1989) was also used to estimate and compare richness expected from a given sampling effort among treatments and also to obtain these values from data of other studies.

Regression analyses were used to investigate the potential linear relationships of forest structure and bat attributes. As most of the forest descriptors were highly correlated, I

derived two orthogonal axes from a Principal Component Analysis (PCA) and used each as independent variables to predict bat response. As vegetation data were taken in different units of measurement, raw values were standardized and the PCA was calculated using a correlation matrix, following further default criteria (Kovach 1999). Given the apparent rarity of the most of the Phyllostominae bats, I ran a Discriminant Analysis (DA) to investigate which features of forest structure could be associated with the presence/ absence of these rare species. Therefore, I ran a one-way ANOVA on the scores of the first DA function to test for significant differences on the centroids of the two groups (presence/absence). All statistical and multivariate analysis were carried out with the SPSS (1998) and MVSP (Kovach 1999) packages.

RESULTS

HABITAT CATEGORIES AND THE FOREST STRUCTURE

Principal Component Analysis based on the data of vegetation structure revealed that the first axis (40% of the total variation) described a gradient between disturbed and undisturbed forest. Variables such as the density of foliage on the upper strata (15-20m ; 20-25m) and the number of large trees (25-35cm; 35-50cm) had the highest weighting on this axis (Table 3.1) pushing in one direction and the density of understory foliage (1-5m) increasing on the other direction. Along this gradient, the five habitat categories were rearranged in three major groups based on their forest structure (Figure 3.1). The capoeiras, characterized by short forests rarely exceeding 10 m tall, showed the highest densities of thin trees (d.b.h. < 10cm) and foliage density at 1-5m height. Interiors of forest (both fragments and controls) depicted the most preserved areas, with a greater number of large trees (25-35cm d.b.h.) and foliage density higher than 15m and a less dense understory (low densities of foliage at 1-5m height). Edges (both fragments and controls) occupied an intermediary position along the first axis, forming a more heterogeneous subset than the other habitat categories. Most of the edge transects (8 out of 12) exceeded the median value of the PCA, and tended to be more disturbed than interiors but less disturbed than capoeiras.

The scores of the sampling sites from interiors, edges and capoeiras were statistically different, thus showing that these three habitats were the actually distinct forest categories based on the PCA axes (ANOVA test; $F=24.9$; $p<0.000$, *a posteriori* Tukey test). On the other hand, scores of fragments and continuous forest sites were not significantly different on the first axis (ANOVA test; $F=0.384$; $p=0.542$), although more fragment sites (six out of

twelve) exceeded the median value on axis 1 than control sites (three out of twelve). Edges located on fragment sites tended to be more disturbed sites than those from continuous forests, with scores showing statistical differences (ANOVA test; $F=5.22$; $p=0.045$). The second PCA axis showed no consistent pattern and explained only 12% of the total variation.

Table 3.1. Loadings of the first two Principal Components from PCA using forest structure descriptors.

Descriptors	Axis I	Axis II
D.B.H. classes		
1 to 10.1cm	0.191	-0.373
10.1 to 15cm	0.071	-0.054
15.1 to 25cm	-0.276	-0.370
25.1 to 35cm	-0.338	0.036
35 to 50cm	-0.313	0.216
Foliage Density		
0 to 1m	0.137	0.501
1.1 to 5m	0.303	0.394
5.1 to 10m	0.259	0.183
10.1 to 15m	-0.296	0.363
15.1 to 20m	-0.380	0.163
20.1 to 25m	-0.345	0.022
25 to 30m	-0.309	0.167
30 to 35m	-0.214	-0.215
Eigenvalues	5.257	1.570
Cumulative % of Variance Explained	40.437	52.516

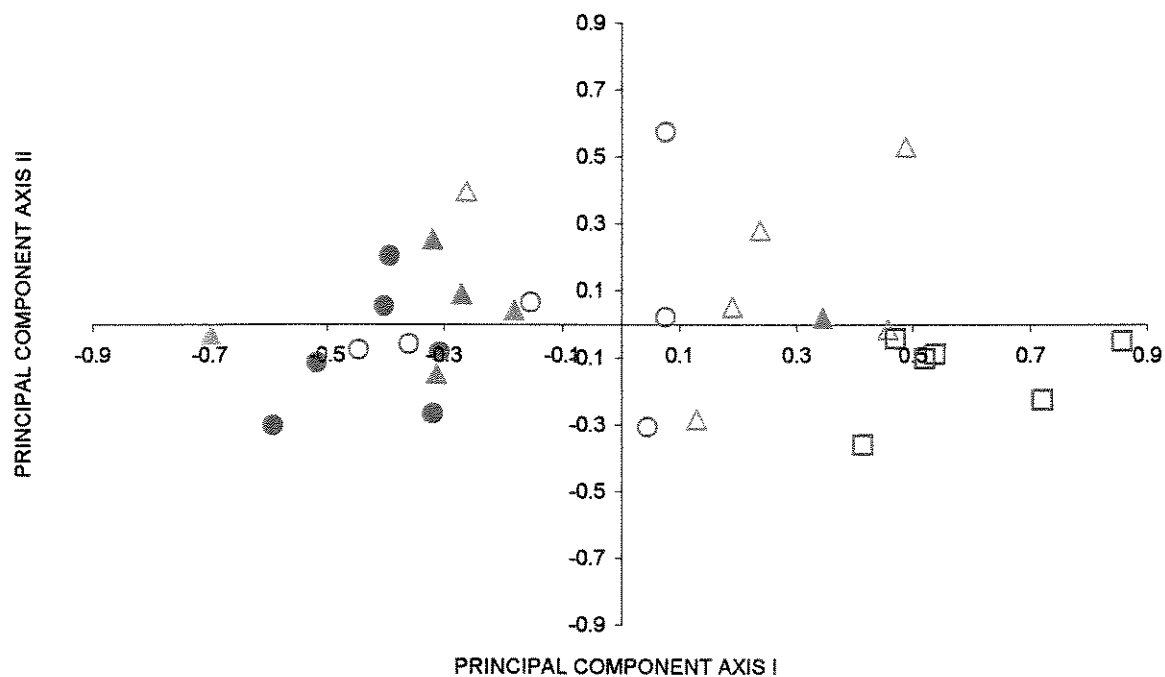


Figure 3.1. Graphical representation of the first two principal components of habitat categories sites on Axis I and II. Continuous forests are represented by circles, forest fragments by triangles and capoeiras by squares. Filled and unfilled circles and triangles markers represent interior and edge sites, respectively.

BAT ASSEMBLAGE OF UNA REGION

After 24 months I accomplished a total of 1268 captures of 30 species (table 3.2). Despite a considerable sampling effort of 41.400 net.meter.hours, a randomized species accumulation curve had not stabilized (Figure 3.2). This indicates that more species would be added with further sampling, although there was a decline in the rate of species accumulation.

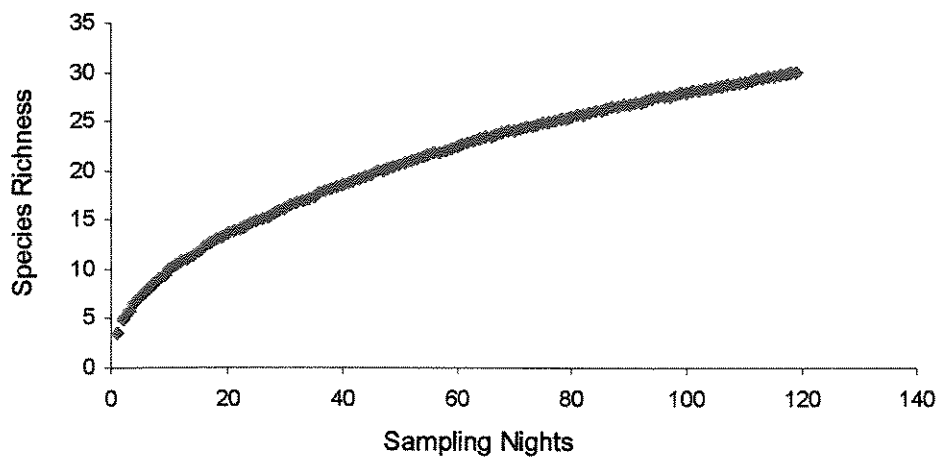


Figure 3.2. Randomized species accumulation curve.

As expected due to the sampling method, the phyllostomidae bats were by far the most frequent and speciose bat group sampled, that comprise 27 species and 99% of captures (table 3.2). This group was largely dominated by frugivorous bats (14 species and 1,237 captures). By considering all the habitat categories together, *Carollia perspicillata* and *Rhinophylla pumilio* were the most abundant bats with 474 captures each, followed by a wide margin by *Artibeus obscurus* with 143 captures. Together, these three species of frugivorous bats accounted for almost 85% of all captures ($n=1,079$). Also, *C. perspicillata* and *R. pumilio* were widespread on the study sites, observed on all 30 transects sampled. Unless specified elsewhere, for the species-level response, I will focus the results on these three dominant species once it was possible to meet the overall assumptions to perform both parametric and non-parametric tests.

On the other hand, 22 species (73%) were rare, represented by fewer than 10 captures. All bats from the subfamily Phyllostominae, which included all the gleaning insectivorous (7), carnivorous (1) and omnivorous (1) bats, were among the rare species and were represented by less than 2 captures. The vampire bats *Desmodus rotundus* were also netted in low frequencies and are also classified as locally rare. Pooled data for the five habitat categories showed six species were widespread (*A. cinereus*, *A. lituratus*, *A. obscurus*, *C. perspicillata*, *M. nigricans* and *R. pumilio*), occurring on all the five habitats (Table 3.2).

Table 3.2. Frequency of bats mist netted in five forest categories at Una region, Brazil. Species are listed in alphabetic order.

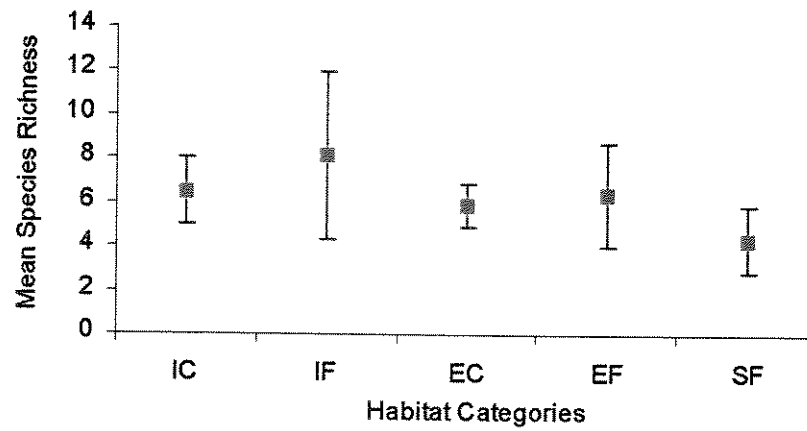
BAT SPECIES	CONTROLS		FRAGMENTS		MATRIX
	interiors	edges	interiors	edges	Capoeiras
Phyllostomidae					
sub-family Carollinae					
<i>Carollia brevicauda</i>	1	5	4	2	0
<i>Carollia perspicillata</i>	81	75	142	93	83
<i>Rhinophylla pumilio</i>	112	84	117	100	61
sub-family Desmodontinae					
<i>Desmodus rotundus</i>	1	0	0	0	0
sub-family Glossophaginae					
<i>Glossophaga soricina</i>	1	1	3	0	2
<i>Lichonycteris obscura</i>	0	0	0	0	1
<i>Lonchophylla mordax</i>	3	1	0	1	0
sub-family Phyllostominae					
<i>Chrotopterus auritus</i>	1	0	0	0	0
<i>Micronycteris hirsuta</i>	1	0	1	0	0
<i>Micronycteris microtis</i>	1	0	0	1	0
<i>Micronycteris schmidtorum</i>	0	0	1	0	0
<i>Phyllostomus elongatus</i>	0	0	2	0	0
<i>Tonatia brasiliense</i>	1	0	0	0	0
<i>Tonatia saurophila</i>	1	0	0	0	0
<i>Tonatia silvicola</i>	0	1	0	0	0
<i>Trachops cirrhosus</i>	0	0	1	0	0
sub-family Stenoderminae					
<i>Artibeus cinereus</i>	9	11	17	12	11
<i>Artibeus fimbriatus</i>	0	0	0	1	0
<i>Artibeus gnomus</i>	1	2	3	0	0
<i>Artibeus jamaicensis</i>	1	1	1	4	0
<i>Artibeus lituratus</i>	7	6	12	7	5
<i>Artibeus obscurus</i>	50	37	27	25	4
<i>Chiroderma villosus</i>	1	0	2	0	0
<i>Platyrrhinus recifinus</i>	0	0	2	0	0
<i>Sturnira lilium</i>	0	0	1	3	0
<i>Uroderma bilobatum</i>	0	0	1	0	0
<i>Vampyroides caraccioli</i>	0	0	1	0	0
Emballonuridae					
<i>Saccopteryx bilineata</i>	0	0	1	1	0
Vespertilionidae					
<i>Epitesicus brasiliensis</i>	0	0	1	0	0
<i>Myotis nigricans</i>	5	2	5	1	1
Total Captures	278	226	345	251	168

BATS AND HABITAT CATEGORIES

The mean species richness and capture frequency reported for each habitat category seem to follow the same pattern observed for forest structure ordination. Transects located on interiors of both fragments and continuous forests tended to have more bat species and captures than transects located on edges, while the surrounding matrix showed the lowest species richness and bat captures (Figure 3.3). This is illustrated by the rarefaction curves, where for a given number of bat captures there were fewer species expected than in capoeiras, whereas edges had intermediary richness and the interior transects had the highest estimated species richness (Figure 3.4).

The distribution of mean capture frequency of *C. perspicillata* and *R. pumilio* showed a small variation among the five categories, while *A. obscurus* tended to show a diminishing capture frequency from interiors of continuous forests to capoeiras (Figure 3.5).

(a)



(b)

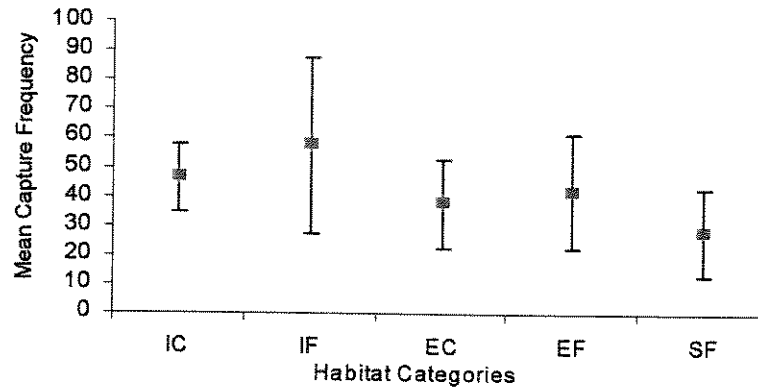


Figure 3.3. Mean ($\pm$ bars are Standard Error) values of species richness (a) and capture frequency (b) of bats across five habitat categories in of bats on the Una, namely interiors of continuous forests (IC), interiors of forest fragments (IF), edges of continuous forests (EC), edges of forest fragments (EF) and secondary forests (SF).

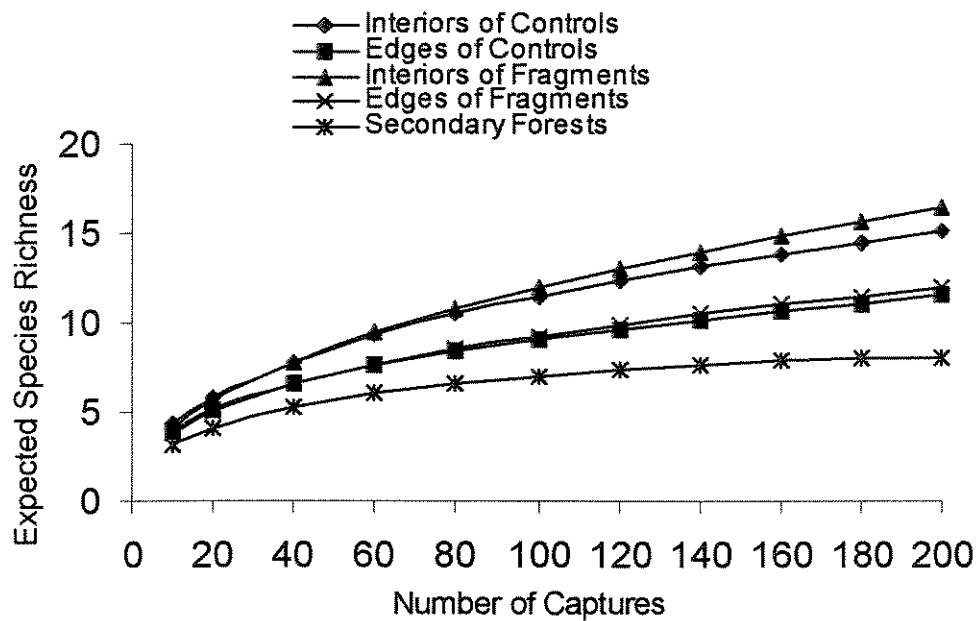


Figure 3.4. Randomized rarefaction curves depicting the expected number of bat species taken from different sample sizes in five habitat categories in the Una region.

