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ESTRUTURA DA COMUNIDADE DE PRIMATAS NA REGIÃO DO TEPEQUÉM, RORAIMA, AMAZÔNIA BRASILEIRA.

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Orientador: Antonio Rossano Mendes Pontes PhD

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Resumo

O impacto antrópico sobre áreas florestadas vem gerando alterações na estrutura da comunidade de primatas em diversas regiões do país. Mesmo em áreas preservadas, competição e distribuição dos recursos podem se tornar importantes determinantes da distribuição desses animais. Com o objetivo de avaliar a influência da ação antrópica e fitofisionomia local sobre a comunidade de primatas e avaliar a dinâmica das populações ao longo do tempo em uma área preservada foram conduzidos inventários e coletas de dados ambientais em uma área impactada, o Assentamento Bom Jesus em 2013, e de uma área preservada, a ESEC Maracá nos anos de 2012, 1997/1998 e 1992, em Roraima. A ESEC Maracá apresentou maior diversidade, abundância e biomassa relativa total de primatas por 10 km andados e percentual de floresta de terra firme, porém menor equitabilidade e percentual de floresta mista em relação à área impactada, apesar disso, as diferenças de parâmetros ambientais e abundância de primatas entre as duas áreas não foram significativas. As variáveis dominância e densidade de árvores com DAP≥10, número de clareiras e corpos d'água melhor explicaram a variação nas abundâncias dos primatas nas áreas. Na ESEC Maracá, ao longo de três anos, foi evidenciado mudanças no tamanho médio de grupos de primatas, e nas abundância e biomassa relativas de algumas espécies, ainda assim, apesar das tendências observadas, as diferenças encontradas não foram significativas.

Palavras-Chave: Primatas, ESEC Maracá, atividade antrópica, uso de habitat, dinâmica de populações.

Abstract

The anthropogenic impact on the forested areas has provoked changes in the primate community structure in many regions of the country. Even though in undisturbed areas, competition and resources distribution may become important determinants of animal distribution. In order to assess the influence of anthropogenic activities and local phytophysiognomies on the primate community, furthermore, to assess the dynamics of the primate populations along time in an undisturbed area we carried out inventories and environmental data collection into a disturbed area in 2013, Bom Jesus settlement, and into a protected area, Maracá Ecological Station in 1992, 1997/1998 and 2012, in Roraima, northernmost Brazilian Amazon. The Ecological Station presented higher diversity, relative abundance and biomass by 10 km walked and terra firme forest percentage however lower evenness and mixed forest percentage compared to impacted area. Nevertheless, differences in environmental parameters and primate abundance between the two areas were not significant. The variables absolute dominance and density of trees with diameter at breast height ≥ 10, number of glades and number of water bodies best explained the variances in primate abundance in the areas. At Maracá Ecological Station, in three years, we evidenced changes in average group size, relative abundance and biomass of some primate species, even so, despite the tendeces showed, the found differences were not significant, as well.

Key words: Primate, Maracá Ecological Station, anthropogenic activities, habitat use, population dynamics.

SUMÁRIO

1. FUNDAMENTAÇÃO TEÓRICA

O Brasil abriga a maior diversidade de mamíferos do planeta com 710 espécies registradas (REIS *et al.*, 2011; PAGLIA *et al.*, 2012; com adições de GREGORIN, TAHARA e BUZZATO, 2011; GUALDA-BARROS, NASCIMENTO e AMARAL, 2012;; MENDES PONTES *et al.*, 2013) dentre esses, destaca-se a maior variedade de primatas no mundo com 116 espécies nativas (MITTERMEIER, RYLANDS e WILSON, 2013). Destas, oito estão criticamente ameaçadas de extinção, que são *Cebus kaapori*, *Sapajus flavius, Sapajus xanthosternus, Chiropotes satanas, Leontopithecus caissara, Brachyteles hypoxanthus, Callicebus barbarabrownae* e *Saguinus bicolor* (IUCN, 2013).

A floresta Amazônica é o maior conjunto contínuo de florestas tropicais do planeta (MEIRELLES FILHO, 2006). No entanto, a sua biodiversidade de primatas varia consideravelmente, onde na região central podemos encontrar de 13 a 16 espécies vivendo simpatricamente (PERES, 1993; 1997b; 1999a; HAUGAASEN e PERES, 2005; KASECKER, 2006). A Amazônia Central apresenta solos pobres, contudo, estes possuem uma restrita camada de matéria-orgânica que se encontra na superfície oriunda da própria floresta onde os organismos vivos reciclam (ciclagem praticamente fechada) os nutrientes dispostos no ambiente, além disso, as altas temperaturas ao longo do ano, somada à elevada umidade relativa do ar garante a sustentação da floresta (ROSS e BIOT, 2002).

Na região do Escudo das Guianas, por sua vez, são encontradas apenas nove espécies de primatas, dos quais até duas podem coexistir (NUNES *et al.,* 1988; LEHMAN, 2000; 2004; MENDES PONTES, PAULA e MAGNUSSON, 2012; ESTE ESTUDO). Esta região é um craton da Plataforma Sul Americana formado por rochas antigas com florestas extensas e muita água, embora apresente solos pobres em nutrientes e ácidos (THOMPSON *et al*., 1992; NASCIMENTO, PROCTOR e VILLELA, 1997; HAMMOND, 2005).

Os primatas representam grande parte da riqueza de mamíferos do país, ficando atrás apenas dos roedores e dos morcegos (PAGLIA *et al*., 2012), eles são também parte de processos ecológicos de suma importância para a manutenção das florestas, como por exemplo, na dispersão de sementes (CHAPMAN e CHAPMAN, 1995; CHAPMAN e ONDERDONK, 1998; CARDOSO, et al., 2011; TUCK HAUGAAUSEN *et al*., 2012; CHAPMAN *et al*., 2013; LEVI e PERES, 2013). Além disso, muitos fatores podem ser determinantes para a diversidade de primatas em uma região, os quais podem ser de ordem natural ou antrópica.

Entre os fatores naturais podemos citar variação no tempo (MILTON, 1982), que está diretamente ligado à variação sazonal do ambiente (EMMONS, 1984), por exemplo, a biomassa de espécies folívoras como *Alouatta* tende a aumentar com a sazonalidade (PERES, 1997a). Ambientes mais sazonais podem apresentar recursos melhor palatáveis aos primatas em maior quantidade e de melhor qualidade (JANZEN, 1975; CHAPMAN e BALCOMB, 1998).

A variação no espaço também é determinante para a diversidade de primatas, pois o número de espécies em uma área é influenciado pela forma que estas dividem as principais dimensões do nicho (LEHMAN, 2004). Sendo assim, espécies simpátricas podem utilizar os tipos de florestas de forma diferenciada, tendo acesso aos recursos específicos e evitando competição (MITTERMEIER e VAN ROOSMALEN, 1981; PERES, 1994; 1997b; KASECKER, 2006).

Um tipo de variação no espaço seria a heterogeneidade do habitat, que significa que quando mais diverso em tipos de florestas o local é, maior a probabilidade de se encontrar espécies de primatas (LEHMAN, 2004; HAUGAAUSEN e PERES, 2007). Outro tipo de variação espacial seria o uso diferenciado do dos estratos florestais (FLEAGLE e MITTERMEIER, 1981), sendo que espécies menores tendem a usar os estratos mais baixos da floresta, enquanto que espécies maiores preferem os estratos mais altos (MITTERMEIER e VAN ROOSMALEN, 1981; MENDES PONTES, 1997; CHAGAS e FERRARI 2010), além disso, espécies mais generalistas são capazes de se distribuir mais uniformemente entre os estratos (MITTERMEIER e VAN ROOSMALEN, 1981). Ambos são fatores importantíssimos que possibilitam a coexistência de primatas (MENDES PONTES, 1997; WARNER, 2002).