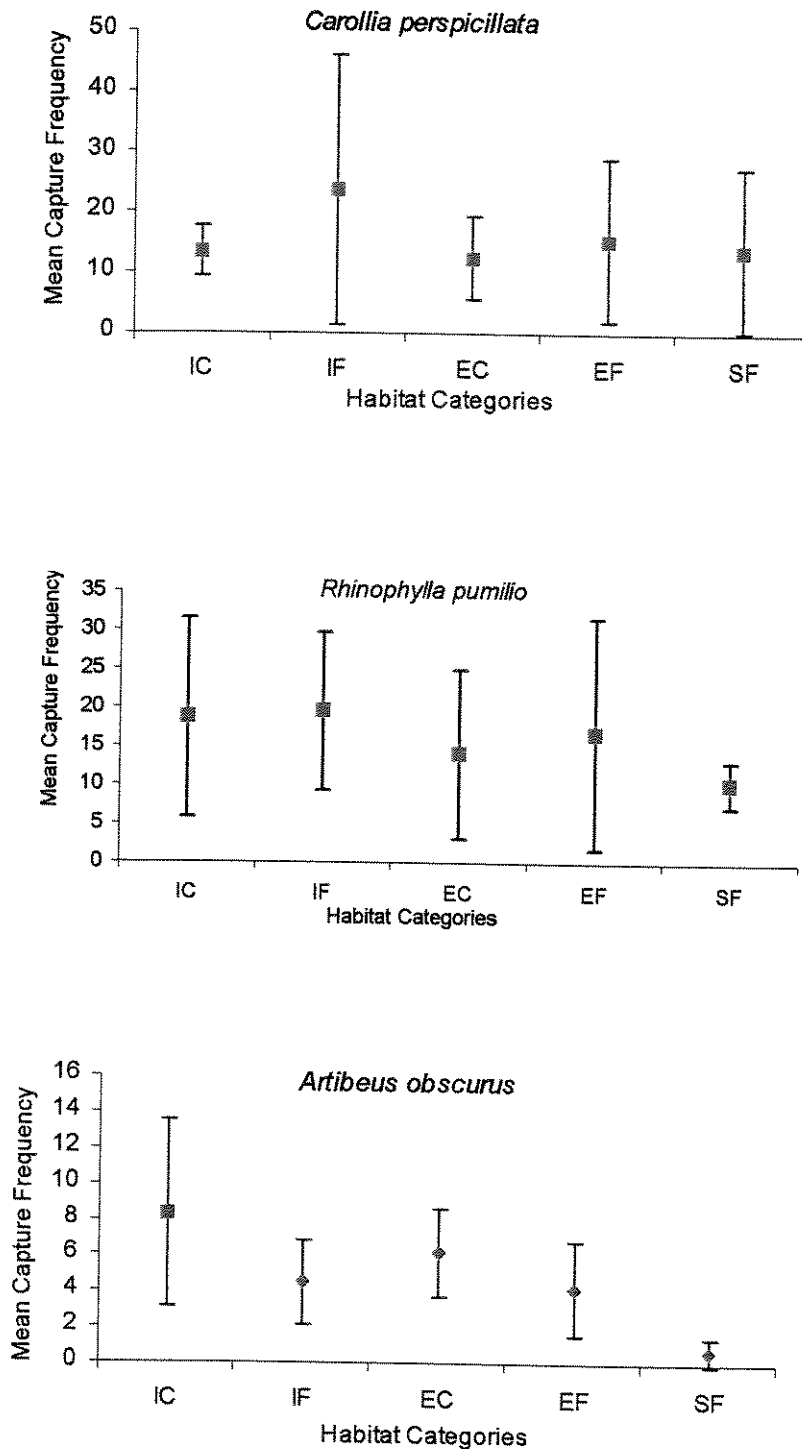


Figure 3.5. Mean ($\pm$ bars are Standard Error) capture frequency of the bats *Carollia perspicillata*, *Rhinophylla pumilio* and *Artibeus obscurus* in five habitat categories, in Una: namely interiors of continuous forests (IC), interiors of forest fragments (IF), edges of continuous forests (EC), edges of forest fragments (EF) and secondary forests (SF).

FOREST PATCHES AND THE SURROUNDING MATRIX

Statistical comparisons by Two-Way ANOVAs (Table 3.3) revealed that the average species richness in capoeiras (4.3 ± 1.5) is significant lower than in mature forest (all sites combined: 6.7 ± 2.7). Mean capture frequency reported for forest patches (45.83 ± 20.3) also tended to be higher than for the surrounding matrix (28 ± 14.91), although this difference was not statistically significant. Bat assemblages in capoeiras were almost entirely composed by frugivorous (5 sp.) and nectarivorous (2 sp.) species. Six species were widespread, and were found in all the four primary forest categories, although no Phyllostominae bats were observed in capoeiras. *Carollia perspicillata* and *Rhinophylla pumilio* had a similar number of captures in capoeiras and primary forest patches, and were the two dominant species in both habitats. On the other hand, *Artibeus obscurus* was also frequently captured in the primary forests (5.79 ± 3.56 captures) but was rarely caught in the surrounding matrix (0.66 ± 0.81 captures).

SMALL AND LARGE FOREST PATCHES

Mean species richness and capture frequency did not differ statistically between transects located in continuous forests and forest fragments (Table 3.3). Bat assemblages in fragments included 24 different species, whereas 19 species were caught along all transects located in continuous forests (Table 3.2); species turnover (beta-diversity) among transects in fragments and continuous forests was the same (one way-ANOVA, $F=0.076$; $p=0.784$).

In both fragments and continuous forests, the frugivorous *C. perspicillata*, *R. pumilio* and *A. obscurus* were the three dominant species. However, *A. obscurus* showed a significantly lower capture frequency in fragments compared with control forests (Table 3.3), whereas the response of the other two dominant species to forest reduction is unclear: no significant differences were found for the capture frequency of *C. perspicillata* and *R. pumilio* between controls and fragments. However, *C. perspicillata* were captured with greater frequency on transects (both controls and fragments) located in Block III, and a strong interaction between blocks and treatments for *R. pumilio* was shown to occur. Both fragments and continuous forests harbored species of Phyllostominae bats. Statistical comparisons between interiors of fragments and continuous forests did not reveal significant differences in species richness, capture frequency and frequency of the three dominant species, although *A. obscurus* tended to be less frequent in interiors of fragments than in continuous forests.

EDGE EFFECT

On average, there was no statistical difference of the mean species richness and capture frequency of bats on transects located in forest interiors and edges (Table 3.3). By considering the bat assemblages in interior and edge, a total of 26 species were sampled in the former habitat while only 16 were caught on edges. Species composition on edges were a subset of the bat assemblages found in interior habitats. Therefore, despite the similarity of species richness and total abundance of bats in interior and edge, species turnover (beta-diversity) was significantly higher between interior transects than observed in edges (one-way ANOVA, $F=46.90$, $p<0.00$)

The distribution of species in edges and interiors revealed that bats from the subfamily Phyllostominae were dramatically under-represented in edge transects, with only two species compared with 8 reported in interiors. Moreover, the two species of Phyllostominae bats in edge habitats were caught in transects that showed vegetation structure more similar to interior transects (see PCA). These sites had lower mean levels of understory foliage and higher quantities of thick trees than the average values reported for edges.

FOREST STRUCTURAL CHANGES AS PREDICTORS OF BAT RESPONSE

Simple linear regression of bat community parameters against the scores on the first PCA axis for vegetation structure showed a relationship between bats and a gradient of forest disturbance. I found a negative, significant association between bat species richness and the forest disturbance gradient described by the PCA first axis ($r^2 = -0.292$; $p=0.002$; Figure 3.6). Highly disturbed sites also showed lower Shannon–Wiener values ($r^2 = -0.262$; $p=0.004$) and a lower capture frequency ($r^2 = -0.190$; $p=0.016$) versus less disturbed sites (Figure 3.6).

The bats *R. pumilio* and *A. osbcurus* also depicted a negative, significant association with forest disturbance gradient (respectively: $r^2 = -0.390$, $p= 0.033$ and $r^2 = -0.363$, $p< 0.000$; Figure 3.7a and b). This relationship does not occur, however, for *C. perspicillata*, a very common species sampled in all transects ($r^2 = 0.027$, $p= 0.387$; Figure 3.7c).

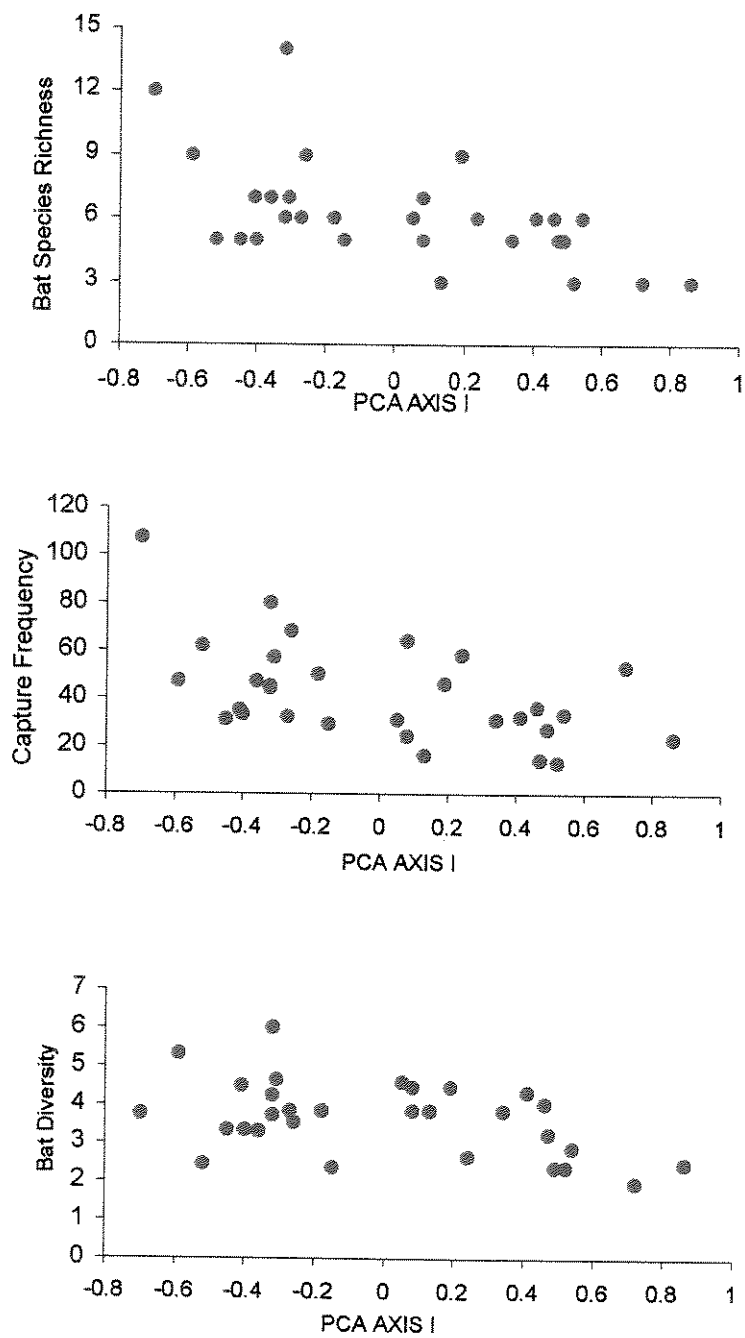


Figure 3.6. Linear relationship of bat species richness, capture frequency and species diversity with a gradient of forest structure disturbance in the Una region, State of Bahia, Northeastern Brazil.

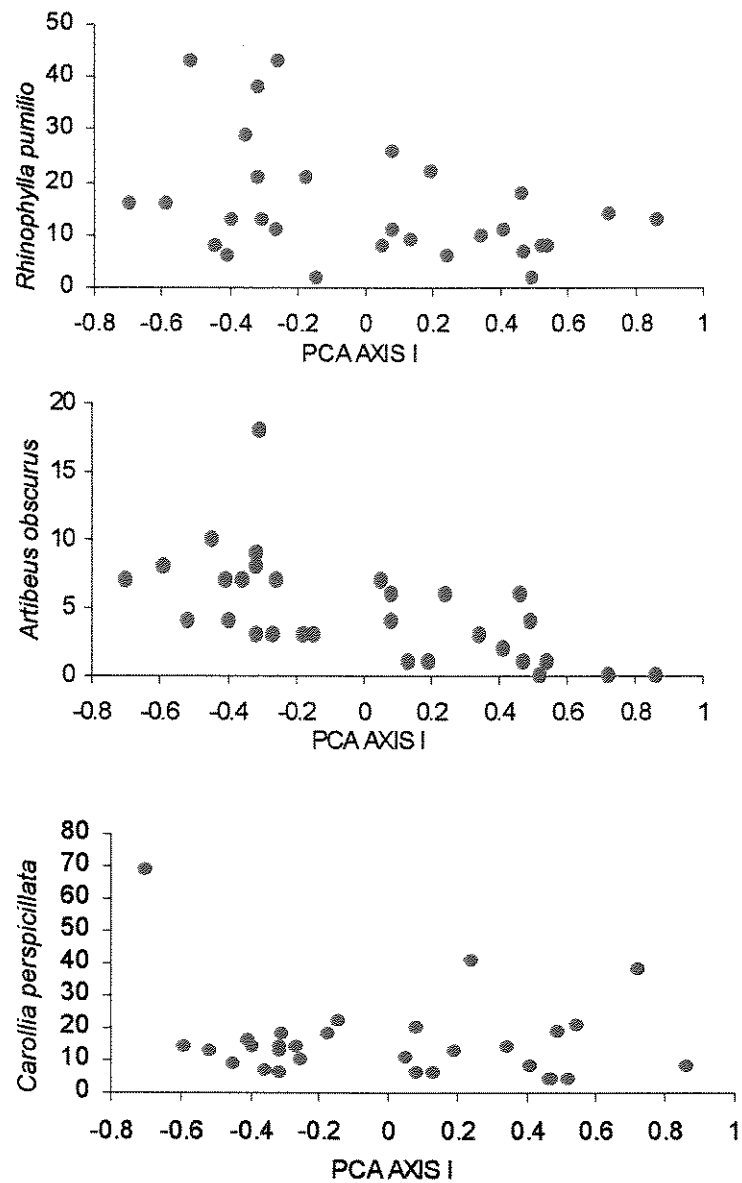


Figure 3.7. Linear relationship of capture frequency of bat species (a) *Rhinophylla pumilio*, (b) *Artibeus obscurus* and (c) *Carollia perspicillata* with a forest disturbance gradient in the Una region, State of Bahia, Northeastern Brazil.

The presence of Phyllostominae bats also was related to the local vegetation structure. A Discriminant Analysis using the presence and absence of Phyllostominae bats as categories, and the vegetation data of forest transects as independent variables, revealed that the first discriminant function explained 100% of the total variation. The canonical correlation was 0.698 ($\chi^2 = 18.028$, $p < 0.000$, Wilk's lambda = 0.513) with a high degree of consistency with 83% of the cases correctly classified. Two variables, the density of foliage at the understory level (1–5 m height) and the number of thick trees (35–50 cm d.b.h.) were important determinants of the first discriminant function. This analysis showed that the presence of Phyllostominae bats is strongly associated with forests with relatively low foliage densities in the understory and the presence of many large trees. By contrast, forests with a dense understory and the presence of many small trees were not used by Phyllostominae bats (one-way ANOVA, $F = 26.59$, $p < 0.00$) (Figure 3.8).

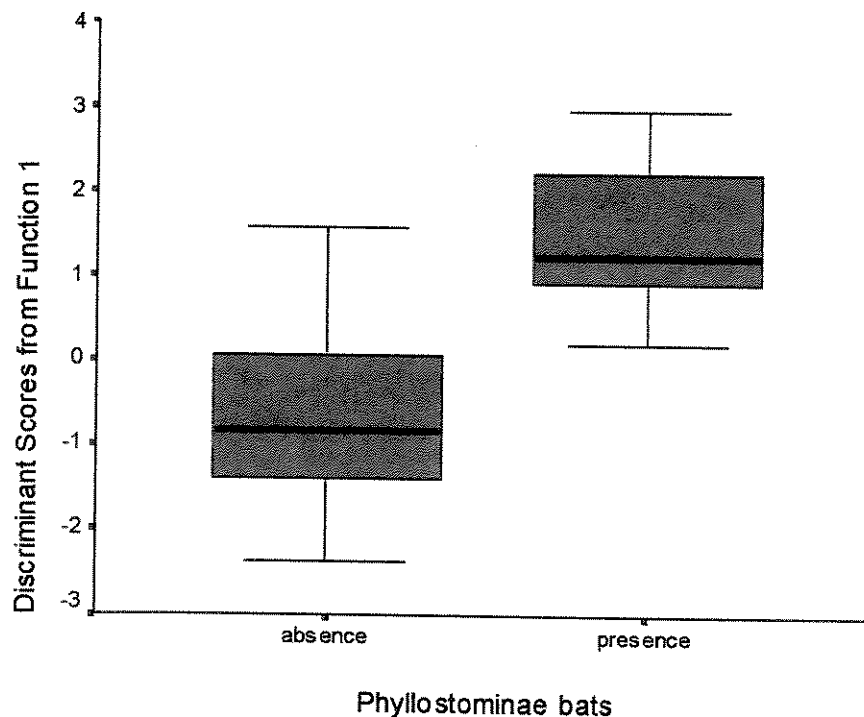


Figure 3.8. Mean values of the scores of the discriminant function taking into account the presence and absence of Phyllostominae bats and the vegetation descriptors. Bars are $\pm$ Standard Error.