Os *Ateles* sp. (primatas especialista) preferem áreas de terra firme (LEHMAN *et al*., 2006), enquanto que espécies do gênero *Cebus* e do gênero *Sapajus*, que são conhecidas por sua grande adaptabilidade, flexibilidade comportamental (FRAGASZY, VISALBERGHI e ROBINSON, 1990) e sucesso adaptativo ligado à sua dieta generalista (EISENBERG e REDFORD, 1999), são mais versáteis quanto ao uso dos ambientes, e árvores de diferentes tamanhos (TERBORGH, 1983; PERES, 1993). Mittermeier e Roosmalen (1981), contudo, descreveram uma diferenciação comportamental entre *Cebus* spp. e *Sapajus apella*, onde eles notaram *S. apella* como sendo mais generalista e ocorrendo em todos os tipos florestais, enquanto que o *Cebus* spp. ocorria em florestas mais altas, e estavam mais restritos aos estratos verticais medianos à mais baixos na floresta.

Eles também notaram que *Ateles paniscus paniscus* era uma das espécies mais restritas, visto que ela foi encontrada exclusivamente em florestas altas e em estratos mais altos. *Saimiri* spp. ocorre principalmente em florestas mais baixas e em estratos mais baixos, enquanto que *Alouatta* spp. prefere florestas mais altas, mas ocasionalmente entra em outros tipos de florestas, além de ficar em estratos médio a altos (MITTERMEIER e ROOSMALEN, 1981).

Limites geográficos de rios podem influenciar diretamente na distribuição de primatas (PUERTAS e BODMER, 1993) além dos níveis de água de uma região (DESBIEZ, BODMER e TOMAS, 2010; BENNETT, LEONARD e CARTER, 2001). Espécies como *Ateles* tendem a ser sensíveis a alagamentos (JOHNS e SKORUPA, 1987), enquanto que *Cebus* pode definir a área de uso de acordo com a presença de água (CAMPOS e FEDIGAN, 2009), e *Saimiri* são conhecidos por favorecerem áreas alagadas (KASECKER, 2006).

Para pequenos mamíferos, fatores como o nível de alagamento na estação chuvosa têm um papel importante em sua distribuição e abundância (AUGUST, 1983). O regime de alagamento das florestas pode alterar os padrões de extensão de área de uso (PERES, 1997b; LEHMAN, 2000). Peres (1999a), em seu estudo sobre os efeitos do tipo de florestas na comunidade de primatas registrou que a densidade e biomassa de primatas em florestas de várzeas são duas vezes maiores do que em florestas de terra firme. Além disso, ele notou que as florestas de terra firmes da Amazônia Central estavam sobre um regime rígido de nutrientes por causa do solo pobre em que se encontravam solo este, que se assemelha bastante com os solos do Escudo das Guianas.

Eventos climáticos extremos como, por exemplo, o El Niño, em muitos lugares podem causar secas severas, estas estão diretamente ligadas à sobrevivência de árvores e produção de frutos, o que pode afetar a diversidade de árvores e a produtividade no local (WHRIGHT *et al*., 1999; BARLOW e PERES, 2004).

A diversidade florística de uma área pode determinar riqueza e abundância de primatas (PUERTAS e BODMER, 1993). As terras firmes na Guiana possuem uma baixa diversidade e abundância de espécies de plantas de alto valor de consumo por primatas, como por exemplo, as plantas da família Moraceae (TERBORGH e ANDRESEN, 1998). Essa família possui três espécies de árvores que são recursos alimentares em períodos críticos de baixa abundância de frutos (MENDES PONTES, 1997).

Outros grupos de plantas que têm desempenhando um papel importantíssimo para os primatas são as palmeiras. Espécies como *Astrocaryum* sp. e *Attalea* sp., representam um recurso alimentar crítico quando o alimento é escarço (TERBORGH, 1983; SPIRONELLO, 1991). Os frutos maduros e imaturos de algumas espécies estão disponíveis no ano todo, inclusive na estação seca, quando a disponibilidade de frutos de polpa é reduzida (SPIRONELLO, 1991; PERES, 1994).

A variação da composição florística latitudinal e longitudinal é um importante determinante na composição de frutos. Além disso, a produção de frutos tem um efeito direto na biomassa e riqueza de primatas, ou seja, assim que a produção de frutos aumenta, concomitantemente aumenta a biomassa e diversidade das espécies de primatas (STEVENSON, QUIÑONES e AHUMADA, 2000). Os primatas dão preferência à áreas com alta abundância de frutas (BRUM, 2011), nesses locais, eles tendem a ter uma área de uso reduzida (HANYA *et al*., 2006). No geral, as espécies de maior porte tendem a consumir frutos e folhas, enquanto os de menor porte se alimentam principalmente de insetos e exsudados (FLEAGLE, 1988).

Os pequenos primatas estão, também, relacionados com a complexidade do habitat (AUGUST, 1983). Segundo Schwarzkopf e Rylands (1989), reservas estruturalmente complexas são aquelas com maior número de árvores, maior número de lianas e uma baixa porcentagem média de árvores com DAP (Diâmetro à altura do peito) maior do que 10 cm. Essas características estão associadas com uma maior riqueza de espécies de primatas.

Em se tratando de fatores de ordem não natural, temos no topo da lista a ação antrópica, que pode causar alterações de grande magnitude na vida dos animais (CLARCKE, COLLINS e ZUCKER, 2002; RILEY, 2007). Tais atividades como queimadas, desmatamento e caça, têm alterado a composição de primatas de determinadas áreas (MICHALSKI e PERES, 2005). Em assentamentos a abundância de primatas tem sido afetada negativamente a em razão dos níveis de pressão de caça e de desmatamento (BOYLE, 2008). Espécies com maior taxa de reprodução tendem a persistir em áreas impactadas, espécies com maior tempo de geração são mais vulneráveis a declínios de população, o que geralmente está ligado às espécies de maior biomassa (BODMER, EISENBERG e REDFORD, 1997).

Em florestas de alto impacto de caça, a biomassa de grandes primatas tem decrescido (PERES, 1990; 2000; PERES e NASCIMENTO, 2006), chegando a ser 27% menos abundantes em áreas com forte pressão de caça do que em áreas com pressão de caça mais fraca (CULLEN, BODMER e PÁDUA, 2000). Nesses locais, grandes dispersores de sementes foram extintos e os de médio porte reduzidos, afetando assim a distribuição de muitas árvores frutíferas gerando consequentemente alterações de paisagens (NUNEZ-ITURRI, OLSSON e HOWE, 2008).

Contudo, a intensidade da caça pode variar regionalmente, e depende da cultura da população local, que vai determinar que espécies serão caçadas, (ROBINSON, 1996) e a biomassa total retirada do ambiente (MELO, 2012). Os assentamentos possuem padrões diferentes de nível de impacto e de caça (ESCAMILLA *et al*., 2000). Além disso, onde as florestas são contínuas as populações de mamíferos tendem a resistir à pressão de caça (ROBINSON, 1996). Nessas florestas, a caça sozinha não é um fator agravante devido ao efeito fonte dreno, onde os habitat com baixa população de mamíferos dependem a imigração das espécies de uma fonte de alta qualidade (PULLIAM e DANIELSON, 1991) permitindo que em alguns lugares a caça seja sustentável a longo prazo (PERES e NASCIMENTO, 2006).

O desmatamento e o corte seletivo causam efeitos de grande importância no ambiente como erosão do solo e exaustão de nutrientes, incêndios, mudanças no regime hidrológico e perda de biodiversidade (FEARNSIDE, 2005). Os primatas podem responder de forma diferenciada ao corte de árvores, o que pode estar diretamente relacionado com a composição florística da área (STEVENSON, QUIÑONES e

AHUMADA, 2000), ao nível de destruição da vegetação local (JOHNS, 1985) e ao tipo de espécies vegetais removidas pelo corte seletivo, o que pode levar a uma depleção de recursos na área (JOHNS, 1985; CHAPMAN e PERES, 2001).