The association of Phyllostominae bats did not follow the same trends reported for the abundance of beetles. I found a weak, though significant positive relationship between the forest disturbance gradient described by the first PCA axis and the abundance of beetles ($r^2=0.404$, $p=0.027$), with a higher abundance of beetles in more disturbed sites (Figure 3.9).

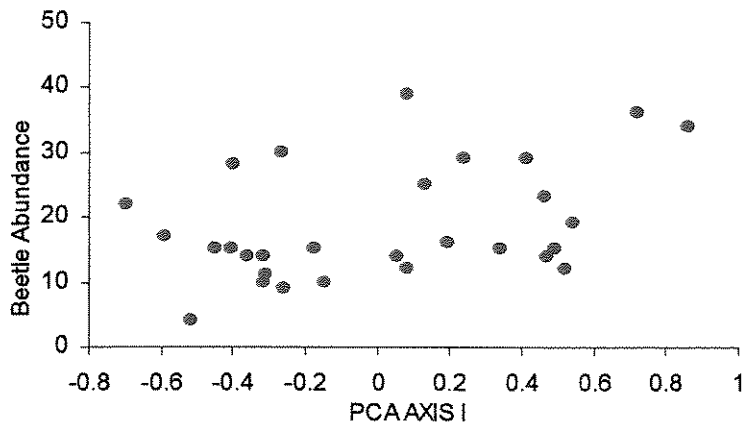


Figure 3.9. Association between beetle abundance and forest disturbance gradient in the Una region, Brazil.

DISCUSSION

BATS AND FOREST FRAGMENTATION

Despite an intensive conversion of the original forest into open areas and other land uses, the forest patches of the Una landscape still harbors diverse and rich bat community, irrespective of patch-size. Fragments hold the same species richness and bat captures as larger, continuous forests. Bat assemblages in forest fragments still include species that are usually associated with continuous and well-preserved forest stands, for example, Phyllostominae. In fact, these small patches showed the same beta-diversity compared with continuous forests and suggest that the conservation of many small fragments in Una region is also important to preserve a rich assemblage of forest dwelling bats.

The lack of forest-area effects on the total species richness agrees with studies made in other forested areas, where the size of forest patches did not lead to a direct

decrease in the local species richness (Estrada et al. 1993; Lumsden 1995; Pedro 1998). However, in all studies the responses of bats to fragmentation were variable among species. This suggests that particular life-history traits may make some bats more tolerant to the effects of fragmentation than others. This variation in response to fragmentation among tropical forest species is also well documented for birds, mammals, ants and frogs (Gascon et al. 1999). For bats, Cosson et al. (1999) suggested that, in a flooded landscape, frugivorous species such as *A. obscurus*, characterized by large body sizes, high abundance in mainland forests and canopy foraging habits were less sensitive to fragmentation, while *R. pumilio* and other small, understory frugivorous bats were less tolerant to habitat reduction and isolation of remnant patches. This observation is the opposite to that of the Una region. I found that *A. obscurus* was sensitive to fragmentation while both *R. pumilio* and *C. perspicillata* showed no differences in the use of fragments and controls. It is widely known that the nature of the surrounding matrix strongly influences the response of many species in fragmented landscapes, such as invertebrates (Webb et al. 1984; Didham et al. 1998), birds (Bierregaard & Lovejoy 1989) and mammals (Laurance 1991; Malcolm 1997; Gascon et al. 1999), including bats (Estrada et al. 1993; Cosson et al. 1999). In contrast to islands, that represent true habitat isolates, the matrix of early secondary growth surrounding the forest patches in Una landscape provides physical connectivity among patches. Both understory frugivorous species, *C. perspicillata* and *R. pumilio*, were also very abundant in these early secondary growth forests, suggesting that for these species fragments and continuous forests are truly connected.

However, the use of secondary forests applies for only a limited number of bats, as this matrix was shown to be less permeable to most of the forest dwelling species of primary forests, particularly Phyllostominae bats. The extremely low capture frequency of *A. obscurus* in the matrix also indicates that these early secondary forests are not frequently used by this frugivorous species. In this case, the primary forest patches are separated by a matrix of inhospitable habitats. But given the short distance among the primary forest patches in Una, hardly exceeding the potential flight distance that the large bodied *A. obscurus* is capable of performing, it is unlikely that this species is affected by the isolation of patches. Therefore, even fragments separated by secondary vegetation are likely to represent accessible habitats for *A. obscurus*. The lower frequency with which this species is using fragments may be related to the availability of food resources. As a fig specialist (Bonnacorso 1979), this canopy frugivore must be able to perform long distance flights to explore a large forest area searching for these sparse, low density tree

species that may be found patchily distributed over a landscape scale (Morrison 1978; Fleming & Heithaus 1981; Bonnacorso & Gush 1987). It is possible that the small size of the fragments in the Una landscape translates into a smaller probability of encountering fig trees compared with continuous forests, making fragments a lower quality habitat in terms of fig tree availability.

For the remaining species not found in the secondary forests, but present in both fragments and continuous forests, the short distance among different forest patches may allow species to move among forest patches. The greatest distance between two forest patches, both continuous and fragments, was only 480 m, which is a short distance for most bats. In other studies dealing with bats, isolation among forest patches seems to be a key factor determining the species richness in fragments (Estrada et al. 1993). The ability of most bats to freely move among patches across the landscape may also explain their apparent tolerance to forest reduction (Lumsden et al. 1995).

Although most of the forest matrix in the Una landscape is composed of secondary forest, other man-made habitats may also be used by bats as foraging areas, corridors or as stepping stones thus increasing not only the potential of bats to move between the habitats, but also as serving as additional foraging sites (Chapter 1). For instance, shade cacao plantations that made up nearly 6% of the total surface area of the three sampling blocks in Una region, is known to harbor rich and abundant bat assemblages (Chapter 4), which has also been observed in other areas (Estrada et al. 1993; Cosson et al. 1999; Medellín et al. 2000). Thus, a combination of the bat ability to fly and explore different habitats, the short distance among forest patches and the presence of habitats in the matrix of Una which might be used by bats probably mitigates the negative effect of the direct reduction and physical isolation of primary forest.

The most evident effect of fragmentation upon bat communities in the Una landscape is the establishment of edges. Although the mean species richness on each edge transect was the same as in interiors, edges are habitats with significantly lower beta-diversity than interiors of forests, with a poorer species pool compared with interior habitats. These marginal portions of primary forest stands proved to be used only by a limited subset of the species found in forest interiors. Edge-induced changes in remnants are among the underlying processes of fragmentation (Murcia 1995). It is widely known that edges considerably affect forest fragments, triggering changes in microclimate (Kapos 1989; Williams-Linera 1990), forest structure (Williams-Linera 1990; Malcolm 1994; Laurance et al. 2001), tree dynamics (Laurance et al. 1998) and seedling recruitment (Benitez-Malvido

1998). Many studies have shown that edges strongly influence community structure, as was demonstrated for beetles (Klein 1989; Didham et al. 1998; Davies et al. 2001), butterflies (Brown & Hutchings 1997), birds (Restrepo & Gómez 1998), terrestrial small mammals (Malcolm 1991; Pardini 2001). However, this is the first study showing that Neotropical bats, particularly the gleaning Phyllostominae, are negatively affected by edges.

Because of the non-linear relationship between perimeter and area and because edge effects are additive (Malcolm 1994), small fragments suffer stronger edge effects than larger remnants. Thus, it is possible that small or irregularly shaped fragments may fail to provide enough core areas to support forest dwelling species. This edge effect may be a powerful force reducing Phyllostominae populations (or minimizing their movements), especially in Una, where 35% of the forest is less than 75 m from the nearest edge, due to the shrinking of the forest remnants in this region.

FOREST STRUCTURE AND DISTURBANCE AS PREDICTORS OF BAT ATTRIBUTES

A large number of studies have demonstrated that Neotropical bats, particularly the Phyllostominae, are sensitive to habitat modification. Species richness, abundance and diversity tend to be reduced in disturbed areas (Johns et al. 1985; Fenton et al. 1992; Wilson et al. 1996; Kalko et al. 1999), attributable to gradients of forest disturbance (Medellín et al. 2000). Perturbations, however, have not been directly associated with any particular, or even a subset, of forest descriptors that, as a consequence, would provide direct clues for understanding the causes of this decrease.

Fragmentation and forest regeneration in Una region have led to several modifications in the original forest structure. Modified habitats such as edges and early secondary forests show a decrease in the density of large trees and the upper foliage strata, following an increase of the foliage density in the understory (1–5 m) relative to interiors. This latter structural change is of particular interest as all bats on the present study were actually sampled in this forest stratum, for mist nets cover a height of 1-3 meters. My results showed that, in the Una landscape, inverse and significant relationships were found between the bat community attributes and this gradient of forest disturbance. Among the dominant species, only *C. perspicillata* was not related to these modifications, whereas the frugivorous *R. pumilio* and *A. obscurus* were less frequent in disturbed areas.

In the Una region, Phyllostominae bats were almost completely restricted to the interior of forests. Although some species are known to include fruits and nectar in their

diet on a regular basis, most gleaning bats largely prey on arthropods. Larger species may also include small vertebrates in their diet. Given the fact that some species depend on specific roosts such as hollow trees and termite nests, the degree of diet and roost specialization are two frequent explanations for the tight association of Phyllostominae bats with more preserved forests (Belwood 1998; Fenton et al. 1992).

I have found no evidence that prey abundance is a factor limiting the presence of these gleaning bats in undisturbed forests in the Una landscape. If beetle abundance correlates with other arthropods also taken as prey by the gleaning insectivorous, the results from my study suggest that more disturbed areas tend to have greater prey density for these bats. Habitat complexity, measured as the development of vertical stratification such as foliage density, is often positively correlated with arthropod abundance and diversity (Didham et al. 1998), specially in the forest understory (Malcolm, 1997), which was the stratum best developed on edges and in capoeiras. On the other hand, the higher densities of large trees reported on interiors of forest possibly translate to an increased availability of roost sites such as hollow trees. This could help explain the close association of these bats with forest interiors. Radio-tracking studies have shown that some Phyllostominae species such as *Tonatia silvicola* and *Trachops cirrhosus* show small foraging areas and commuting distance varying from 200 m up to 1.5 km (Kalko et al. 1999). However, even the shortest distances are within the range between the roost sites on interiors of forests and other transects on edges or in capoeiras, that are usually located contiguous to interior forests in Una. It is possible for a bat to roost in the interior of a forest in Una and to commute to foraging areas on edges and capoeiras which, as demonstrated here, may represent areas with higher densities of food prey. Therefore, it is unlikely that edges and secondary forests are out of reach for bats roosting in interiors of forests in Una landscape.

Aside from possible roost and food limitations, my results suggest that the foliage density of forest understory is an important factor influencing the positive association of Phyllostominae bats to less disturbed forests. This bat response may be related to bats' locomotory abilities. Bats are constrained in the use of habitat by different textures of the foraging space. Structurally complex habitats such as forests may also be translated on an increase of obstacles, such as tree trunks, branches, stems and foliage, that bats must detect and avoid when flying. The amount of physical obstacles present in each habitat may strongly influence in the bat foraging behaviour, complicating food detection and pursuit (Fenton 1990; Schnitzler & Kalko 1998). Most of the Phyllostomidae bats,

including the insectivorous gleaners, show both morphological and sensorial adaptations that enable them to explore structurally complex habitats, as they are adapted to foraging within vegetation, such as the dense strata of tropical forests (Fenton 1990). However, there might be an upper limit for vegetation density above which even bats well suited for flying in crowded conditions might find vegetation too thick to perform maneuverable flights, and thus experience difficulties for food detection. Crome and Richards (1988) showed that even insectivorous microchiropterans classified as closed canopy specialists, that were well adapted to perform flights in complex microhabitats in Australian rainforest, were not observed in old gaps. They suggested that this was probably due to the fact that the early successional habitats had a dense vegetation layer at 3-4m high and was probably too dense to allow movements even for these dense-vegetation specialists. Similarly, it is possible that the higher densities of foliage in the forest understory (1-5 m) of edges and capoeiras may impose difficulties for foraging bats in Una region. Autoecological research on the Phyllostomine *Tonatia silvicola* pointed out that it seems to forage in areas of tall secondary forest, but with little understory (Kalko et al. 1999).

For bats that use echolocation as a foraging tool, dense vegetation can further complicate the detection, classification and location of food. This is because echoes from the prey can be masked by the dense background (Schnitzler & Kalko, 1998), although recent studies have demonstrated that Phyllostomidae often use additional sensory cues such as olfaction and passive hearing (Kalko 1995). It may also be important to consider different hunting strategies among the Phyllostominae species that may lessen the restrictions imposed by density of vegetation on prey location and capture. For instance, the small gleaning bat, *Tonatia silvicola*, relies on the hang-and-wait hunt strategy, where bats hang on the perch and capture prey during short sally flights, immediately coming back to the perch to process the prey (Kalko et al. 1999). Bats that use this foraging strategy may need very little open space to perform short flights, and may not need to be highly maneuverable to forage. These bats still must fly within thick vegetation to commute from the roost to feeding areas, however.

These limitations can also hold true for at least the two dominant frugivorous species, *R. pumilio* and *A. obscurus*, that were also responding predictably to a vegetation density gradient. It is also possible that the clutter level of forest understory is correlated with other important features not measured directly in the present study, but that strongly determine bat response to disturbance. Because basic information concerning roost, diet

and other important aspects of the ecology and natural history of most bat species is not known, it is difficult to explain this correlation.

IMPLICATIONS FOR CONSERVATION

In Una landscape, small fragments are key elements for any conservation strategy designed for bats. Although the larger forest patches in Una may provide the source for most bat populations, small fragments maintain, in their current state, practically the same group of species found in the largest remnant. The fact that the largest tracts in the whole Una region fall into the range size of patches investigated in the present study, makes this finding particularly important. The biological value of fragments may be largely determined by certain features of the local landscape, or by the species' abilities to cross and venture out into modified habitats. The nature of the surrounding matrix, mainly comprising secondary forests, provided connectivity for at least a fraction of the bat species. The small distance among forest patches is also a key factor influencing the maintenance of high levels of species richness in fragments. Therefore, the maintenance of a rich bat assemblage in the Una forest remnants may rely not only on the total amount of primary forest left, but also on these particular features of the local landscape that should be kept. Given the ability of bats to use multiple habitats, rather than patches and continuous forests, it appears that the whole landscape should be the unit of management considered hereafter (Law & Dickman 1998).

Bats as a group were strongly influenced by overall modifications on the forest structure. The restriction of Phyllostominae bats to little disturbed sites such as forest interiors make them specially vulnerable to increasing forest fragmentation, regeneration and further forest modifications. The growing pace of deforestation in the Una landscape, specially with the expansion of pastures and coffee, imposes serious threats for the local biota most confined to forest interiors, including the Phyllostominae bats. Monitoring certain populations should be a first step recommended in order to prevent decrease or disappearance of these species, that deserve particular conservation attention.

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CAPÍTULO 4

O PAPEL POTENCIAL DAS PLANTAÇÕES SOMBREADAS DE CACAU (*Theobroma cacao*) PARA A CONSERVAÇÃO DE MORCEGOS NO SUDESTE DA BAHIA, BRASIL

RESUMO

Plantações de cacau sombreado, ou cabruças, formam um importante componente do que resta da Mata Atlântica do nordeste brasileiro, representando cerca de 40% da cobertura florestal remanescente no estado da Bahia. Tem sido proposto que tais plantações sombreadas, serviriam como ambientes florestais para muitas espécies, embora poucos estudos tenham mostrado o quão dependentes estes sistemas são da proximidade de florestas nativas. Eu investiguei o papel potencial deste sistema de plantio sombreado como hábitat para a fauna de morcegos na região sul da Bahia, estabelecendo a influência da floresta neste sistema. Eu também analisei se as modificações na estrutura da floresta nos sistemas de cabruca poderiam servir de preditores para a resposta das comunidades de morcegos. Através do método de amostragem por redes de neblina, comparei os parâmetros de comunidade (riqueza, abundância e diversidade) em floresta nativa e plantações sombreadas localizadas em duas regiões com diferentes paisagens, variando no total de floresta nativa disponível. As cabruças adjacentes a florestas primárias revelaram uma rica e abundante comunidade de morcegos, com amostras contendo taxas de captura, riqueza, diversidade e equitabilidade significativamente maiores que os valores encontrados para florestas primárias. Este panorama é alterado quando as plantações são imersas em uma matriz com florestas mais distantes (> 5.000 m). As amostras das comunidades de morcegos nas cabruças isoladas são menos diversas do que em florestas e cabruças próximas às matas, mas os dois tipos de cabruças ainda comportam espécies associadas a habitats prístinos. Características da estrutura da floresta, particularmente a densidade da folhagem do estrato de subosque (1-2 m) e subdossel (5-10 m), são importantes modificações estruturais determinando a resposta destes animais alados a este tipo de uso da terra. Os resultados encontrados aqui têm importantes implicações práticas para a conservação de morcegos em uma escala regional.