A dieta das espécies de primatas pode determinar a sua sobrevivência no local, espécies generalistas tendem a sofrer menos influência do corte seletivo, ou em alguns casos, serem beneficiadas (ISABYRE-BASUTA e LWANGA, 2008). O grau de frugivoria e o tamanho do corpo das espécies apresenta relação negativa com a sobrevivência das espécies em áreas perturbadas (JOHNS e SKORUPA, 1987). *Callicebus* spp. são conhecidos por serem afetados pelas derrubadas de árvores, embora eles ocorram em áreas com maior pressão de caça, estes animais vivem em grupos pequenos ocupando territórios também pequenos, além disso, podem adotar um orçamento de energia altamente conservativo e aumentar a dieta de folhas em relação à de frutos (MICHALSKI e PERES, 2005).

A degradação das florestas resultante do corte seletivo e dos incêndios facilitados pelo desmatamento vem gerando um processo de fragmentação, que é quando a cobertura florestal original é reduzida a manchas pequenas e cada vez mais isoladas (FAHRIG, 2003). A presença de água e o nível de perturbação nos fragmentos são importantes determinantes da presença de alguns primatas e de carnívoros (MICHALSKI e PERES, 2005).

O tamanho do fragmento está positivamente relacionado com a riqueza de primatas (BOYLE e SMITH, 2010). Animais em ambiente fragmentados são mais acessíveis aos caçadores (ROBINSON, 1996), além disso, a perda de dispersores acarreta em uma modificação nas comunidades de árvores em áreas fragmentadas (HOWE, 1984). A qualidade dos remanescentes de floresta é também um fator importante na determinação da ocupação do fragmento pelos primatas, particularmente aqueles que ocupam ambientes com alta área basal e dossel fechado como *Ateles* spp. (MICHALSKI e PERES, 2005).

Com o processo de corte seletivo, um prejuízo muito maior do que a quantidade de árvores removida pelo corte propriamente dito é gerado, por exemplo, no Pará, para cada árvore retirada, 27 outras morrerão ou serão severamente prejudicadas (VERÍSSIMO *et al*., 1992). Somado a isso, a perda total de árvores resultante do corte seletivo cria aberturas que permitem a ação do sol e do vento criando assim ambientes favoráveis aos incêndios (FEARNSIDE, 2005). Áreas que sofrem queimadas são preditoras negativas da diversidade de primatas, onde, por exemplo, espécies como *Alouatta* sp. e *Calithrix* sp. são afetadas pela ação do fogo (MICHALSKI e PERES, 2005).

A mortalidade de plantas em áreas sujeitas a incêndios está relacionada ao tamanho destas, sendo que árvores maiores e mais largas são mais resistentes do que as plantas do sub-bosque (PERES, 1999b), além disso, o efeito das queimadas no ambiente pode se estender até longo prazo (PERES, BARLOW e HAUGAASEN, 2003). No sub-bosque o fogo afeta principalmente pequenos artrópodes (PERES, BARLOW e HAUGAASEN, 2003), estes organismos, por sua vez, são fonte de alimento imprescindível para espécies generalistas como *Cebus*, *Sapajus* e *Saimiri* (TEHBORGH, 1983), logo, a depleção dos estratos mais baixos está diretamente ligada à baixa abundância de espécies insetívoras (EMMONS, 1984; PERES, BARLOW e HAUGAASEN, 2003).

Sintetizando, as diferenças entre as composições de mamíferos em uma área estão mais relacionadas o tipo de ambiente e com a história de perturbação antropogênica na área. O regime de perturbação dentro dos fragmentos florestais é um determinante da taxa de extinção local de primatas e de carnívoros. Com isso, estudos sobre a comunidade de primatas tanto em áreas degradas como em áreas preservadas, ajudam a entender a ecologia desses animais, bem como o papel deles no ecossistema, e a influência do ambiente e seus estados atuais, sobre as espécies. O melhor entendimento de como as espécies respondem aos fatores ambientais e antrópicos é valor inestimável quando se tem em vista a conservação dos primatas.

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3. OBJETIVOS

3.1. Objetivo geral:

Determinar a estrutura, avaliar a riqueza, abundância e diversidade da comunidade de primatas na região do Tepequém, estado de Roraima, extremo norte da Amazônia brasileira.

3.2. Objetivos específicos:

3.2.1. No cenário proposto, formado por duas regiões: (i) uma floresta protegida (legalmente preservada) e uma (ii) floresta impactada, numa região de assentamento humano:

a) Determinar a riqueza, abundância, biomassa e diversidade de primatas.
b) Relacionar os componentes estruturais do ambiente com a comunidade de primatas, e determinar a preferência do uso do habitat pelas espécies.
c) Verificar se a riqueza e os parâmetros de abundância variam de acordo com a estrutura do habitat.
d) Avaliar como o impacto antrópico pode afetar a riqueza e os parâmetros de abundância do estoque local e regional de primatas.

3.2.2. No cenário proposto de uma região legalmente preservada avaliada em três anos:

a) Determinar a riqueza, abundância, biomassa e diversidade de primatas.
b) Relacionar os componentes estruturais do ambiente com a comunidade de primatas, e determinar a preferência do uso do habitat pelas espécies.
c) Verificar se a riqueza e os parâmetros de abundância variam de acordo com a estrutura do habiat.
d) Verificar se a riqueza e os parâmetros de abundância variam ao longo dos anos, e como variam.

4. CAPÍTULO 1

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Rodrigues, C. M. & Mendes Pontes, A. R. Influence of Human Impact on Primate Community in Brazilian Amazon Northernmost, Roraima.

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Abstract

Primate communities have been affected by a range of environmental variables, and in the last decades they have been also affected by a sum of strong anthropogenic pressures. Thus, we aimed to test the influence of anthropogenic activities or/and on vegetation structure on primate community, and determine which environmental variables are important for primate species. We assessed the primate community an the environmental variables from two areas at northern Brazilian Amazonia, one protected

(Maracá Ecological Station) in 2012 and one disturbed (Bom Jesus settlement) in 2013, by using line transect method and we tested the differences in diversity and abundance parameters between areas. Although primate richness and diversity were higher at Maracá, we found no significant differences in the primate abundance, biomass and average group size between the areas. However, species' abundance and biomass in the upper strata were higher at the settlement. Forest at Maracá was more diverse in habitat, and presented larger trees, more glades and water source, whereas, at the settlement, forest were denser, higher and presented more tree with diameter at breast height > 10 cm. Water availability and tree diameter were very important to *Saimiri sciureus*, whereas, *Alouatta macconelli* and *Ateles belzebuth* tended to relate to forest glades and vegetation height, *Callicebus lugens* was negatively correlated to water source. Human impacts may not be directly affecting the primate communities in the northern Roraima, but, in a long-term view, unless strict conservation action takes place, will lead to local diversity depletion.

Keywords: Human impact, Settlement, Maracá Ecological Station, Primate Community, Northern Amazon.

Introduction

Primate richness in the Northern Brazilian Amazonia has been considered one of the lowest of the Neotropics (Lehman 2000; 2004; Mendes Pontes 2012), with five species, in average, per primate assemblage (Mendes Pontes 1999; Nunes et al. 1988). Additionally, primate average group size, relative abundance and biomass are also considered one of the lowest of the Neotropics (Mendes Pontes 1999; 2004). Into this region, overall primate assemblages' mean group size, relative abundance and relative biomass are higher in protected areas (e.g. Viruá National Park, Maracá Ecological Station and reserves at French Guyana), sometimes twice or three times higher compared to disturbed areas (e.g. settlements in Roraima and French Guyana) (calculated from data available in Alves 2012; Cordeiro 2008; Melo 2012; Mendes Pontes 1999; Thoisy et al. 2005).

Several natural effects and environmental variables can affect primate diversity (Defler 1996), for instance, soil nutrients and fertility (Defler 1996; Gentry and Emmons 1987), and seasonality or amount of rainfall (Emmons 1984) and severe droughts, can affect plant species richness, tree survival and fruit production (Barlow and Peres 2004; Wright et al. 1999).

Others variables such as habitat type (Haugaasen and Peres 2005) and complexity (Schwarzkopf and Rylands 1989), proximity to flooded areas (Haugaasen and Peres 2005) and water levels (Desbiez et al. 2010), seasonality (Branch 1983) and fruit abundance (Brum 2011; Mendes Pontes 1999; 2000; 2004; Mourthé 2012; Robinson and Redford 1986) have a paramount role in primate diversity. Habitat heterogeneity is a major factor which allows sympatric species to live together without competition (Mendes Pontes 1997; Warner 2002), as well as spatial use of the habitat (Fleagle and Mittermeier 1981).

Anthropogenic disturbances, mainly found in human settlements have been, also, influenced primate communities, especially due the hunting and deforestation (Boyle 2008). In areas regularly hunted, large primates have been extirpated and medium-sized primates are reduced 61% compared with protected forests (Nunez-Iturri et al. 2008). Significant declines in the biomass of large-bodied species have been recorded in several Neotropical areas under hunting pressure (Bennett et al. 2001; Carrillo et al. 2000; Peres 1997; Sussman and Phillips-Conroy 1995; Wright et al. 2000). These species are the main responsible for the larger amount of primate biomass in an area (Moura 2007; da Silva et al. 2005) and seed dispersal (Chapman and Onderdonk 1998). According to Johns and Skorupa (1987), the survival rate is related to the body mass, and in addition, the level of frugivory has a negative relationship to survival in disturbed areas. Bodmer et al. (1997) says that primate species with lower reproductive rates, which is associated with larger primate species, are more vulnerable to a decline in population.

The human disturbance overall is likely to affect plant richness, distributions and, consequently, production (Chapman and Peres 2001; Johns 1985). Resource availability can influence primate group size either by limiting the number of animals an area can support or by influencing foraging efficiency (Chapman and Chapman 2000; Terborgh 1983). An increase in group size will lead to an increase in the area that must be covered to find adequate food supplies, in other words, to supply the needs of the whole group in a specific period of time, all group members would travel further and spend more energy than would be in case they would forage in smaller groups (Milton and May 1976).

Small primate species tend to be generalists (Terborgh 1983) and this feature may allow their persistence in areas under anthropogenic pressure (Michalski and Peres 2005). Most of them are non-game species, which in areas where game-species abundance and biomass decrease, their abundance tends to increase (Lopes and Ferrari 2000), leading to a slight decrease in overall primate abundance. In many areas, nevertheless, the disturbances are so aggravating that even smaller primate's abundance is affected (Nunez-Iturri et al. 2008; Puertas and Bodmer 1993).

Other problematic faced by the primate species in disturbed areas are forest burning, selective logging and, hence, forest fragmentation. Forest burning is a negative predictor of primate richness, and primate species such as *Alouatta* spp., *Callithrix* spp. and *Callicebus* spp. are directly affected (Michalski and Peres 2005; Peres et al. 2003). Regarding selective logging, primate species can respond in different ways, and it will depend on the phenological composition of the area and even the animal's diet, where, unlike large-bodied specialists, small generalist species tend to be less affected (Isabyre-Basuta and Lwanga 2008), although *Callicebus* spp. monkeys are known to be affected by selective logging (Johns 1991; Michalski and Peres 2005).

In continuous forest, however, mammalian hunting by itself may not be too aggravating due the possibility of species resettlement, in which mammal populations from low-quality habitats rely on immigration from a source of high-quality habitat (Pulliam and Danielson 1988). Furthermore, human settlement areas present different patterns of impact (Escamilla et al. 2000) and the hunting effort may vary depending on the region and local taboos (Robinson 1996). Thus, impacted areas with no hunting pressure, primate abundance tend to be similar to the protected areas (Cullen et al. 2001).

Thus, in this study we propose to assess the diurnal primate community in two areas, a disturbed and a protected area in Roraima, northernmost Brazilian Amazon, in order to determine the importance of anthropogenic activities, vegetation structure and environmental variables on their dynamics.

Methods

Study sites

The study sites were placed in northernmost Brazilian Amazon, Roraima, which belongs to the Guiana Shield. Within this region assessed two areas, which were: (a) one area under anthropogenic pressure, Bom Jesus settlement, and (b) one which is legally protected, Maracá Ecological Station (Figure 1).

The region, where both study sites are placed, is situated in a transition zone between Tropical Rain Forest and Wooded Savanna (Milliken and Ratter 1990). The local vegetation is composed mainly by semideciduous submontane forest with uniform canopy followed by dense ombrophilous submontane forest with emergent canopy and presents, as well, small areas of secondary vegetation with palm trees and seasonal semideciduous forest with emergent canopy (IBGE 2005a).

The general Köppen classification to northern Roraima is Aw, but, two specifics climatic types can be found in this region, which are, Equatorial humid (with about three dry months) and Tropical equatorial zone, semi humid (with four to five dry months) (IBGE 2002). Temperature can range from 20 to 40 ºC (Mendes Pontes 1994), and rainfall can be under 100 mm during dry season (Sombroek 2001) and, during the wet season, rainfall can reach 2000 mm (Barbosa and Ferreira 1997; Mendes Pontes 1994).

Maracá Ecological Station

Maracá is a fluvial island situated between two channels which arise from the bifurcation of the Uraricorea River. The northern channel, Santa Rosa, ranges about 105 km and the southern channel, Maracá, ranges about 100 km, thenceforth, the two channels come together to form, once more, the Uraricoera River (Milliken and Ratter 1990).

The average rainfall in the island is 1500 mm and the mean temperature is about 30ºC. Both rainfall and temperature can vary considerably throughout the year which presents well determined wet (April to September) and dry (October to March) seasons (Mendes Pontes 1994; 2000; Thompson et al. 1992)

The predominant forest types at the Ecological Station are terra firme forest and mixed forest (Mendes Pontes 2000) and the altitude can vary from 74 m to about 180 m, being on average, flatter in the east (data available in Maracá Ecological Station official website: http://esecmaracarr.blogspot.com.br/).

The fauna in the Maracá Ecological Station is relatively poor with low abundance and densities (Haugaasen and Peres 2005; Mendes Pontes 2004; Mendes Pontes et al. 2010). Only six primate species are recorded for the area, which are, the red howler monkey (*Alouatta macconnelli*), the white-belied spider monkey (*Ateles belzebuth*), the brown capuchin monkey (*Sapajus apella*), the cairara monkey (*Cebus olivaceus*), the squirrel monkey (*Saimiri sciureus*) and the nocturnal monkey (*Aotus trivirgatus*) (IUCN 2013).

Bom Jesus settlement

Bom Jesus area is one of the settlements projects created on October 25th, 1999 by National Institute of Colonization and Agrarian Reform (INCRA) in order to create areas for livestock and agricultural exploitation in Amazonian rainforest. The area comprises about 17 830 hectares situated in Amaraji county, northern Roraima (IBGE 2005b) and is about 41 km far from Maracá Ecological Station. The settlement is placed in the Urariquera structural geological domain (IBGE 2005c), and the local vegetation is composed mainly by semideciduous submontane forest with uniform canopy and dense ombrophilous submontane forest with emergent canopy (IBGE 2005a).

Studies with mammalian community are absent for the Bom Jesus settlement. The local primate species are probably the same expected for northern Roraima, which are the same found at Maracá Ecological Station and the white-handed titi monkey (*Callicebus lugens*) (IUCN 2013; Mendes Pontes 1994; Nunes et al. 1988).

The main human disturbances we can find at the settlement are hunting, deforestation caused by agriculture, extension livestock and selective logging and forest burning.