Palavras-chave: morcegos, cabruças, Mata Atlântica, conservação, estrutura de comunidades

**THE POTENTIAL ROLE OF SHADE CACAO PLANTATIONS
(*Theobroma cacao*) FOR BAT CONSERVATION IN SOUTHERN BAHIA,
BRAZIL**

ABSTRACT

Shade cacao plantations are important components of what is left of the Atlantic rainforest in Northeastern Brazil, comprising nearly 40% of the forest cover in the state of Bahia. It has been proposed that these traditional shade plantations, locally known as cabruças, would serve as habitat surrogates for many forest dwelling species, though a few studies have shown how dependent these habitats are to nearby forest remnants. Here I investigated the potential role of this traditional crop for support of bat assemblages in southern Bahia, establishing the extent to which the bat community structure found in this agricultural system is influenced by the proximity of forest tracts. I also investigated whether the modifications of forest structural features in cabruças could predict the response of bats. Using mist nets, I compared the bat community attributes (richness, abundance, diversity) on native forest tracts and shade cacao plantations located in two distinct landscapes varying in the total amount and proximity of forest tracts. Cabruças contiguous to forest tracts showed a rich and abundant bat community, with samples showing capture rates, species richness, diversity and evenness significantly higher than those reported for primary forest tracts. This situation changes, however, when shade plantations are located at some distance from forest tracts (> 5,000 m). Bat communities in isolated cabruças are less diverse than those found in forests and nearby cabruças, but both cabruças still include species usually associated with pristine habitats. Features of forest structure, particularly the foliage density of understory (1-2 m) and overstory (5-10 m), are important structural modifications determining the response of these flying animals to this land use. The results achieved here have important practical implications for bat conservation on a regional scale.

Keywords: Bats, shade cacao, Atlantic Forest, conservation, community structure

INTRODUCTION

The increasing pace of forest reduction worldwide is a subject of major concern, especially on the biologically rich tropical regions that have suffered a severe process of forest conversion (Myers 1980). Except for the extensive area covered by the Amazon forests most tropical remnants are currently represented by small, scattered patches immersed on a matrix of man-made habitats (Shafer 1990; Camara 1991).

Most of the conservation effort worldwide is driven to preserve these forest relics by proposing or actually setting them aside as conservation units, although the pristine, relatively continuous and intact areas comprise a quite small portion of the total land surface. Considering that a great amount of the native biota can also thrive in managed systems, it seems promising to conceive how these habitats could be actually incorporated on a broader conservation scheme, as they represent nowadays roughly 95% of the terrestrial environment (Western & Pearl 1989; Pimentel et al. 1992; Perfecto et al. 1996). Some agroecosystems are particularly more prone to harbor a diverse biota, as they are typically characterized by a high diversity of vegetation and are of paramount importance as cash crops in some tropical countries (Pimentel et al. 1992; Power & Flecker 1998; Rice & Greenberg 2000). One of these traditional systems that is grown successfully in the tropics is the shade cacao plantation (*Theobroma cacao*). As a native forest crop of the Amazonian basin (Young 1994), this understory species has been planted in many tropical areas, mostly in a traditional system where the forest understory is replaced by the cacao shrubs and the canopy layer is thinned with a few individuals left to provide shade.

In the Southern State of Bahia, Brazil, lies the core region of the national cocoa production, placing the country amongst the major producers in the world for decades (Alvim & Rosário 1972). Roughly 10% of the global area of cocoa harvesting (FAO 1996) and 20% of the world's production (Alger & Caldas 1996) comes from Brazil. Although cacao is also planted following the total removal of the native forest, the traditional system of growing the cacao under the native canopy is locally known as *cabruças*, and represents more than 65% of the total area covered by cacao plantations (Alger & Caldas 1996; May & Rocha 1996).

The *cabruças* have been serving as a major barrier to deforestation and timber trade in Southern Bahia, and might explain the fact that this region harbors the last remnants of what is left from the Atlantic forest in northeastern Brazil (Alves 1990). As happened with the remaining Atlantic forest, most of the forest tracts left are represented

by small, scattered and often disturbed forests, but the bulk of the green tapestry visualized by aerial photographs in southern Bahia is, in fact, a mosaic of secondary forests and areas of cabruças. More than 330.000 ha, roughly 40% of the remaining Atlantic forest in Southern Bahia is covered by cabruças, while native forests comprise only a third of this area (May & Rocha 1996). Considering this important regional representation of cabruças, it is unlikely that any conservation strategy designed to conserve these forests relics will succeed unless it takes into account the importance of these managed areas on a regional scale.

Despite their general similarity to an original forest, the cabruças are highly disturbed systems, resulting in a severe reduction of the plant species composition, with the removal of 90% and 100% of the native canopy trees and understory layers, respectively (Mori et al. 1983; Alves 1990). Yet, by providing a structurally simpler, though still stratified forest, the cabruças are used as habitat by many forest dwelling species, including the recently described bird, the Pink-legged Gravateiro (*Acrobatomis fonsecai*), the endangered Golden-headed Lion Tamarin (*Leontopithecus chrysomelas*) and the Yellow Capuchin (*Cebus apella xanthosternos*) (Dietz et al. 1996; Pacheco et al. 1996). No other agricultural activity carried out in Southern Bahia shows this high potential to serve as habitat surrogate, forest corridors, stepping stones and buffers that might be important for mitigating the negative effect of forest reduction and isolation (Alves 1990).

Hence, an ambitious national plan to set up a biological corridor stretching across the cacao region has been proposed by the Brazilian government (G7 Pilot Program 1997). In this scenario, cabruças will be of paramount importance as, in some areas, they may represent not only the sole possible links between forest patches but also the only sort of forested habitat available.

Even considering that shade cacao plantations in many tropical countries can harbor many forest-dwelling species, sometimes reaching levels of animal species richness that even rival those of native forests (Room 1971; Majer 1978; Power & Flecker 1998; Argolo 2001; Dixo 2001), it appears that a major challenge for any conservation strategy encompassing the cabruças is to understand to what extent this managed system can hold the original biota. For instance, it has been demonstrated that the proximity of forest patches strongly influences the local diversity of cabruças, suggesting that some species are able to use them only in a limited way such as secondary habitats or population sinks, yet such knowledge is available for only a limited number of species

(Alves 1990; Estrada et al. 1993a, 1993b, 1994; Dietz et al. 1996; Parrish et al. 1998; Rice & Greenberg 2000).

Comprising almost one-third of the Brazilian land mammal fauna (Marinho-Filho & Sazima 1998), bats are a biological group closely associated with forest tracts (Fenton et al. 1992). They play an important role for the functionality of tropical systems, and are thought to respond predictably to gradients of forest disturbance (Medellín et al. 2000). In the present study my goals were two-fold. First, I proposed to investigate how the cabruças in Southern Bahia can support the local bat assemblages, and whether these local communities may be influenced by the proximity of large forest tracts. Secondly, I searched for potential ecological predictors that might be underlying the response of these bat assemblages. As a major concern of conservation lies on those species mostly associated with less disturbed forests, I particularly focused on the response of the Phyllostominae bats to the cabruças, as most species are regarded as restricted to pristine and low disturbed forests and should be seen as the most vulnerable species (Fenton et al. 1992; Johns et al. 1985).

To accomplish these goals, I compared these bat communities in 32 sites located in forests and cabruças localized in two regions characterized by distinct landscape context. I also assessed the vegetation structure in forests and cabruças to verify the major structural changes in this managed habitat; and investigated the existence of potential associations between these features and bat response. As all Phyllostominae bats include arthropods in their diets on a regular basis, I also assessed the abundance of potential prey items in the study areas as a potential explanatory variable for these vulnerable species.

METHODS

♦ STUDY AREA

The cacao region of Bahia state, Brazil, lies in the southern region between 41°30'W and 18°15'S coordinates, comprising an area of roughly 91,819km² (Mori & Silva, 1979). The vegetation follows altitudinal and topographic variations. Following the classification proposed by Gouvêa et al. (1976), southern Bahia has two different physiognomies, the hygrophyllic or wet forest near the coast, where sandy soils predominates, and the mesophytic vegetation occurring in more inland regions and on richer soils. The mean annual temperature is 24°C and the rainfall averages 1,500

mm/year, with no identified seasonality, though a rainless period of 1-3 months may occur from December to March (Mori et al. 1983).

◆ SITES SELECTION

The present study was carried out in two regions located in the southern State of Bahia, Brazil, which harbors distinct proportions of shade cacao and native forest tracts. The first region comprises the core zone of cocoa production in the Bahia State, located along the road linking Ilhéus and Itabuna municipalities (Figure 1.1b). Cocoa farms highly predominate on the landscape, and the remaining forest is mostly represented by limited stands inside a “sea of cabruças” (Figure 1.1b). Alger (1998) stated that, by the mid 1980's, the average farm with over 1,000 ha had retained roughly 30% of the original forest. However, most of these native stands are usually limited on hilltops, on low productive soils or areas at some distance from roads, and the bulk of the forest matrix comprises shade cacao plantations under the cabruca system (May & Rocha 1996). In this area I selected two sites of cabruças to sample bats. Both sites were located on properties that formed a continuous area of cabruca, with few and small forest patches, usually less than < 60 ha, scattered and immersed on this cabruca matrix. These sites were at some distance to forest patches (> 5,000 m), and herein I will refer to these sites as the isolated cabruças.

The second region selected was located around Una municipality, about 10km west from the ocean, where the largest native forest remnants are actually concentrated. The predominant poor sandy soils of Una region imposed limitations on the establishment of large plantations, which is the key factor explaining why the forest remnants are mostly located along this coastal zone. The cabruças of Una are usually small, concentrated along river valleys and small plots of relatively better soils. A detailed study on the landscape mosaic at Una region revealed that from an area of 14,300 ha that was analyzed, 50% were dominated by primary forests wherer cabruças comprised only 6% (see Chapter I). These shade plantations ranged in size from 17 up to 270 ha, and were always located close or even adjacent to forest patches, resulting in a mosaic of small scattered cabruças embraced by the surrounding rain forest stands varying in size and succession stages. In 1990, the Una Biological Reserve was established and effectively protects 7,022 ha, though at least other 14,216 ha of private owned forests were somehow contiguous with the reserve, including some private reserved (Araujo et al. 1988). In this region around the Una Biological Reserve, I chose 24 sites on remnants of mature, tall

forests ranging from 100 to more than 1,000 ha, and 6 sites of shade cocoa farming contiguous to forests, ranging from 17 up to 250 ha, which I called cabruças of Una (Figure 1.3).

◆ BAT SAMPLING

I sampled bats by setting up mist nets in each site along a 100 meter transect. On each sampling night I used three nine meter, three six meter and two twelve meter long mist nets, totaling 69 meters of net that remained open for 5 hours after sunset each night. Nets were checked every half hour and bats were caught and kept inside cloth bags until the end of the night. Before releasing the bats, I took measurements such as weight and forearm length, identified each individual and collected feces when present. Bats were assigned in each one of the following feeding guilds based on the predominant class of dietary items: frugivorous, nectarivorous, hematophagous, aerial and gleaning insectivorous. The latter class comprised all the bats from the subfamily Phyllostominae, as they glean arthropods from surfaces, though some species may also take small vertebrates, fruits and nectar. This classification relied on the feces analysis carried out in the laboratory and on available data in the current literature (Gardner 1977; Humphrey et al. 1983; Aguiar 1994; Faria 1996; Kalko 1996; Fenton et al. 1999).

For the Una region, each of the 30 sites was equally sampled during four non-consecutive nights, resulting in 96 nights in forests and 24 in cabruças of the Una region. Sites located in isolated cabruças were sampled two and five nights, resulting in only seven nights of sampling.

◆ VEGETATION STRUCTURE SAMPLING

I took advantage of the data collection of the RestaUna Project (Projeto RestaUna, *in press*), where the vegetation structure was assessed on transects located in the Una region, for forests and cabruças. Although I did not measure directly the vegetation structure of the isolated cabruças transects, given the fact that the forest modification in this managed system occurs in a predictable way, I assumed a similar pattern between the two areas of cabruças.

The vegetation structure of forest and cabruças the in Una region was assessed along the 30 transects by measuring the foliage density, following Malcolm (1995). Using a 3m pole to allow a vertical sighting, the intervals occupied by foliage (e.g. estimation of the foliage hitting this imaginary vertical line) were recorded for each forest vertical

stratum: 0-1m; 1-2m; 2-3m; 3-4m; 4-5m; 5-10m; 10-15m; 15-20m; 20-25m; 25-30m and 30-35m height (Figure 2.1). These measurements were taken in twelve points regularly spaced along each sampling transect, the raw data for each transect used on the analysis were the resulting mean values of foliage density in each forest stratum.

♦ ARTHROPOD ABUNDANCE

I measured the insect abundance available for gleaning insectivorous bats, here encompassing all the Phyllostominae species. As these bats glean arthropod prey from surfaces such as the ground, branches, trunks or foliage, an alternative method to sample arthropods from the forest understory was used in this study (Davies 1986). The insects were collected using a wooden cross-shaped structure, covered with white cotton cloth to see the biological material. This structure is used as a tray which is placed under a branch or small bushes of the forest understory, which are beaten with a small wooden stake. All the fallen arthropods are collected and fixed in ethanol 70% for later identification. Along each of the 36 transects, 20 branches were randomly selected for arthropod sampling. I selected the data concerning only beetles as they are thought to be one of the main food sources for insectivorous Phyllostominae (Humphrey et al. 1983; Fenton et al. 1999) and also because I could count on a reasonable sample for statistical tests, as beetles were abundant and widespread in the present study. I used the total captures of beetles for each transect as replicates for each forest category. All the sampling were carried out by the RestaUna team. A more detailed description of the method and general results can be found elsewhere (Brescovit et al. *in press*).

♦ DATA ANALYSIS

For all the statistical analyses I used nights as samples, so the raw data were species richness and capture frequency actually observed in each sampling night, with 96 observations for forests, 24 for cabruças at Una and 7 for isolated cabruças. Therefore, the sampling effort was not equally distributed among the three treatments, as it was greater in forest tracts and cabruças in Una than for the isolated cabruças. These unbalanced experiments impose serious difficulties for univariate statistical tests; among other things they can strongly affect the probabilities of error type I (Underwood 1998). I therefore relied on a randomization procedure in which I compared the mean species richness and capture frequency observed from the seven night sampling in the isolated cabruças with a frequency of these parameters obtained by randomly reordering the

original data from the sites of forests and the cabruças of Una. These distributions were calculated from 1,000 permutations from which the program (SAS 1998) randomly selected subsamples of 7 nights resulting in 1,000 new mean values of species richness and total values of capture frequency for each treatment. I then verified how the values actually obtained from the seven night sampling of isolated cabruças differed from the other two treatments by considering the significance level as the percentage of values that were extreme or more in the randomized frequency distribution curves (Manly 1991). For comparisons between the forests and cabruças at Una region I carried out a one-way ANOVA on the randomized results for each subsample.

To verify the existence of associations between bat composition and vegetation structure I used the Mantel (1967) test by first calculating two dissimilarity matrices, one between all pairs of transects in terms of bat composition and the other for the vegetation structure data (vertical stratification), using the Bray-Curtis index. After 10,000 Monte Carlo permutations a correlation between the two matrices was calculated with a significant level of 0,05. Simple linear regression analysis was used to investigate potential associations of forest structure and bat attributes. As all forest descriptors were highly correlated, I derived two orthogonal axes from a Principal Component Analysis (PCA), used as independent variables to predict bat response. The PCA was calculated using a correlation matrix, following further default criteria (Kovach 1999). The diversity indices used here were the Shannon-Wiener diversity index (H_2') and the Pielou index of evenness (H'/H_{max}).

RESULTS

BAT COMMUNITIES

I recorded 45 species of bats, with the 2,883 captures in all three habitats (Table 4.1). The bulk of the bat species and captures were dramatically skewed towards the neotropical family Phyllostomidae, representing roughly 99% of all captures and 39 species. Three frugivorous species accounted for nearly 75% of all bat captures, with the most frequent being *Carollia perspicilata*, *Rhinophylla pumilio* and *Artibeus obscurus*. In contrast, uncommon and rare species (< 10 captures) made up the bulk of the species reported. Phyllostominae bats were also present in all three treatments; from a total of 16 species, 14 can be considered rare as they were represented by less than 10 captures.