Sampling Design

We carried out diurnal primate surveys in three line transects each study site. Trails from Maracá Ecological Station (trails L3, L4 and L5) were 5 km long, 1 km far from each other, and every 50 meters were marked with tags made of pipe with a metal plaque on the top containing the name of the trail and the distance of the point in meters (Figure 1). The trails were part of the Biodiversity Research Program (PPBio) RAPELD grid (Magnusson et al. 2005).

At Bom Jesus settlement, we opened three trails (trails T0, T1 and T2) with 3 km extension, marked each 50 meters, as well, and 500 meters far from each other due the impossibility of finding an area which would place a three trails, with the same pattern of those from Maracá Island, without neither exiting the continuous forest nor entering any close farm (Figure 1). Trails from both study sites were totally cleaned of debris to minimize disturbance while walking.

Primate surveys

The surveys were carried out in the beginning dry season at Maracá Ecological Station (October to December 2012) and in the end of the season at Bom Jesus settlement (February to April, 2013). We performed the surveys by using the line transect method (Buckland et al. 1993; Burnham et al. 1980), wherewith we standardized 100 km diurnal effort per trail, totaling 300 km walked at each study site.

Each trail were traveled by two people simultaneously (the researcher and the guide) at a speed of 1.5 km/h, starting from 05:30 h until 16:30 h, with short regular stops (each 20 or 30 minutes) in order to seek out primates; we also had one hour break, every survey, from noon to 13:00 h.

For each primate sighting, we collected the following data: (a) primate species, (b) date, (c) time, (d) animal-observer distance, (e) angle from the trail to the animal, (f) location on the trail, (g) forest type, (g) age, (h) sex, (i) animal activity, (j) vertical stratum height according to Van Roosmalen (1985) and Mendes Pontes (1997), which are, ground, understory (0-15 m), lower canopy (15-20 m), middle canopy (20-25 m), high canopy (25-30 m) and emergent canopy (> 30 m), and (k) occasional polyspecific relationships.

Habitat structure

Phytophysiognomies or habitat types

The forest types were identified during the surveys and classified according to Mendes Pontes (1994; 1997) and Milliken and Ratter (1990).

We identified nine vegetation types at Maracá Ecological Station, which were, terra firme forest, mixed forest, carrasco, pau roxo forest (predominating *Peltogyne gracilipes* Leg. Caesalphiniacea), buritizal forest (predominating *Mauritia flexuosa* Arecaceae), lowland forest, liana lowland forest, campinarana and campina (for forest types details see Mendes Pontes 1994; 1997; 1999; 2000; Milliken and Ratter 1990).

At Bom Jesus settlement we identified six phytophysiognomies, as follow, terra firme forest, mixed forest, carrasco, lowland forest, liana lowland forest and sororocal forest (predominating *Phenakospermun* sp. Strelitziaceae).

Environmental variables

We collected environmental data, each 50 meters point marked along the trails, totaling 100 points for Maracá trails and 60 points for Bom Jesus settlement. At each point, we employed the *Point-Center Quarter*' (PCQ) method (Muller-Dombois and Ellenberg 1974) on the four closest trees with DBH (Diameter at Breast Height) > 10 (or with trunk circumference at breast height ≥ 45 cm). We estimated the four trees height, the number of lianas and identified the strata types found in the surrounding area of each point.

The data collected were used to calculate the environmental variables density and absolute dominance of trees with DBH > 10 cm, vegetation height, total basal area of trees with DBH > 10 cm, average tree diameter, number of glades and number of water bodies. The environmental parameters were calculated with the software FITOPAC 2.1.2.85.

Data analysis

In order to assess the primate community structure in both impacted and preserved areas, we calculated the following parameters: (a) sighting rate (groups/10 km walked) which consists on the number of primate records, multiplied by 10 and divided by total kilometers walked in the area, (b) average group size (individuals/ group), which consists on the number of individuals of a species divided by the number of groups, (c) primate relative abundance (individuals/ 10 km walked) which is the product between sighting rate and average group size (Chiarello 1999), and (d) relative biomass (kg/10 walked) which is product between relative abundance and average species' body mass (Galetti et al. 2009) (mean species body mass calculated from data available in Eisenberg and Redford 1999; Emmons and Feer 1997).

Primate diversity in the protected and impacted area was calculated by Shannon-Wiener diversity index, and, to test species evenness, we used Smith and Wilson Index of Specie Evenness.

Before testing the differences between data from both study sites, we performed a *Shapiro-Wilk Test* in order to assess whether data group presented normal distribution, if not, we picked up the correspondent non-parametric test.

We performed the *Student's T Test* (for independent sampling) in order to test whether differences in average group size, relative abundance and biomass, and strata use were significant. If data had no normal distribution we used *Mann-Whitney U-Test*.

To understand whether variations in environmental parameters explain primate relative abundance variations in the region, we performed a *Redundancy Analysis* (RDA). Moreover, we did a *Correlation Analysis* (CA) to verify negative or positive correlation among environmental parameters and primate relative abundance, biomass and average group size. For data with normal distributions we performed *Pearson's Correlation* and for non-parametric data we performed *Spearman's Correlation.*

In order to run the *Student's T Test* and RDA tests we used the software R Project. To run *Shapiro-Wilk Test*, *Mann-Whitney U Test* and correlations tests we used BIOSTAT 5.0 software. Overall, we assumed $P < 0.05$ (two-tailed) to indicate significant values.

Results

Samplings and studied species

We obtained 121 primate records, 82 at Maracá Island and 39 at Bom Jesus settlement. Six diurnal primate species were documented, which were: the white-belied spider monkey (*Ateles belzebuth*), the red howler (*Alouatta macconnelli*) and the cairara monkey (*Cebus olivaceus*), recorded in both study sites. The white-handed titi monkey (*Callicebus lugens*), were found only at the settlement, whereas the squirrel monkey (*Saimiri sciureus*) and the brown capuchin monkey (*Sapajus apella*) were found only at Maracá.

Species abundances parameters by studied area

Group size

Overall primate group size in the protected area were on average 4.17 ± SD 4.23 individuals per group, whereas the impacted area were 3.74 ± SD 2.05 individual per group.

We did found no significant differences in mean group size between Maracá Ecological Station and Bom Jesus settlement (Student's T test: t=-1.204, df=9, P=0.2592). *Saimiri sciureus* presented the largest mean group size into Maracá Ecological Station, while *Sapajus apella* presented the lowest mean group. Within the human settlement, *Alouatta macconnelli* obtained the largest mean group size, unlike the white-handed titi monkeys which presented the smallest groups (Table 1).

Relative abundances

The Ecological Station presented an overall primate relative abundance of 2.28 individuals/10 km walked, whereas Bom Jesus settlement presented 1.28 individuals/10 km walked. We found no significant difference in primate relative abundance comparing the studied areas (Student’s T test: t=-1.5121, df=9, P=0.1647).

Cebus olivaceus obtained the highest relative abundance into both preserved and impacted area, on the other hand, brown capuchin and white-handed titi monkey obtained the lowest relative abundances into Maracá Ecological Station and Bom Jesus settlement, respectively (Table 2).

Relative biomass

Overall, Maracá obtained 46.49 kg/10 km walked of primate relative biomass, Bom Jesus, on the other hand, obtained 26.94 kg/10 km walked, even so, we did not find any significant difference in the primate relative abundance between both areas (Student’s T test: t=-0.975, df=9, P=0.355).

Within each studied area, *A. belzebuth* and *C. olivaceus* obtained, respectively, the first and second higher relative biomass of the primates species recorded. In contrast, *S. apella* obtained the lowest relative biomass among Maracá Ecological Station species, and *C. lugens* obtained the lowest relative biomass among Bom Jesus settlement species (Table 2).

Diversity parameters and species evenness

Maracá Ecological Station showed higher species diversity (SHANON-WIENER: 1.21), although lower species evenness (SMITH AND WILSON INDEX OF

SPECIES EVENNESS: 0.28) compared to Bom Jesus settlement (SHANON-WIENER: 1.16; SMITH AND WILSON INDEX OF SPECIES EVENNESS: 0.64).

Primate *vs*. Forest Strata

Primates exploited mainly the understory and the low canopy at Maracá Ecological Station and middle canopy at Bom Jesus settlement (Figure 2). We found *Sapajus apella* and *Saimiri sciureus* (species recorded only at Maracá Ecological Station) only in the understory of the forest, with a relative abundance of, respectively, 0.1 and 2.6 ind/10 km walked, and relative biomass of, respectively, 0.3 and 2.6 kg/ 10 km walked. *Callicebus lugens*, recorded only at Bom Jesus settlement, were found only in the understory (relative abundance, 0.2 ind/10 km walked and relative biomass, 0.3 kg/10 km walked) and in the low canopy (relative abundance, 0.1 ind/10 km walked and relative biomass, 0.1 kg/10 km walked) of the forest.

Regarding to the relative abundance and biomass of the species recorded in both study sites (Figure 3 and 4), we found cairara monkey mainly in the understory at Maracá and the middle canopy at the settlement. The white-belied spider monkey was recorded mainly in low and middle canopies at the ecological station and in middle and high canopy at the settlement. The howler exploited the strata, in which it was recorded, evenly at Maracá, but, at the settlement, the species was found only in middle canopy.

Due to the few records available, we join data from understory and low canopy (0-20 m), and from middle canopy and high canopy (20-30 m) to perform the statistical test, in order to verify differences in relative abundance and biomass of primates species between the strata of the two areas. We found no significant variation in primates abundance (Mann Whitney U test: U=16.5, Z=0.6429, P=0.5203) and biomass (Mann Whitney test: U=13.5, Z=1.0714, P=0.2840) at lower strata between both study sites, on the other hand, we found a significant difference in the primate species relative abundance at the higher strata of the forest from the areas, (Mann Whitney test: U=0.5, Z=2.327, P=0.02), but not regarding to relative biomass (Mann Whitney test: U=04, Z=1.4697, P=0.1416).

Phytophysiognomics variables and environmental aspects

Maracá Ecological Station presented lower density of trees with DBH > 10, absolute dominance of trees with DBH > 10 and average vegetation height than Bom Jesus settlement. Maracá, however, presented higher average diameter of trees, total basal area, number of glades and water bodies (Table 3).

In both studied areas, the predominant forest types were terra firme forest and mixed forest (Figure 5).

Primates *vs*. Phytophysiognomies

None of the two studied areas presented primate species records in all phytophysiognomies recorded. At Maracá, we found primates in terra firme forest, mixed forest, buritizal and lowland forest, whereas, at Bom Jesus they were recorded at terra firme forest, mixed forest, lowland forest, liana lowland forest and sororocal.

At the preserved area, we recorded all five primate species in the mixed forest, and we observed squirrel monkeys in all forest types which had primate records. At the impacted area, the terra firme forest presented all four primates species recorded for the area, and we observed cairara monkeys in four of the five forest types which had primate records (terra firme forest, mixed forest, liana lowland forest and sororocal forest).

The highest primate relative abundance we found for Maracá Ecological Station was from *S. sciureus* in lowland forest and from *C. olivaceus* in terra firme forest. *A. belzebuth* obtained the highest relative biomass values in the forest types it was recorded (terra firme forest, mixed forest and buritizal forest). In the lowland forest, cairara monkeys obtained high relative biomass, although it had presented low relative abundance (Figure 6).

At the impacted area, the white-belied spider monkey obtained the highest values of relative abundance and relative biomass (Figure 7).

Primates *vs*. environmental aspects

The RDA analysis showed that the two firsts axes explained, respectively, 68.06% and 27.24% of the variations in primate’s relative abundance. Density and absolute dominance of tree with DBH > 10, number of glades and number of water bodies better explained those variations. The results have suggested that trails form the settlement were related with density and absolute dominance of tree with DBH > 10. From the three trails at Ecological Station, only trail L5 showed a slight relation with the number of water bodies, on the other hand, the others two trails showed no clear relation with the environmental variables (Figure 8).

The red howler and the white-belied spider monkey were related to the average vegetation height and the number of glades. Squirrel monkey and cairaras were related to the number of water bodies. Species placed centrally (brown capuchin and white-handed titi monkeys) did not obtain any clear relation with the environmental variables in this study.

By analyzing the relationship among the recorded primate species and the environmental variables, we found significant correlation among *S. sciureus* and total basal area of trees with DBH > 10, mean DBH and number of water bodies. The last one presented also, significant correlation with the relative abundance of *C. lugens*. *A. macconnelli* and *A. belzebuth* were correlated with the number of glades. The other correlations among primate species and the environmental variables did not show any statistical significance (Table 4).

Discussion

Primate community structure

Overall, primate species richness found in this study was as expected for the area (Cordeiro 2008; IUCN 2013; Mendes Pontes 1997; Mourthé 2012; Nunes et al. 1988), although this is considered one of the least diverse communities when compared to other regions of the Amazonian Forest (Haugaasen and Peres 2005; Kasecker 2006; Peres 1993; 1997). The low primate diversity in Rio Negro basin, within Guyana Shield is related to the poor soils (Hammond 2005; Thompson et al. 1992), which limits plant productive and influences directly in primate distribution (Defler 1996; Lehman 2004).

The variation found in primate average group size between the two, protected and disturbed, areas was low and not significant, even for *A. macconnelli* which average group size at the settlement was more than twice that recorded at Maracá Island.

Primate assemblage's average group size at Maracá Ecological Station, was about 1.6 times lower than the mean from others protected areas from the Guyana Shield (6.68 ± SD 1.92) (Alves 2012; Cordeiro 2008; Melo 2012; Thoisy et al. 2005), and about 1.5 timer lower than the mean from others records performed at Maracá (6.3 ± SD 1.06) (Cordeiro 2008; Mendes Pontes 1999; 2004; Nunes et al. 1988).

Differences in primate assemblage's average group size among protected areas were higher than among disturbed areas, where, groups size at Bom Jesus settlement, was about 0.5 times lower than the mean from others human settlements from Roraima (4.2 ± SD 0.86) (Alves 2012, Melo 2012), and about 1.2 times lower than the mean from others human settlements from Guyana (4.92 ± SD 1.02) (Thoisy et al. 2005).

Primate average group size is related the area that group must coverer in order to find adequate food supplies (Milton and May 1976). First of all, some resources (e.g. fruits) are available in patches; second, species which depend on food available in patches (e.g. frugivorous) tend to form small groups when food is scarce (Chapman and Chapman 2000).

Capuchin monkeys tend not to form subgroups; they are able to remain together under certain conditions under which other species would form subgroups, by increasing their reliance on insects which tends to be more uniformly distributed (Chapman 1990).

During the surveys we observed polyspecific associations between *Cebus olivaceus* and *Saimiri sciureus*. Polyspecific associations benefit species by increasing foraging and feeding efficiency, depending on food availability in the forest, survivorship, and most importantly predator avoidance (Terborgh 1983; Mendes Pontes 1997).

Primate's relative abundance and biomass at Maracá Ecological Station was lower compared to other studies at protected areas in Roraima (Alves 2012; Melo 2012) and even at the Unity (Mendes Pontes 1999, 2004). On the other hand it was higher compared to abundances in French Guyana (Thoisy et al. 2005). Regarding to impacted areas, data found in this study was also lower than that from others settlements in Roraima (Alves 2012; Melo 2012).

Despite overall primate relative abundance and biomass, at the impacted area have been about twice lower than in the conservation unity, the variation in species' abundance and biomass between the areas were not significant, as well.