SPECIES RICHNESS AND CAPTURE FREQUENCY

There were significant differences in the mean species richness and capture frequency among samples from the three treatments. Comparisons between forests and cabruacas in the Una region revealed that, while forest sites were four times more intensively sampled than cabruacas, they accounted for 1,100 captures and 29 bat species, which is less than the 39 species with 1,314 captures reported for the cabruacas (Table 4.1). In fact, 100% of the mean species richness and capture frequencies (Figure 4.1a) of samples obtained by the randomization procedure for the forest sites were lower than those from the distribution of the mean values found for cabruacas. This result clearly shows that samples from the latter habitat are significantly richer and more abundant (Figure 4.1b) in bats than those from primary forest patches.

Isolated cabruacas also showed higher mean capture frequency compared with forest tracts, though this value was similar to those reported to cabruacas from Una (Figure 4.1b). On the other hand, results of species richness from isolated cabruacas contrasted sharply from those obtained for cabruacas close to forests. (Figure 4.1a). Although samples from isolated cabruacas showed more bat species than those taken from primary forests, 99.6% of mean species richness values obtained for cabruacas in Una were higher than those from isolated cabruacas.

SPECIES DIVERSITY AND EVENNESS

Species diversity, measured by H' , was highest for the cabruças in Una ($H' = 3.38$), intermediate in forests ($H' = 2.32$) and lowest in the isolated cabruças ($H' = 1.44$). The evenness component of species diversity revealed that individuals were more equally distributed on the cabruças ($H'/H_{\max} = 0.63$) and forests ($H'/H_{\max} = 0.47$) of Una, but the isolated cabruças showed a clear dominance of a single species ($H'/H_{\max} = 0.31$). This latter habitat type was clearly dominated by a single species (*C. perspicillata*, representing roughly 80% of all captures). Conversely, the most frequent species in forests and in cabruças of Una accounted for 35 and 37% of the total captures, respectively.

The dominance pattern of common forest species was reflected in the nearby cabruças (Figure 4.2). The three most frequent species found on forests in Una, *R. pumilio*, *C. perspicillata* and *A. obscurus*, were also the three dominant species on nearby cabruças. On the other hand, isolated cabruças were totally dominated by *C. perspicillata*, while *R. pumilio* and *A. obscurus* were among the rare species. In fact, there were significant changes in the capture frequency of the three most common forest species on both cabruças. The randomized distributions showed that capture frequency of all the three dominant forest species increased significantly in nearby cabruças. *Carollia perspicillata* were particularly more frequent on isolated cabruças, while *R. pumilio* and *A. obscurus* were seldom observed in samples from these habitats (Figure 4.3).

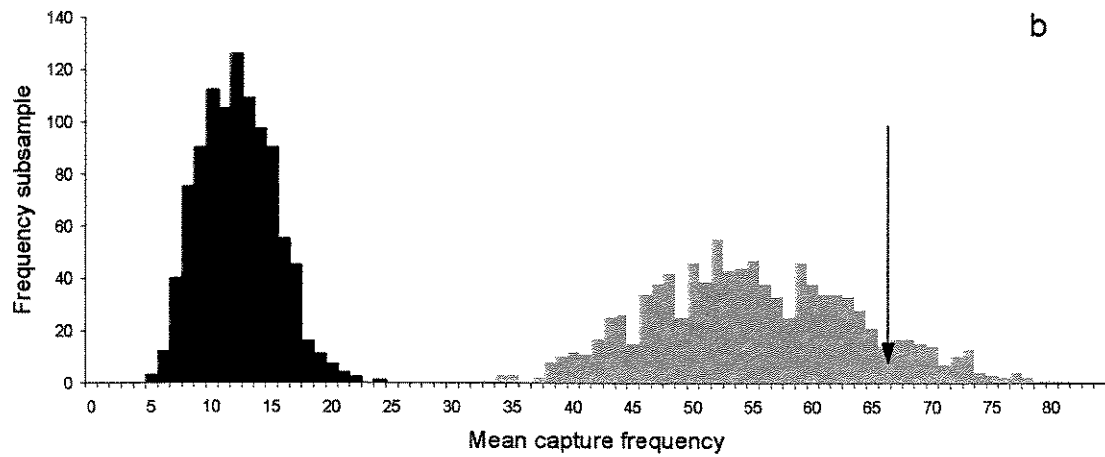
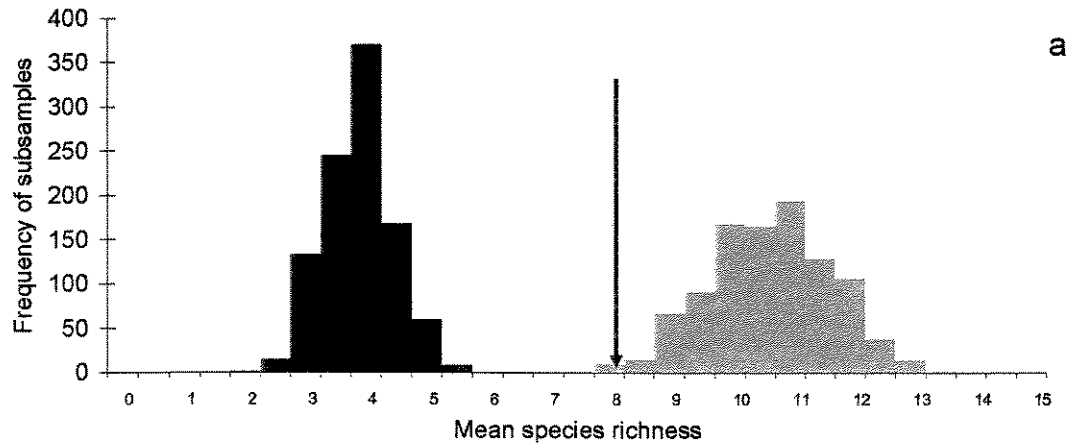


Figure 4.1. Distribution of species richness (a) and capture frequency (b) for 1,000 random seven-night samples taken from all night samples from forest (dark shade bars) and cabruca (light shade bars) sites in Una region. Arrows indicated mean of variables reported for isolated cabruca. Species Richness: cabruca from Una > Isolated cabruca > forest sites; Capture frequency: Isolated cabruca > cabruca from Una = forest sites.

Table 4.1. Capture frequency of bats in three habitat types in southern Bahia, Brazil.

Bat Species	Primary	Cabucas	Isolated
<i>Anoura caudifer</i>	0	0	1
<i>Anoura geoffroyi</i>	0	3	0
<i>Artibeus cinereus</i>	49	47	12
<i>Artibeus fimbriatus</i>	1	4	1
<i>Artibeus gnomus</i>	6	8	3
<i>Artibeus jamaicensis</i>	7	22	1
<i>Artibeus lituratus</i>	32	38	4
<i>Artibeus obscurus</i>	139	150	1
<i>Carollia brevicauda</i>	12	14	1
<i>Carollia perspicillata</i>	391	464	376
<i>Chiroderma villosum</i>	3	5	1
<i>Choeroniscus minor</i>	0	2	1
<i>Chrotopterus auritus</i> *	1	1	0
<i>Desmodus rotundus</i>	1	9	1
<i>Epitesicus brasiliensis</i>	1	1	0
<i>Glossophaga soricina</i>	5	27	27
<i>Lamproncyteris brachyotis</i> *	0	1	0
<i>Lonchophylla mordax</i>	5	8	0
<i>Micronycteris schmidtorum</i> *	1	1	0
<i>Micronycteris hirsuta</i> *	2	2	0
<i>Micronycteris microtis</i> *	2	0	0
<i>Mimon crenulatum</i> *	0	7	4
<i>Molossops planirostris</i>	0	1	0
<i>Myotis nigricans</i>	13	4	2
<i>Myotis</i> sp1	0	0	1
<i>Phylloderma stenops</i> *	0	2	0
<i>Phyllostomus discolor</i> *	0	85	2
<i>Phyllostomus elongatus</i> *	2	0	1
<i>Phyllostomus hastatus</i> *	0	10	0
<i>Platyrrhinus lineatus</i>	0	15	4
<i>Platyrrhinus recifinus</i>	2	21	2
<i>Rhinophylla pumilio</i>	413	199	10
<i>Saccopteryx bilineata</i>	2	2	2
<i>Sturnira lilium</i>	4	61	1
<i>Sturnira tildae</i>	0	8	0
<i>Thyroptera tricolor</i>	0	1	0
<i>Tonatia brasiliense</i> *	1	8	0
<i>Tonatia saurophila</i> *	1	0	0
<i>Tonatia silvicola</i> *	1	1	0
<i>Tonatia</i> sp1 *	0	2	0
<i>Trachops cirrhosus</i> *	1	2	6
<i>Trinycteris nicefori</i> *	0	7	0
<i>Uroderma bilobatum</i>	1	68	5
<i>Vampyressa pusilla</i>	0	3	0
<i>Vampyrodes caraccioli</i>	1	0	0
TOTAL OF SPECIES	29	39	25

* Phyllostominae

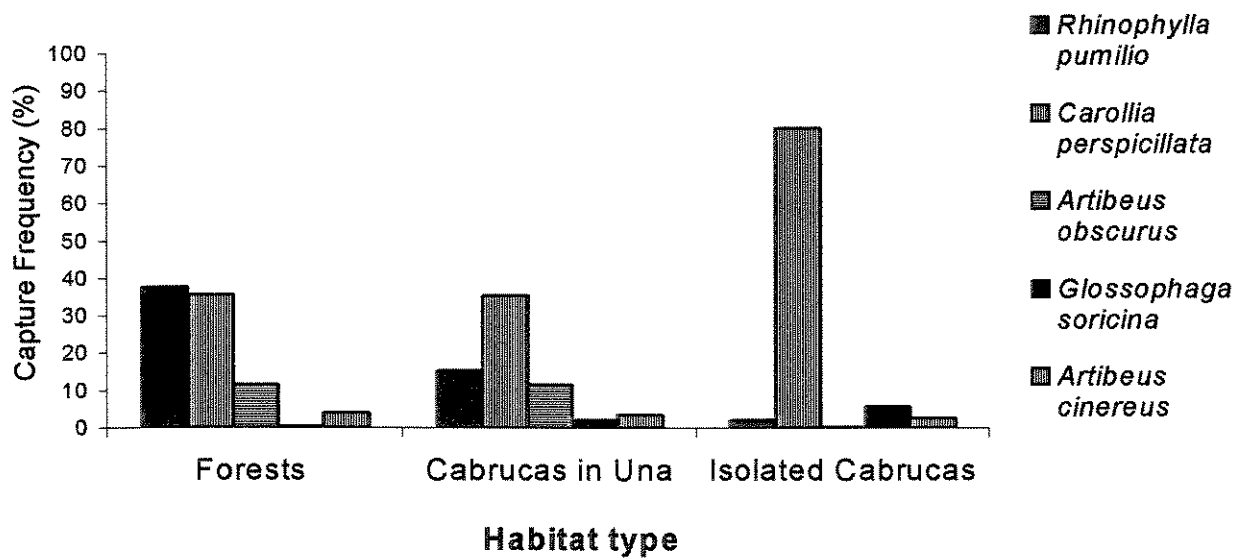


Figure 4.2. Proportional representation of the most frequent species reported on forest sites in Una and in the two types of cabruças in southern Bahia, Brazil. In each habitat type, species are shown following the same sequence: *R. pumilio*, *Carollia perspicillata*, *Artibeus obscurus*, *Glossophaga soricina* and *Artibeus cinereus*.

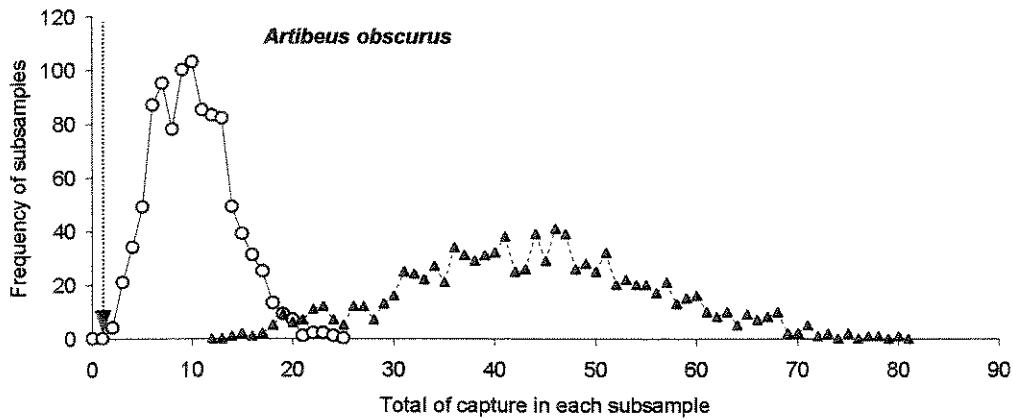
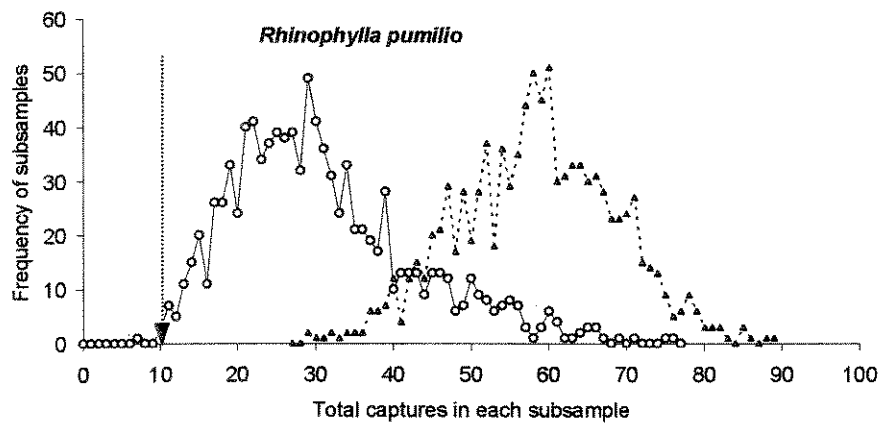
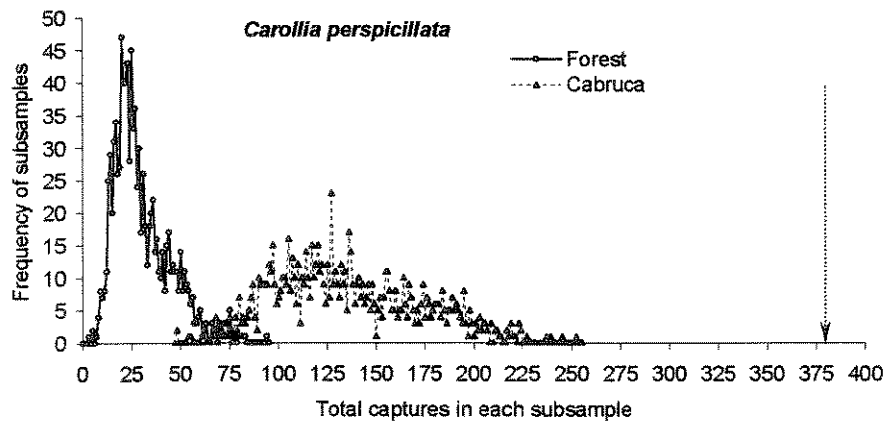


Figure 4.3. Distribution of total captures of *Carollia perspicillata*, *Rhinophylla pumilio* and *Artibeus obscurus* to 1,000 random seven-night subsamples taken from all night samples from forest and cabruca sites in Una region. Arrows represent total captures from samples in isolated cabrucas

FEEDING GUILDS

The proportions of the feeding guilds were similar on all sampled habitats (Table 4.2). Frugivorous bats comprised the bulk of species and captures reported in the three habitats, particularly in primary forests. It is noteworthy that, despite the unbalanced sampling effort among habitats, the number of frugivorous species sampled were almost the same in forests and both cabruças. There was an influx of some special frugivorous species such as *Sturmira lilum*, *Uroderma bilobatum*, *Platyrrhinus lineatus* and *Platyrrhinus recifinus* in cabruças of Una. These species usually forage on early successional forests searching for fruit though they might depend on resources from the nearby forests.

Forests were also characterized by a poor representation of nectarivorous bats, both in terms of species and captures. The increased representation of nectarivores in cabruças may be mostly due to an increased capture frequency of *Glossophaga soricina*, that was especially frequent in isolated cabruças (Table 4.1). *Glossophaga soricina* is, in fact, a generalist species that can exploit a variety of resources including fruits, nectar and also small insects, which might explain their great success in disturbed areas.

The gleaning insectivores were not restricted to primary forests, but were found in all three habitats. Species number and the proportional representation of this guild were higher in cabruças than the nearby forest, lower than isolated cabruças. Vampire bats were rare in all treatments, especially in primary forests.

Table 4.2. Proportional representation of feeding guilds in forests and cabruças in southern Bahia, Brazil. Numbers are % of the total captures in each guild, followed by the number of species in parenthesis.