Primate survival rate is related to body mass, and, in addition, the level of frugivory has a negative relationship to survival in disturbed areas (Johns and Skorupa 1987). The larger species (e.g. *Ateles* spp. and *Alouatta* spp.), therefore, mainly the frugi-folivorous, are responsible for the high amount of primate biomass in the area (Moura 2007; da Silva et al. 2005).

Frugivorous species (e.g. *Ateles* sp.) is related to density and distribution of food resources (Chapman 1990), which is generally distributed in clumps (Milton and May

1976). On the other hand, folivorous species (e.g. *Alouatta* sp.), depend mainly on resources which are available throughout the year and are not distributed in restricted areas (leaves) (Chapman 1897). Thus, situations in which frugivorous tend to be negatively affected, folivorous can persist with few or even no problem (Emmons 1984), since many folivorous species diet is generalist, and consist in around 49% of leaves and only 28.5% of fruit and have more types of food in their diet than spider monkeys (Chapman 1987).

If differences in primate structure found are not significant between Maracá Ecological Station and Bom Jesus settlement, what could explain those variations?

Some hypothesis may probably explain those differences in primate structure between the study sites, such as, (a) the lack of some Cebids in the impacted area (e.g. *Sapajus apella* and *Saimiri sciureus*), (b) local vegetation and habitat structure (Alves 2012; Haugaasen and Peres 2005; Lehman 2004; Stevenson 2001), (c) local fruit abundance (Lehman 2004; Stevenson 2001), (d) water source (e) Anthropogenic impacts (Johns 1985) which can also affects fruit production leading to a forest depletion (Barlow and Peres 2006; Chapman and Peres 2001; Johns 1985).

Environmental structure and habitat use

Some studies have shown the environmental structure as a key element to primate community structure (August 1983; Peres 1997; 1999). Maracá Ecological Station's forest structure is more heterogeneous than Bom Jesus, although, primate were recorded in more habitat types at the settlement (N=5), rather than in Maracá (N=4)

Bom Jesus settlement presents higher density and absolute dominance of trees with DBH > 10 cm and average vegetation height, however primate diversity seems to be more related to total basal area and high average DBH (Michalski and Peres 2005; Stevenson 2001), which we found at Maracá Island. Besides, Maracá presented higher proportion of terra firme forest, in which, primate community is known to be more diverse (Mendes Pontes 1994; 1997; 2000), furthermore, presents larger trees and 3.28 times more water sources than the settlement.

Habitat complexity by itself plays an important role in primate diversity than habitat heterogeneity (August 1983). Structurally ‘complex’ areas have high mean number of trees, high mean number of lianas, low mean percentage of large trees (> 10 cm in diameter at breast height) per quadrat, and streams (Schwarzkopf and Rylands 1989).

Sympatric species can use the forest resources in different ways in order to avoid competition, some of which may form polyspecific groups to improve foraging and defense (Chagas and Ferrari 2010; Mendes Pontes 1997). As found in this study, larger primate species (e.g. *A. belzebuth* and *A. macconnelli*) tend to use more intensely the higher strata (Buchanan-Smith et al. 2000; Kasecker 2006; Schreier et al. 2009), they were also significantly correlated to the number of glades, although we found a different pattern between both impacted and preserved area.

At Maracá Ecological Station, the understory presented high overall primate relative abundance, and low canopy obtained the highest relative biomass, whereas, at Bom Jesus settlement the middle stratum obtained higher overall primate relative abundance and biomass. At Maracá, *S. sciureus*, were recorded only at the understory, this data corroborate with Mittermeier and Van Roosmalen (1981) data, in which, *Saimiri* sp. was the only species that was not found most often in high forest, and more than 60% of all *Saimiri* observations were in the understory stratum. *Cebus olivaceus* and *Sapajus apella*, were recorded mainly at the lower strata of the forest and Alouatta macconnelli were recorded mainly at middle strata in both study sites, the same pattern was found by Mittermeier and Van Roosmalen (1981).

We found no significant difference in abundance and biomass of species at the lower forest strata (understory plus low canopy) between impacted and preserved areas, whereas, variation in species abundance and biomass in higher forest strata (middle canopy plus high canopy), between the study sites were significant.

A. belzebuth, A. macconnelli obtained higher relative abundance and biomass in the higher strata at the impacted areas and *C. olivaceus* was more abundant at the settlement but its relative biomass was higher at Maracá higher strata. Both *C. olivaceus* and *A. belzebuth* relative abundance and biomass decreased with the increasing strata height at the Ecological Station, on the other the hand, at Bom Jesus their relative abundance and biomass increase with the strata height. The increased amount of primate species in higher strata at disturbed areas, particularly those large ones which can be hunted (Bodmer et al. 1997, da Silva et al. 2005), is, probably, due to the attempt in avoiding contact with any human disturbance (Torre et al. 2000).

The absence of *Sapajus apella* and *Saimiri sciureus* has probably reduced the relative abundance and biomass at the lower strata at Bom Jesus settlement, which is mainly accessed by generalist species (Terborgh 1983). Understory and lower strata at disturbed forests tends toward depletion, that is, in increasingly stressed forests, the understory structure changes, with, subsequent loss of terrestrial herbs, epiphytes, understory shrubs, and lianas, moreover, the level of understory fertility may provide a simple indicator of overall ecosystem productivity (Gentry and Emmons 1987). A decrease in insectivorous species may be associated to a decrease of herbivorous insects in areas with poor soils and understories (Emmons 1984).

The RDA analysis showed that *Cebus olivaceus* and *Saimiri sciureus* were related with water body presence, and correlation analysis supported the data for *S. sciureus*. Kasecker (2006) showed that *Saimiri sciureus* favored the flooded areas to the unflooded. This species was also significantly correlated to areas with larger trees and was mainly found in lowland forest at Maracá.

Cebus sp. can determine the home range and core areas according to the water source distribution and in the dry season they exploit the areas close to permanent water sources, on the other hand, in the wet season they avoid those areas (Campos and Fedigan 2009). *C. olivaceus'* relative abundance and biomass was higher at terra firme forest as recorded by Cordeiro (2008) and Mittermeier and Van Roosmalen (1981), but also in lowland forest in both study sites.

Callicebus lugens was recorded only at Bom Jesus, mainly in liana lowland forest followed by terra firme forest; it was also presented a significantly negative correlation to water presence. *Callicebus* sp. is likely to be affected by forest burning and selective logging (Johns 1991; Michalski and Peres 2005). However, living in small groups with low energetic needs, allow *Callicebus* spp. to be highly tolerant to forest disturbances, since they are generalist species (Palacios et al. 1997) and also able to make use of invertebrates in their diet (Milton and Nessimian 1984).

*A. belzebuth'*s relative abundance and biomass was higher at terra firme forest in Maracá, and at lowland forest in Bom Jesus. This species is generally found in terra firme forest (Lehman et al. 2006), but, as theorized by Van Roosmalen (1985), spider monkeys should be the species most likely to use flooded forests because they have a diet composed largely of fruits, and terra firme forests are characterized by low fruit abundance and low species diversity for fruiting trees (ter Steege 1993). *A. macconnelli* were recorded mainly at mixed forest at Maracá, and in terra firme forest at the settlement.

Nowadays, human impacts at Bom Jesus settlement may not produce enough damage to affect directly the primate communities in the northern Roraima, although, long-term disturbances within the area will lead into significant changes in primate structure, which, unless conservation alternatives be implemented, will lead to local species depletion.

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Tables

Table 1. Average group size (Mean ± Standard Deviation) of primate species recorded at Maracá Ecological Station (M) in 2012 and at Bom Jesus settlement (BJ) in 2013, in Roraima, Brazilian Amazon northernmost.

Species	**M**	**BJ**
Saimiri sciureus	8.56 ± 4.47	0
Sapajus apella	3.00 ± 0	0
Cebus olivaceus	3.77 ± 4.25	3.59 ± 2.07
Alouatta macconnelli	2.14 ± 3.89	5.33 ± 2.08
Ateles Belzebuth	3.86 ± 4.25	4.54 ± 2.17
Callicebus lugens	ra[1]	1.67 ± 2.08

[1]Specie records absent in the literature for the area.