FEEDING GUILDS	FORESTS	CABRUCAS OF UNA	ISOLATED CABRUCAS
Frugivorous	96.45 (14)	85.77 (16)	89.79 (14)
Nectarivorous	0.91 (02)	3.04 (04)	6.17 (03)
Gleaning insectivorous	1.09 (09)	9.82 (13)	2.77 (04)
Aerial insectivorous	1.45 (03)	0.68 (05)	1.06 (03)
Hematophagous	0.09 (01)	0.68 (01)	0.21 (01)

STRUCTURAL CHANGES ON CABRUCAS AS ECOLOGICAL PREDICTORS

Vegetation profiles of the study sites showed that all forest strata are present in cabruças, but there are clear differences in the foliage density of these strata between forests and cabruças (Figure 4.4). Except for the herbaceous layer (0-1 m) and the layers occupied by the crowns of cacao shrubs, all the remaining forest strata in cabruças tended to be less developed than those from forest areas. Most notably, there are two important gaps below the forest canopy in which the vertical strata are particularly sparse in cabruças compared with primary forests: just below (1-2 m) and above (4-10 m) the crowns of cacao shrubs. Cabruças are slightly shorter than primary forests, reaching a maximum height of 30 m, although a relatively dense protective cover of forest canopy is still maintained (10-30 m height).

This architecture of the cabruças may be an important potential explanatory variable to understand the response of bat communities to these habitats. I found a positive and significant correlation between forest structure descriptors and bat community structure on transects located in the Una region, as shown by the Mantel-test for comparisons of similarity matrices ($r=0.51$, $p<0.002$).

I then searched for the main features of vegetation profiles that potentially could explain this pattern. Principal Component Analysis revealed that forest sites were widespread along the first axis (Figure 4.5), which depicted a gradient of high densities on the forest understory of 2-4 m height and low canopy densities (15-25 m). In this axis, cabruças were clustered with some forest sites (Table 4.3). Cabruças formed a separate entity only along the second axis, accounting for only a small fraction of the total variation (20%). Forests were characterized by sites with higher densities between 1-2 m and 5-10 m height, whereas cabruças showed higher densities at 3-4 m height, the stratum occupied by the cacao shrub crowns.

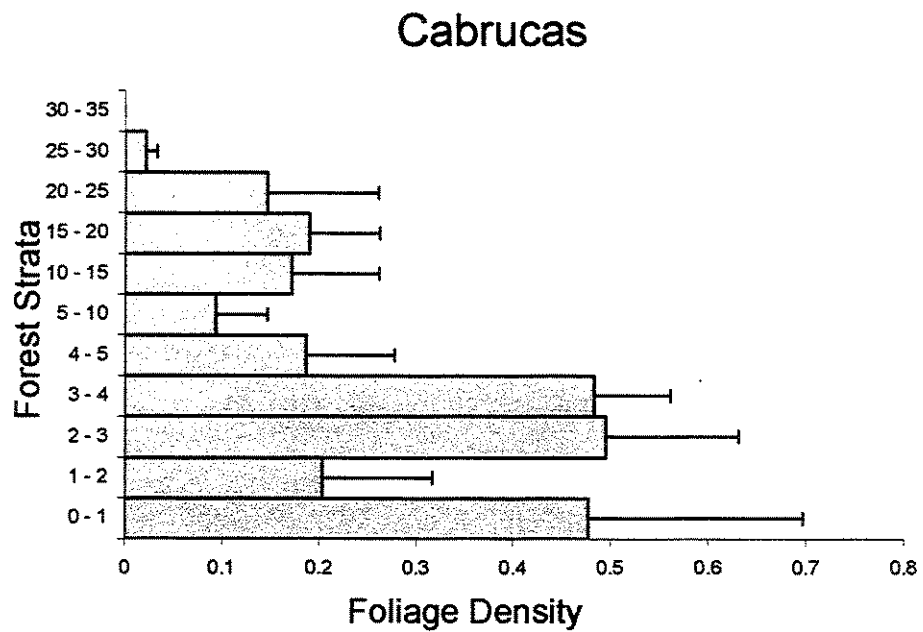
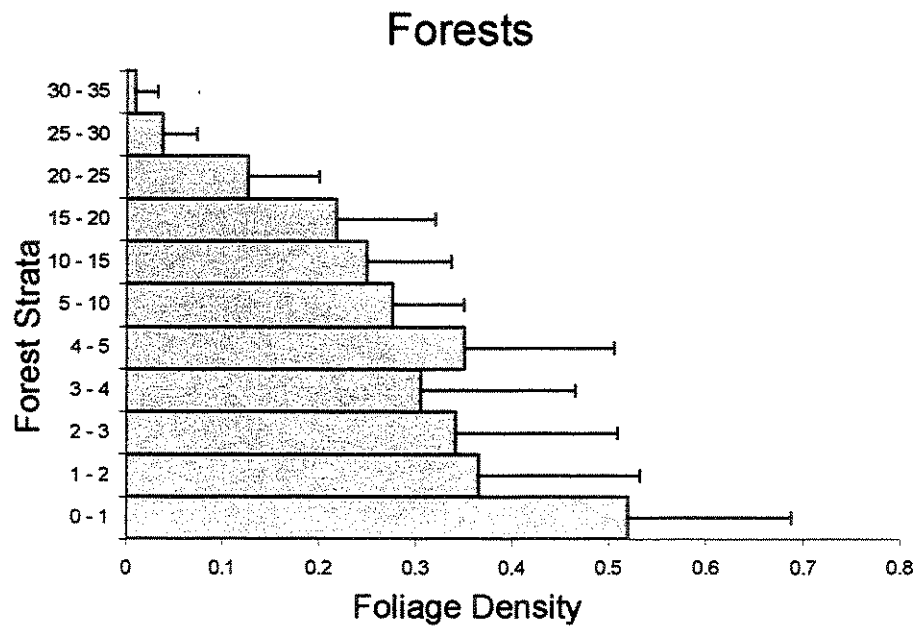


Figure 4.4. Vertical profiles of forests and cabruças in the Una region, represented by the interval occupied by foliage. Values depicted here for each stratum are the mean density (foliage heighty/meter) from all replicates in each stratum.

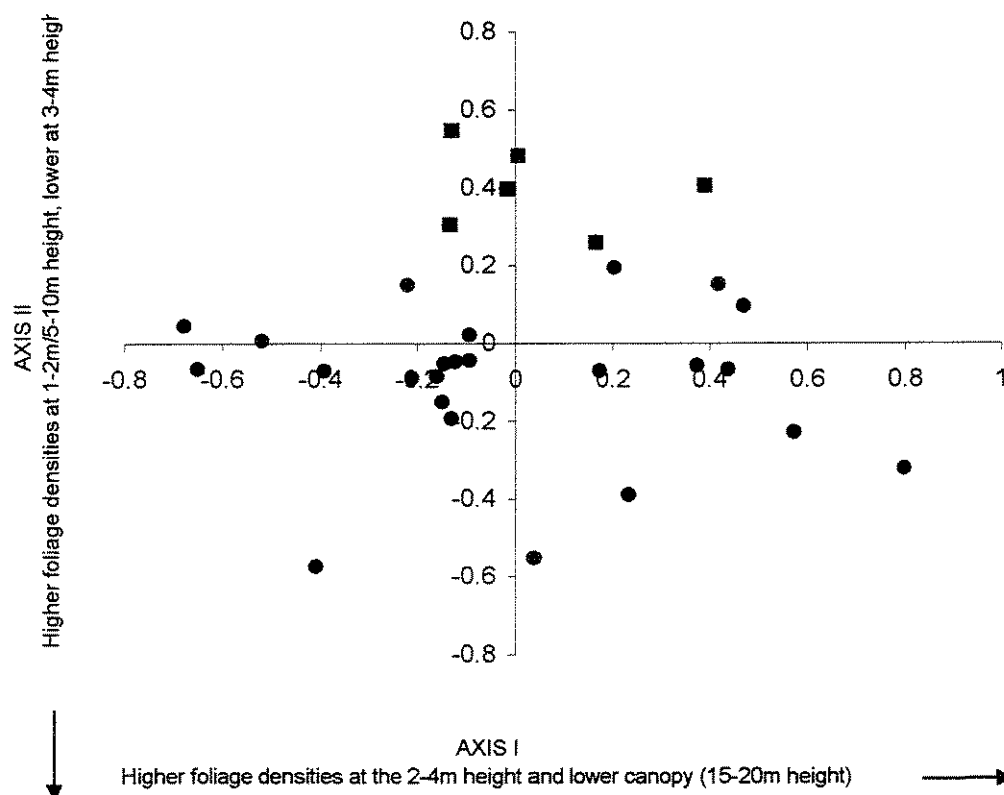


Figure 4.5. Projections of the site scores of the first two principal components of sites of forests and cabruças from Una region on axes I and II. Forest sites are shown by dots symbols while squares represent cabruças.

Table 4.3. Factor loadings on the first two Principal Components using descriptors of forest structure on forests and cabruças in the Una region, Brazil. Bold values are the two highest absolute values for each axis.

Descriptors	Axis I	Axis II
0-1 m	0.058	-0.290
1-2 m	0.203	-0.509
2-3 m	0.439	0.082
3-4 m	0.323	0.284
4-5 m	0.348	-0.273
5-10m	0.175	-0.505
10-15m	-0.119	-0.333
15-20m	-0.399	-0.096
20-25m	-0.368	0.119
25-30m	-0.331	-0.276
30-35m	-0.298	-0.169
Eigenvalues	3.71	2.15
Cumulative % of Variance Explained	33.75	53.36

BAT RESPONSE TO ECOLOGICAL PREDICTORS

I ran simple linear regressions with the PCA axes I and II, representing ecological gradients of forest structure, and species richness, capture frequency and diversity. A weak and non-significant relationship was found between the first PCA axis and species richness ($r^2=0.001$, $p= 0.859$), diversity ($r^2=0.00$, $p= 0.972$) and total capture frequency ($r^2=0.002$, $p= 0.796$). On the other hand, axis II was important to discriminate cabruças from all remaining forest sites. However, this gradient was not a good predictor of neither species richness ($r^2=0.508$, $p= 0.000$), nor capture frequency ($r^2=0.487$, $p= 0.000$), nor bat diversity ($r^2=0.037$, $p= 0.000$), as it was possible to discern only two categories (forests and cabruças sites) rather than a gradual changing on the values of these parameters (Figure 4.6).

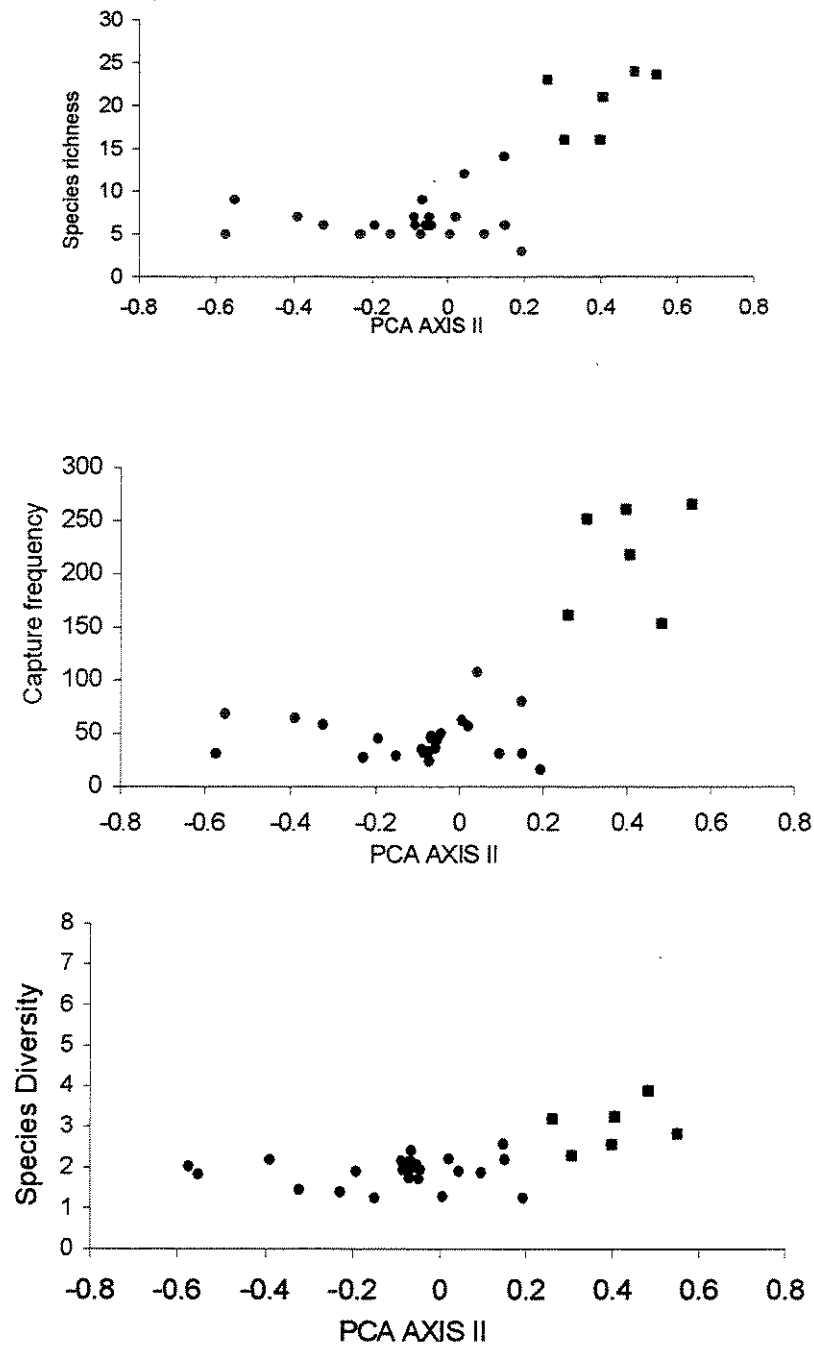


Figure 4.6. Relationship between bat species richness, capture frequency and diversity (as Shannon-Wiener index) and the second axis of PCA analysis, showing decreasing density of the forest understory (1-2 m) and overstory (5-10 m). Dot markers are forest sites while sites of cabrucas from Una are shown in square markers.

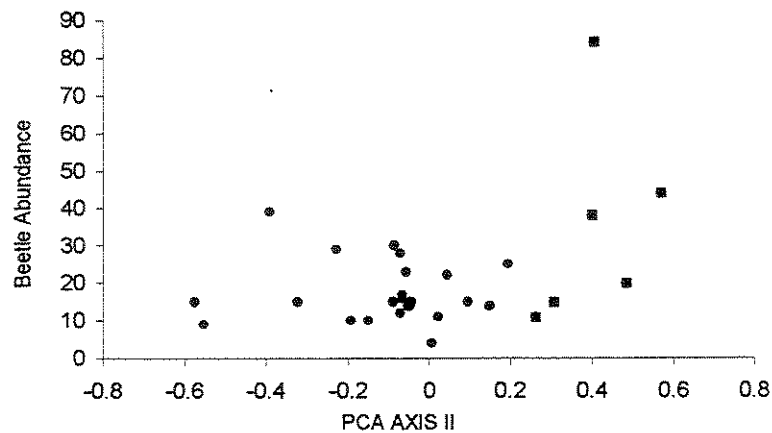


Figure 4.7. Relationship between beetle abundance and the second axis of the PCA analysis. Dot markers are forest sites while cabruca sites are shown in squares.

The same analysis was carried out to investigate whether beetle abundance was associated with the gradient of understory and overstory densities (Figure 4.7). Beetle abundance was not associated with the second PCA axis describing a disturbance gradient ($r^2 = 0.146$, $p = 0.03$).

DISCUSSION

Bats were not equally distributed in forests and cabruças. Rather, in the Una region these traditional shade crops revealed higher levels of bat diversity, with richness, capture frequency and an even distribution of species surpassing those values found on nearby forests. These cabruças immersed in a matrix of primary stands also mirrored some important features of community structure from native forests. The three most common species in forests were also present in higher frequencies and were widespread among sites of cabruças in Una. They also showed an increased proportion of the forest dwelling Phyllostominae bats, which in cabruças included at least 13 of the 16 species reported in the present study.

Overall, these results support the general assertion that shade cacao plantations act as important habitats for some elements of the native biota. Studies comparing the diversity of biological groups in shade plantations elsewhere have shown similar results.

diversity of biological groups in shade plantations elsewhere have shown similar results. Shade coffee plantations in Central American countries, which are structurally similar to cabruças, were rich in both resident and migratory birds (Greenberg et al. 1997; Parrish et al. 1998), ants (Torres 1984) and other arthropods (Perfecto et al. 1999). Shade cacao plantations from Africa also showed extremely high diversity of ants (Room 1971; Majer 1978). The community structure of frogs and lizards in the same sites sampled for bats in the Una region showed the same values of species richness in cabruças and nearby primary forest, although lizards were more abundant and statistically less even in cabruças (Dixo 2001). Studies in forests and agricultural areas in two landscapes of Mexico have shown that shade plantations were regularly used by many bat species, though species richness was significantly higher in forest tracts (Estrada et al. 1993a; Medellín et al. 2000). Similar results were observed for birds and nonvolant mammal communities (Estrada et al. 1994).

The existence of forest tracts close to cabruças appears to be a key factor affecting the potential of shade plantations to serve as habitats for many forest dwelling species (Alves 1990; Dietz et al. 1996; Parrish et al. 1998; Greenberg 1998). The results from isolated cabruças in southern Bahia corroborate this idea for bat assemblages. The generally high bat diversity in cabruças drops sharply in the absence of nearby forests. Samples taken from isolated cabruças were more sparse, with significantly lower mean number of species than cabruças from Una, though still richer than primary forests. In isolated cabruças, samples were highly dominated by a single species, while two other frugivores naturally common in native forests were poorly represented. On the other hand, generalist species such as *Glossophaga soricina* tend to successfully colonize this agroecosystem. It seems that the bulk of forest dwelling species reported in cabruças in Una are colonizers from the nearby forests, that act as sources of populations that ventured out into cabruças for foraging or commute between feeding and roosting areas, rather than truly residents. If this situation is true, cabruças are effective corridors and foraging habitats for most of the species living in the nearby forest.

The fact that most species of bats depend largely on the proximity of forest tracts sheds some light on the potential role of cabruças as biodiversity reservoirs in southern Bahia. Apparently, cabruças *per se* do not maintain all the resources required by most forest species, though other components of the bat assemblages, more adapted to intermediate and higher levels of disturbances, have an advantage for colonizing cabruças. Estrada et al. (1993a) noted that shade cacao plantations were particularly rich

in frugivorous and nectarivorous species that were attracted by fruiting and flowering trees of the canopy cover. The high species richness found in the cabruças of southern Bahia was partially due to an increase in the number and abundance of some species well adapted for foraging in both early and late succession areas. For instance, the frugivorous bats, *Sturmira lilium*, *Platyrrhinus lineatus* and *Platyrrhinus recifinus*, which were rarely or never observed in the forest samples but were quite common in cabruças, are known to feed on fruits of *Solanum*, *Cecropia* and other pioneer plants found in disturbed areas and also reported to occur in cabruças. I particularly noted in all cabruças sites, a high concentration of *Piper* species, which comprise the bulk of the diet of *C. perspicillata*, a bat found in high frequencies in cabruças regardless of isolation from natural forests. The increasing representation of nectarivorous species on the cabruças, most notably *Glossophaga soricina*, may be closely linked with the presence of many flowering trees of Juerana (*Parkia pendula*) in cabruça sites (personal observation). All these frugivorous and nectarivorous bats, however, also comprise the bat assemblages characteristic of Neotropical forests in many areas, though they seem to be particularly favored in plantations like cabruças.

The fact that a rich assemblage of phyllostomine bat species was also found in cabruças is noteworthy. These gleaning bats were particularly well represented on the cabruças near forest tracts, though at least three species were also observed in isolated cabruças. It has been suggested that these rare species show specific feeding and roost requirements that prevent them from surviving outside preserved forests (Fenton et al. 1992). At least three species of gleaning bats were seen roosting in cabruças of Una. A large colony of *Phyllostomus discolor* was found roosting in the hollow trunk of an old large tree of Pequi (*Caryocar edule*) and a termite nest harbored 11 individuals of *Tonatia sivicola*. An individual of *Trachops cirrhosus* was caught leaving a hollow tree in isolated cabruça just before sunset, showing that this individual was actually a resident of the isolated cabruça. These observations suggest that some gleaner bats can also rely on cabruças as roost sites.

More specialized understory frugivorous and insectivorous birds were absent even from cabruças close to forest tracts in southern Bahia (Alves 1990; Faria et al. 2000). Greenberg et al. (1997) also noted a lack of more specialized forest bird species from the understory of shade coffee plantations in Chiapas, Mexico, and suggested that the high diversity of bird communities in shade plantations is due to an influx of more generalist species and the maintenance of some forest dwellers.

ECOLOGICAL CORRELATES OF BAT RESPONSE TO THE CABRUCÁ SYSTEM

As demonstrated here and elsewhere (Mori et al. 1983; Alves 1990; Johns 1999), the thinning process of cabrúca formation results in striking changes in the original forest structure. Besides the modification in the plant species composition, vertical stratification profiles revealed that cabrúcas are particularly less developed in some strata below the canopy. I showed here that bats are influenced by modifications on forest structure. Samples taken from sites of cabrúcas, with lower densities of foliage at 1-2 and 5-10 meters height were richer, more abundant and more diverse than samples taken from forest sites. This response may depend on particular features related to bat ecology and their use of habitat.

Forests represent structurally complex habitats for a flying, echolocating bat (Fenton 1990). Flying bats must detect and avoid an array of obstacles such as branches, trunks, and the thick foliage layers that characterize forest habitats (Schnitzler & Kalko 1998). The relatively open spaces in the forest understory and overstory in cabrúcas may facilitate the foraging activity of bats, as they allow these flying animals to move freely through the vegetation, though still under the protective cover of the forest canopy. This idea is consistent with the fact that most understory bats make use of flyways in the forest, which are open spaces within the crowded vegetation, such as trails, ravines, and other natural openings. These flyways are thought to be the most productive netting sites in natural forests (Kunz & Kurta 1988), as bats predictably use these routes to commute from roost to feeding areas, among feeding areas, and also as foraging space.

The relatively low density of vegetation in some forest strata in cabrúcas represents a situation with few obstacles to be avoided during flight in all directions, unlike the eventual and limited open spaces found in native forests that, in many cases, do not represent the shortest distance between two points that bats must cross to reach feeding or roosting sites. These open spaces in cabrúcas probably allow bats to choose better routes that represent a trade-off between the distance and the time to reach targets, which in turn minimizes the energy expenditure of flight.

Although the gradient of foliage density was not associated with the abundance of beetles, it is possible that the forest architecture from cabrúcas facilitates prey detection and pursuit. Beetles, which may represent one of the most important food items for gleaner bats (Humphrey et al. 1983; Fenton et al. 1999) were sampled from understory bushes, which in cabrúcas are represented exclusively by cacao shrubs. The open space

right above and beneath the dense crowns of cacao shrubs can further facilitate prey detection and the access of a flying bat that glean prey from the substrate. Furthermore, the dense foliage of the cacao crowns also provides substrate for many insect prey. Therefore, the presence of Phyllostominae bats on the cabruças may be partly explained by the forest structure and access to prey items.

This also holds true for frugivorous and nectarivorous bats. A large-scale inventory carried out in shade cacao plantations in southern Bahia revealed that, from a list of 144 canopy tree species observed to occur in the cabruças, at least 9 were widespread and known to be used by many bat species as food resource (Vinha & Silva 1982). In the herbaceous layer, species such as those from the genus *Piper*, *Solanum* and others commonly reported in the diet of many understory frugivorous are also present in high densities in cabruças (Vinha et al. 1983). It appears that cabruças, by providing food resources, such as fruits, nectar and insects, and also representing areas where foraging is facilitated, can hold high levels of bat species richness.

BATS AS INDICATOR SPECIES?

The fact that some bats species are closely associated with pristine forests, coupled with the response of community attributes to gradients of disturbance levels, has led some authors to propose the use of bats as bioindicators (Fenton et al. 1992; Johns et al. 1985; Pedro 1998; Medellín et al. 2000). It is important to note, however, that the response of bats to habitat disturbance does not necessarily reflect that of other biological groups. I showed here that bats were influenced by the structural modifications that characterize the cabruca system, as they responded to features of forest structure that are directly modified in shade crops (e.g. foliage densities in some specific heights on the understory and overstory layers). Bats seem to respond in a positive way to such modifications, and when forest tracts are close to shade crops, most forest dwelling bats are able to use these plantations, in frequencies usually higher than those in nearby forests. Further investigation of the response of other groups in the same sites of forest and cabruca at the Una region revealed that at least three other biological groups showed different responses to the cabruca system. Faria et al. (2000) found that at least 26 species of forest dwelling birds and two small non-volant mammals were not reported to occur in cabruças surrounded by primary forests. The same was also observed for frugivorous butterflies (Accacio 2001). It is likely that the drastic reduction in plant species and the modification in the forest vertical profile in cabruças impose different limitations for

distinct biological groups. For instance, some forest dwelling birds and small mammals, which are dependent on high density of the forest understory, are likely to be adversely affected in the cabruças. The total removal of the native understory plant species that provide berries and other food resources for small mammals and birds, as well as specific hosts for some species of butterflies is likely to be a key factor explaining species loss in cabruças. Greenberg et al. (1997) also noted a lack of more specialized forest bird species from the understory of shade coffee plantations in Chiapas, Mexico. Similarly, Alves (1990) called attention to the fact that the cabruca formation in southern Bahia does not provide habitat for many species of small specialized understory frugivorous and insectivorous birds that rely on the native forest understory.

Studies dealing with the comparative responses of many biological groups facing habitat disturbances should be carried out before proposing that a single group such as bats should be considered as efficient indicators of habitat disturbance or disruption and, especially as organisms indicating ecosystem integrity. Given the results presented here, it appears that Phyllostominae bats are not faithful indicators of habitat integrity, as many species and captures were reported to occur on cabruças, shown here to be highly modified habitats in comparison with forest remnants. Rather than indicating maintenance of original forest features, they appear to be associated with specific modifications that occur in cabruças, such as structural changes in the forest vertical profile. I suggest a cautionary view on the potential of bats, particularly the Phyllostominae, as tools to assess habitat integrity. We still need to establish to what extent bats are responding to forest modifications, and what they are really indicating in terms of habitat integrity or disturbance.

CABRUCAS AND CONSERVATION IN SOUTHERN BAHIA

The importance of the cabruca system in southern Bahia as potential habitat for regional biodiversity lies not only in the wide area it covers, but also in its strategic location. The cacao region encompasses one of the richest pockets of biodiversity along the entire Atlantic coast. These lowland forests are known to be centers of endemism for many biological groups including plants (Mori et al. 1981; Prance 1982), insects (Brown 1991), reptiles (Jackson 1978), birds (Haffer 1974) and mammals (Rylands 1982).

I demonstrate here that bats, as a major component of the local extant mammal assemblages, effectively can use cabruças as foraging habitats and, when forests are close to cabruças, can use these habitats as effective corridors among remnants for most

forest dwelling species. What this biological information brings to the planning of a conservation strategy for the region is quite important. It is undeniable that the future of the last remnants of forest in southern Bahia is also influenced by what will become of the cabruças. If the small, scattered plantations in the Una region are replaced by other activities such as sun coffee or pastures. This will certainly reduce the area of important foraging sites and pathways linking the forest patches for bats as well as other organisms. Equally, the replacement of the large shade plantations by any other activity that reduces structural and floristic resemblance to native forest will certainly threaten the local biodiversity that, although probably reduced when compared with communities in primary forests, finds in cabruças the only forest-like habitats left at a large scale.

Different approaches should be taken for the two landscapes assessed in the present study. In the Una region, and probably in the remaining areas along the coast where cacao is still cultivated, the small and scattered shade cacao plantations must be maintained as effective biological corridors linking forest tracts. The extensive matrix of shade plantations in the core region of cocoa production should also be kept, though initiatives must encourage the establishment of natural preserves within this matrix, either by maintaining the few remnants available or by allowing shade plantations to regenerate.

We have lost more than we can afford from the Atlantic rainforest. Any kind of habitat that potentially harbors a rich biological assemblage, serving as reservoirs, corridors, buffers or any function that mitigates the loss of biodiversity, should be protected and incorporated into a broader conservation network. What we have to do now is to gather and use the biological information to guide our decisions. This will allow us to apply limited resources to effectively protect biodiversity in such a way that we can optimize and predict what is actually going to be protected and, if nothing is done in a near future, what will be lost forever.

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EPÍLOGO

Este trabalho, escrito em capítulos independentes, traz importantes informações ecológicas que podem auxiliar na conservação dos morcegos na região de Una e, até certo ponto, de outras áreas do sul da Bahia. Neste epílogo meu objetivo foi sintetizar e enfatizar alguns pontos abordados ao longo do trabalho, ligando os principais resultados obtidos em cada capítulo separadamente.

No início eu faço uma análise do padrão de riqueza de espécies encontrado na região de Una, comparando com os demais estudos conduzidos em outras regiões. Embora aqui sejam apresentadas análises não contempladas nos capítulos anteriores, este procedimento sintetiza os dados discutidos, principalmente, nos capítulos III e IV.

Discuto, ainda, pontos importantes que emergem dos resultados obtidos neste estudo e dentro da pesquisa conjunta gerada pelo Projeto RestaUna, e que podem servir como base para o delineamento de uma estratégia de conservação para a região de Una.

A PAISAGEM DE UNA E A RIQUEZA DE MORCEGOS

O presente estudo foi a primeira pesquisa intensiva e padronizada sobre morcegos conduzida em uma área de floresta úmida de baixada na região nordeste do Brasil. Mesmo considerando as amostragens nos 36 transectos e seis tipos de hábitat dentro do desenho experimental do projeto RestaUna, não foi possível atingir a assíntota na curva acumulada de espécies (Figura 5.1). Este padrão de curva é comum entre os levantamentos para morcegos conduzidos na região neotropical (Fleming et al. 1972; Findley 1993). É possível considerar que, utilizando o método de rede de neblina, nenhum levantamento chegou a incluir todas as espécies que poderiam ser capturadas através desta metodologia (Kalko 1997; Simmons & Voss 1998). Isso reflete a grande riqueza da comunidade de morcegos Neotropicais e a raridade da maioria das espécies deste grupo.

Analisar se a comunidade encontrada na paisagem de Una difere em riqueza de espécie de outras localidades na Mata Atlântica é uma tarefa ainda mais difícil, por vários motivos. As comparações são complicadas devido a problemas metodológicos e a variação na intensidade de esforço amostral entre os diferentes inventários (Simmons & Voss 1998). Mesmo entre os estudos conduzidos através do método de rede de neblina, variações quanto ao comprimento, altura e espessura da malha utilizada geram

diferenças na capturabilidade entre as diferentes espécies da comunidade. Outros ainda incluem amostragens em abrigos diurnos, e através deste procedimento várias espécies pouco freqüentes ou raramente capturadas em redes são anexadas ao conjunto total. Uma grande variação ocorre também em relação a heterogeneidade nos sítios de amostragem dentro de um mesmo estudo, e até mesmo no posicionamento estratégico das redes. No entanto, a maior dificuldade vem do fato de que o estudo em Una foi o primeiro conduzido no Brasil em uma escala de paisagem, abrangendo amostras em vários remanescentes florestais além de considerar sítios na matriz de ambientes modificados. Os demais levantamentos são limitados a poucos sítios de coleta, normalmente localizados dentro de determinadas áreas de floresta (Pedro 1998).

É possível, no entanto, verificar se a riqueza de espécies em uma dada localidade dentro da paisagem amostrada em Una difere daquelas registradas para outras áreas da Mata Atlântica. A figura 5.2 mostra a comparação entre as curvas aleatorizadas de rarefação (Krebs 1989) construídas a partir dos dados de levantamentos realizados em quatro áreas de preservação na Mata Atlântica do sudeste do Brasil (Marinho-Filho 1985, Pedro 1992; Aguiar 1994; Faria 1996) com aquela obtida com a riqueza de espécies registradas nos cinco transectos de amostragem localizados dentro dos limites da RebioUna. As amostras da RebioUna apresentam uma riqueza similar à esperada para pelos demais levantamentos.

A riqueza total registrada neste estudo para a paisagem de Una foi de 45 espécies, levando-se em conta as amostragens em todos os 36 transectos dentro do projeto RestaUna (Figura 1.3; ANEXO I). Como foi mostrado nos capítulos III e IV, fica claro, no entanto, que esta riqueza em Una está, basicamente, associada à presença de cabruças na matriz. Do total de espécies de morcegos registradas na paisagem de Una, 29 foram capturadas nos remanescentes florestais, 8 nas capoeiras e 39 nas cabruças. Pelo menos 16 espécies ocorreram exclusivamente na matriz, sendo 15 delas só nas cabruças.

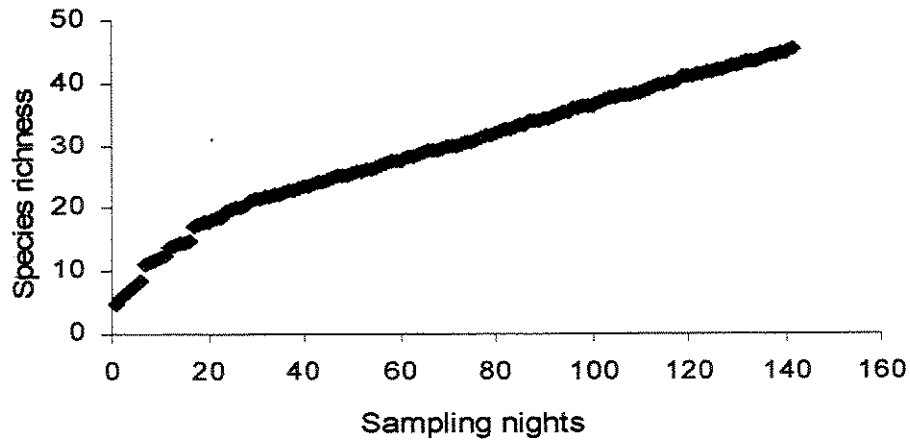


Figura 5.1. Curva aleatorizada de acúmulo de riqueza de espécies nos 36 transectos de amostragem do projeto RestaUna, na região de Una, sudeste da Bahia, Brazil.

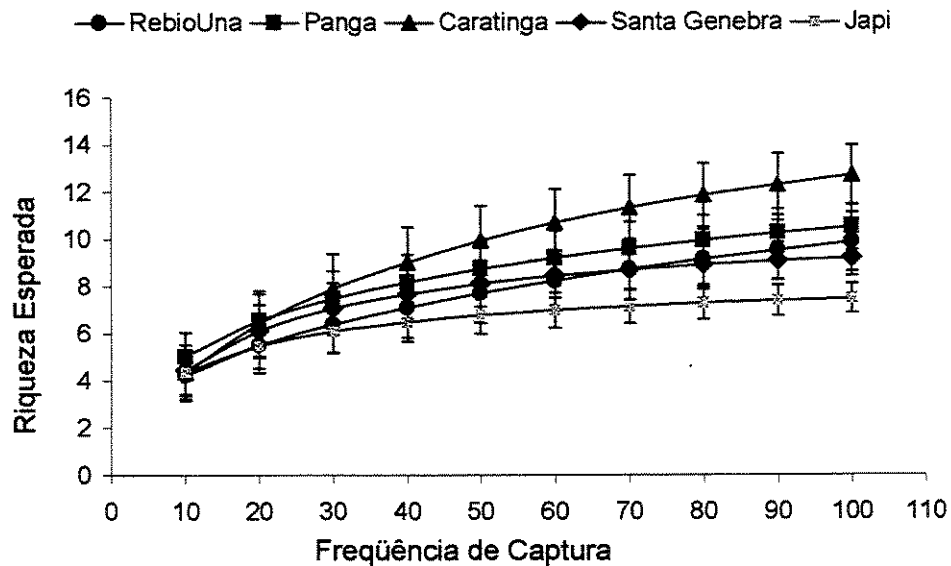


Figura 5.2. Curvas aleatórias de rarefação para cinco áreas de floresta preservada na Mata Atlântica, a Reserva Biológica de Una (RebioUna), Reserva do Panga (Pedro 1992), Caratinga (Aguiar 1994), Santa Genebra (Faria 1996) e Serra do Japi (Marinho-Filho 1985). As barras representam um desvio padrão acima e abaixo da riqueza média esperada por amostra.

A grande importância dos ambientes de cabruca na matriz de Una fica evidente quando a riqueza de espécies em Una é comparada com aquela obtida para duas paisagens distintas do México onde plantações sombreadas também compõem parte significativa dos ambientes de entorno (Estrada et al. 1993; Medellín et al. 2000) (Tabela 5.1). As comparações revelaram que a matriz da região de Una contribui significativamente mais para a riqueza total de morcegos do que as matrizes das outras duas regiões do México ($\chi^2=8,079$; $p<0,02$).

Tabela 5.1. Número de espécies de morcegos em áreas de florestas (incluindo aquelas presentes nas matrizes) e a riqueza de espécies presentes somente nas matrizes da região de Una, Brasil e em duas regiões do México, Los Tuxtlas (Estrada et al. 1993) e Chiapas (Medellín et al. 2000).

Paisagens	riqueza nas florestas	riqueza nas matrizes
Una, Brasil	29	16
Los Tuxtlas, México	32	3
Chiapas, México	27	7

Ao contrário do que ocorre em Una, a paisagem das duas regiões no México ilustra uma situação onde fragmentos florestais de vários tamanhos e as áreas de cultivo são imersas em uma matriz onde predominam áreas de pasto. Embora as cabruças representem apenas uma pequena parte do total da paisagem nos três blocos de amostragem em Una (5,9% - capítulo I), todas estão imersas ou conectadas com os remanescentes florestais, situação que não ocorre nas regiões do México. Em Los Tuxtlas, ainda, os remanescentes florestais são geralmente menores (2–2.000 ha) e mais distantes entre si do que os de Una (Capítulo I), e Estrada et al. (1993) mostram inclusive que a distância entre estas manchas foi um bom preditor da riqueza esperada.

Estas comparações, juntamente com o que foi discutido no capítulo IV, mostram a relação entre a presença de uma rica fauna de morcegos em cabruças e a proximidade de manchas de floresta nativa.

É importante realçar, ainda, que este levantamento em Una revelou que pelo menos três espécies de morcegos, anteriormente conhecidas apenas para a região Amazônica e florestas da América Central, de fato também ocorrem neste trecho do nordeste brasileiro: *Micronycteris microtis*, *Micronycteris schimidtorum* e *Vampyrodís caraccioli* (Marinho-Filho & Sazima 1998; Simmons & Voss 1998). Trata-se de uma ampliação considerável da distribuição geográfica destas três espécies. Levando-se em conta que a região sul da Bahia abriga os últimos remanescentes da Mata Atlântica do nordeste, é provável que estas espécies também estejam confinadas a apenas estas floresta na porção atlântica.

Os morcegos parecem responder às modificações na estrutura da floresta decorrentes da fragmentação, regeneração e uso da terra. Ambientes florestais com um grande adensamento do subosque e raleamento dos estratos superiores, como sítios de borda e capoeira, são mais pobres em espécies (Capítulos II, III e IV). Por outro lado, ambientes florestais modificados que mantenham uma cobertura de dossel semelhante às florestas originais, mas que apresentam uma menor densidade do subosque, como as cabruças, parecem manter uma rica e diversa fauna de morcegos, especialmente quando existem florestas próximas. Este fato ilustra que morcegos, assim como outros grupos biológicos, são sensíveis a mudanças na qualidade do hábitat florestal, e estão respondendo de forma variável a diferentes tipos de perturbação. Cabruças, bordas e capoeiras são todos ambientes modificados em relação, por exemplo, aos sítios de interior de floresta em Una. No entanto cada um dos três tipos de ambiente apresenta características distintas de perturbação. Este conjunto de resultados mostra que o uso de morcegos como indicadores de perturbação ou integridade de florestas deve ser analisado com cautela, conforme foi discutido no capítulo IV. É necessário estabelecer a que características específicas da perturbação os morcegos estão respondendo (Medellín et al. 2000).

Na paisagem de Una, a proximidade entre os remanescentes e a presença de uma matriz que inclui ambientes com permeabilidade variável para os morcegos permite a existência de uma fauna rica e diversa nesta região. Embora a maioria das espécies de morcegos filostomídeos possa atravessar áreas abertas (Estrada et al. 1993; Galindo-González et al. 2000), a distância de isolamento entre remanescentes parece ser importante para explicar a riqueza de comunidades em outras paisagens antropizadas (Estrada et. al. 1993). A grande mobilidade deste grupo de mamíferos, a proximidade entre os ambientes florestados e a presença de cabruças na paisagem devem ser importantes para a manutenção desta rica fauna na região de Una.

Em Una fragmentos pequenos mantêm, no seu conjunto, o mesmo grupo de espécies também encontradas nas áreas de floresta contínua, incluindo espécies raras e de níveis tróficos superiores, como os insetívoros e carnívoros catadores da sub-família Phyllostominae. Este resultado também foi encontrado para outras comunidades animais na região de Una. Para pequenos mamíferos, aves, morcegos, lagartos, sapos e borboletas, os pequenos fragmentos da região de Una também mantêm praticamente o mesmo grupo de espécies encontrado nos grandes remanescentes (Pardini et al. 2000). A formação de bordas, no entanto, afeta uma parcela da comunidade de morcegos na região de Una. Nestas faixas onde ocorre a conexão abrupta entre a porção marginal do remanescente florestal e uma área aberta, como pastagem, foram detectadas modificações estruturais que limitam a presença de determinadas espécies, particularmente os morcegos filostomíneos. Embora as capoeiras tenham se mostrado ambientes pobres em morcegos, é possível que a presença destes ambientes no entorno dos remanescentes florestais esteja mitigando o efeito de borda. Mesquita et al. (1999) mostraram que áreas em regeneração têm um papel importante para o tamponamento do efeito de borda em fragmentos na Amazônia. A simples presença de uma estrutura florestal na matriz, mesmo que modificada em relação aos ambientes de floresta madura, parece contribuir de forma eficiente para diminuir a mortalidade de árvores em fragmentos florestais, assim também diminuindo a penetração do efeito de borda.

UMA POLÍTICA DE CONSERVAÇÃO

Os resultados obtidos na presente pesquisa, e que fazem parte de uma investigação mais abrangente, dentro do projeto RestaUna, serviram de base para a elaboração de um conjunto de diretrizes biológicas para nortear uma política de conservação para a região de Una. Estas diretrizes, apresentadas em anexo (ANEXO II), mostram a importância da região de Una como uma área rica em espécies de vários grupos taxonômicos, inclusive morcegos. A importância da natureza e distribuição espacial de remanescentes e ambientes de entorno na região é realçada e deve ser mantida, sendo uma característica-chave para explicar esta alta diversidade biológica em uma área intensamente explorada pelo homem.

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ANEXO I. Lista de espécies de morcegos coletadas nos 36 transectos de amostragem do Projeto RestaUna, incluindo florestas maduras (interiores e bordas de áreas florestas contínuas e fragmentos), capoeiras e cabrucas na região de Una, sul da Bahia. Nomes apresentados em ordem alfabética.

Espécies	Florestas	Capoeiras	Cabrucas
<i>Anoura caudifer</i>	-	-	-
<i>Anoura geoffroyi</i>	-	-	+
<i>Artibeus cinereus</i>	+	+	+
<i>Artibeus fimbriatus</i>	+	-	+
<i>Artibeus gnomus</i>	+	-	+
<i>Artibeus jamaicensis</i>	+	-	+
<i>Artibeus lituratus</i>	+	+	+
<i>Artibeus obscurus</i>	+	+	+
<i>Carollia brevicauda</i>	+	-	+
<i>Carollia perspicillata</i>	+	+	+
<i>Chiroderma villosum</i>	+	-	+
<i>Choeroniscus minor</i>	-	-	+
<i>Chrotopterus auritus</i> *	+	-	+
<i>Desmodus rotundus</i>	+	-	+
<i>Epitesicus brasiliensis</i>	+	-	+
<i>Glossophaga soricina</i>	+	+	+
<i>Lamproncycteris brachyotis</i> *	-		+
<i>Lichonycteris obscura</i>		+	
<i>Lonchophylla mordax</i>	+	-	+
<i>Micronycteris hirsuta</i> *	+	-	+
<i>Micronycteris microtis</i> *	+	-	-
<i>Micronycteris schmidtorum</i> *	+	-	+
<i>Mimon crenulatum</i> *	-	-	+
<i>Molossops planirostris</i>	-	-	+
<i>Myotis nigricans</i>	+	+	+
<i>Myotis</i> sp1	-	-	-
<i>Phylloderma stenops</i> *	-	-	+
<i>Phyllostomus discolor</i> *	-	-	+
<i>Phyllostomus elongatus</i> *	+	-	-
<i>Phyllostomus hastatus</i> *	-	-	+
<i>Platyrrhinus lineatus</i>	-	-	+
<i>Platyrrhinus recifinus</i>	+	-	+
<i>Rhinophylla pumilio</i>	+	+	+
<i>Saccopteryx bilineata</i>	+	-	+
<i>Sturnira lilium</i>	+	-	+
<i>Sturnira tildae</i>	-	-	+
<i>Thyroptera tricolor</i>	-	-	+
<i>Tonatia brasiliense</i> *	+	-	+
<i>Tonatia saurophila</i> *	+	-	-
<i>Tonatia silvicola</i> *	+	-	+
<i>Tonatia</i> sp1 *	-	-	+
<i>Trachops cirrhosus</i> *	+	-	+
<i>Trinycteris nicefori</i> *	-	-	+
<i>Uroderma bilobatum</i>	+	-	+
<i>Vampyressa pusilla</i>	-	-	+
<i>Vampyrodes caraccioli</i>	+	-	-

ANEXO II

Documento: “Pesquisa científica e políticas de conservação: o Projeto RestaUna, um estudo de caso”, produzido durante o “Encontro brasileiro de pesquisadores da Mata Atlântica”, promovido pela Universidade Estadual de Santa Cruz (UESC) e o Centro de Recursos Ambientais (CRA), em julho de 2001, em Itacaré, Ilhéus, Bahia. Documento disponível em <http://www.restauna.org.br>.

A região de Una é formada por um mosaico de florestas e ambientes alterados que, em seu conjunto, ainda abriga uma fauna rica e característica da região. Isso inclui 22 espécies ameaçadas, 23 espécies endêmicas e quatro espécies novas, considerando apenas os grupos de borboletas frugívoras, sapos e lagartos de serapilheira, aves, morcegos e pequenos mamíferos. Esta informação, por si só, já é de grande valor. Até o momento ignorava-se em que quantidade e quais espécies ainda são abrigadas pelas matas remanescentes no entorno da Reserva Biológica de Una, apesar da região sudeste da Bahia ser reconhecida como uma área importante biologicamente.

Diretriz 1- Deve-se concentrar esforços conservacionistas na região que, apesar do reduzido tamanho das florestas remanescentes e das inúmeras alterações sofridas, ainda sustenta grande diversidade biológica.

Entretanto, há uma perda substancial de grandes mamíferos e algumas aves, os grupos mais afetados na região, cujas populações foram drasticamente reduzidas provavelmente pela caça. Há também uma perda significativa de árvores de grande porte pelo corte seletivo de madeira. Os efeitos drásticos que a caça pode ter sobre populações silvestres são conhecidos, mas a importância deste tipo de atividade depende de sua intensidade, período de duração e do tamanho das populações desses animais. Fica demonstrado que a caça é uma das consequências da antropização com efeitos mais deletérios para a fauna da região do entorno da Reserva Biológica de Una.

Diretriz 2- O controle da caça e do corte seletivo de madeira deve ser uma ação prioritária em qualquer sistema de conservação da região.

Para pequenos mamíferos, aves, morcegos, lagartos, sapos e borboletas, os pequenos fragmentos da região de Una mantém, em seu estado atual, praticamente o mesmo grupo de espécies encontrado nos grandes remanescentes. Este resultado é bastante peculiar, pois estudos em outras regiões mostram que fragmentos com tamanho

equivalente aos encontrados no entorno da Reserva Biológica de Una (30-100 ha) perdem várias espécies em relação a porções maiores de mata.

Diretriz 3- Os pequenos fragmentos de mata são peça-chave para a conservação da fauna e flora regionais, e qualquer estratégia de conservação deve levar em conta a preservação de tais fragmentos.

Esses fragmentos são, em média, tão pequenos, que por si, só não seriam capazes de sustentar a diversidade biológica que abrigam. O valor dos fragmentos está diretamente associado à conectividade entre eles, propiciada pelos ambientes antrópicos de seu entorno, que são florestais, e à presença de fragmentos de maior extensão de floresta na região. No contexto da paisagem de Una, as cabruças e capoeiras funcionam, pelo menos para algumas aves, borboletas, pequenos mamíferos e lagartos, não só como corredores, mas como extensões da floresta.

Diretriz 4- A manutenção de ambientes de entorno florestais, formados por cabruças e capoeiras, permeáveis às espécies de floresta, é fundamental para a preservação da biodiversidade regional.

O efeito de borda é o conjunto de alterações físicas e biológicas que se observa na faixa de mata em contato com outro tipo de ambiente (geralmente pastagens ou áreas abertas). O efeito de borda detectado nas matas em contato com pastagens da região de entorno da Reserva Biológica de Una é acentuado, e o tamanho dos fragmentos geralmente é pequeno. A continuidade do desmatamento poderia provocar o colapso da fauna e flora local pela perda das áreas centrais (não afetadas pelo efeito de borda) dos fragmentos de Una.

IMPORTANTE: A substituição de áreas de vegetação espontânea em regeneração por sistemas agroflorestais de produção comercial deve ser feita da maneira menos traumática possível para o ambiente. Por exemplo, a implantação de espécies vegetais de interesse comercial deve ser feita na medida do possível, sob a vegetação atual ou em faixas alternadas a elas e nunca por substituição brusca da vegetação nativa ("derruba total").

Diretriz 5- É de extrema importância suprimir a conversão de matas em ambientes não florestais e evitar a conversão de cabruças e capoeiras em ambientes abertos.

Das três principais informações expostas acima - pequenos fragmentos que sustentam uma fauna mais rica do que a esperada, o efeito deletério causado nas comunidades biológicas florestais pelo estabelecimento de áreas abertas e a grande permeabilidade dos ambientes de cabruca e capoeira ainda comuns na região - conclui-se que: a fauna da região está sendo mantida, a despeito do pequeno tamanho das áreas remanescentes, porque as manchas de florestas funcionam como um todo, ligadas pelos diversos ambientes florestais alterados que as entremeiam. A quebra deste sistema pode levar à perda brusca de diversidade regional.

Diretriz 6- O planejamento do uso da terra na região deve ser feito de forma a manter a configuração do mosaico ambiental constituído de áreas de floresta pequenas e grandes, capoeiras e agro-florestas.

Diretriz 7- É possível expandir o tamanho da área protegida na região de Una, não só pela ampliação das áreas de floresta propriamente ditas, mas também através da inclusão dos componentes deste mosaico em Unidades de Conservação.