Table 2. Primate relative abundance and biomass per 10 km walked at Maracá Ecological Station (M) in 2012 and at Bom Jesus settlement (BJ) in 2013, in Roraima, Brazilian Amazon northernmost.

Species	**Relative Abundance (individuals/10 km)**		**Relative Biomass (kg/10 km)**	
	M	**BJ**	**M**	**BJ**
Saimiri sciureus	2.57	0	2.41	0
Sapajus apella	0.10	0	0.31	0
Cebus olivaceus	5.53	2.03	17.98	6.61
Alouatta macconnelli	0.50	0.53	3.68	3.92
Ateles belzebuth	2.70	1.97	22.01	16.03
Callicebus lugens	ra[1]	0.33	ra[1]	0.38
TOTAL	11.4	4.86	46.39	26.94

[1]Specie records absent in the literature for the area.

Table 3. Environmental variables, based on DBH > 10 trees' records, of Maracá Ecological Station (M), recorded in 2012, and Bom Jesus settlement (BJ), recorded in 2013, in Roraima, Brazilian Amazon northernmost.

	M	**BJ**
Tree Density (Individuals/ha)	162.33	262.92
Absolute dominance (m^2/ha)	16.51	21.38
Average vegetation height (m)	17.36	18.97
Total basal area (cm^2)	158.71	56.92
Average diameter (cm)	29.64	26.63
Number of glades	16.00	12.00
Number of water bodies	23.00	7.00

Table 4. Correlation results among primate relative abundance and environmental variables (density of trees with DBH > 10, absolute dominance of trees with DBH > 10, average vegetation height, total basal area of trees with DBH > 10, average diameter (DBH), number of glades and number of water bodies) from Maracá Ecological Station, recorded in 2012, and Bom Jesus settlement, recorded in 2013, in Roraima, Brazilian Amazon northernmost. For data with normal distributions we performed *Pearson's Correlation* (r) and for non-normal data we performed *Spearman's Correlation* (rs). (t) *Student's T Test*; (df) Degree of freedom; (P) p-value; (ns) non significative.

Species	**Tree Density**	**Absolute dominance**	**Vegetation Height**	**Total basal area**	**DBH**	**Number of glades**	**Number of water bodies**
Saimiri sciureus	rs= -0.5768; t=-1.4123; P=0.2307	rs= -0.0911; t=-1.829; P=0.8638	rs=0.0304; t=0.0607; P=0.9545	rs=0.8804; t=3.7131; **P=0.0206***	rs=0.8804; t=3.7131; **P=0.0206***	rs=0.2258; t=0.4636; P=0.667	rs= 0.8197; t=2.862; **P=0.0458***
Sapajus apella	rs= 0.6547; t=1.7321; P=0.1582	rs= 0.1309; t=0.2641; P=0.8047	rs= -0.6547; t=-1.7321; P=0.1582	rs= 0.1309; t=0.2641; P=0.8047	rs= 0.1309; t=0.2641; P=0.8047	rs= -0.4171; t=-0.9186; P=0.4103	rs= -0.1309; t=-0.2641; P=0.8047
Cebus olivaceus	r=-0.6848; t=-1.8795; df=4; P=0.1333	rs=-0.3143; t=-0.6621; P=0.5441	rs=-0.3143; t=-0.6621; P=0.5441	r=0.7591; t=2.3324; df=4; P=0.08	r=0.6268; t=1.6089; df=4; P=0.1828	r=0.1224; t=0.2466; df=4; P=0.8173	r=0.7811; t=2.5015; df=4; P=0.0666
Alouatta macconnelli	r=-0.228; t=-0.4684; df=4; P=0.6639	rs=0; t=0; P=ns	rs=0.3189; t=0.6729; P=0.5379	r=0.307; t=0.6453; df=4; P=0.5539	r=0.4021; t=0.8784; df=4; P=0.4293	r=0.9039; t=4.2276; df=4; P**=0.0134***	r=0.0102; t=0.0204; df=4; P=0.9847
Ateles belzebuth	r=-0.3383; t=-0.7191; df=4; P=0.5118	rs=0.0286; t=0.0572; P=0.9572	rs=0.4286; t=0.9487; P=0.3965	r=0.5445; t=1.2984; df=4; P=0.2639	r=0.6296; t=1.6209; df=4; P=0.1803	r=0.9155; t=4.5517; df=4; **P=0.0104***	r=0.2249; t=0.4616; df=4; P=0.6683

Callicebus lugens	rs= 0.0338; t=0.0677; P=0.9493	rs= -0.3719; t=-0.8012; P=0.4679	rs=-1.1352; t=-0.273; P=0.7984	rs=-0.3719; t=-0.8012; P=0.4679	rs= -0.5409; t=-1.2862; P=0.2677	rs= 0.3592; t=0.7698; P=0.4843	rs=-0.8452; t=-3.1623; **P=0.0341***

* Significative values.

Figures Labels

Figure 1. Location of the study sites, Bom Jesus settlement and Maracá Ecological Station, State of Roraima, Brazil (modified from Mendes Pontes 1997) and the trails surveyed in Bom Jesus settlement (T0, T1 and T2) and in the RAPELD grid from Maracá Ecological Station (L3, L4 and L5).

Figure 2. Overall primate relative abundance (individuals/10 walked) and relative biomass (kg/10 km walked) by forest strata type at Maracá Ecological Station (M), recorded in 2012, and at Bom Jesus settlement (BJ), recorded in 2013, in Roraima, northernmost Brazilian Amazonia. UN=Understory (0-15m), LC=Low Canopy (15-20m), MC=Middle Canopy (20-25m) and HC=High Canopy (25-30m).

Figure 3. Relative abundance (individuals/10 km walked) of the same primate species recorded at Maracá Ecological Station in 2012, and at Bom Jesus settlemen in 2013, by forest strata type, in Roraima, northernmost Brazilian Amazonia. Stratum symbols: UN=Understory (0-15m), LC=Low Canopy (15-20m), MC=Middle Canopy (20-25m) and HC=High Canopy (25-30m).

Figure 4. Relative biomass (kg/10 km walked) of the same primate species recorded at Maracá Ecological Station in 2012, and at Bom Jesus settlement in 2013, by forest strata type, in Roraima, northernmost Brazilian Amazonia. Stratum symbols:

UN=Understory (0-15m), LC=Low Canopy (15-20m), MC=Middle Canopy (20-25m) and HC=High Canopy (25-30m).

Figure 5. Proportion of the forest types recorded at Maracá Ecological Station (M) in 2012, and at Bom Jesus settlement (BJ) in 2013, in Roraima, Brazilian Amazon northernmost. Terra firme forest (TFF), mixed forest (MIF), carrasco forest, (CAR), pau roxo forest (PRF), buritizal forest (BUR), lowland forest (LLF), liana lowland forest (LLL), campina (CAM), campinarana (CAN) and sororocal forest (SOR).

Figure 6. Relative abundance (individuals/10 km walked) and relative biomass (kg/10 km walked) of the primate species recorded at Maracá Ecological Station in 2012, Roraima, Brazilian Amazon northernmost, by local forest types where were obtained primates records. Terra firme forest (TFF), mixed forest (MIF), buritizal forest (BUR), lowland forest (LLF).

Figure 7. Relative abundance (individuals/10 km walked) and relative biomass (kg/10 km walked) of the primate species recorded at Bom Jesus settlement in 2013, Roraima, Brazilian Amazon northernmost, by local forest types where were obtained primates records. Terra firme forest (TFF), mixed forest (MIF), lowland forest (LLF), liana lowland forest (LLL) and sororocal forest (SOR).

Figure 8. RDA analysis (biplot for first and second axes) of primate relative abundance recorded at Maracá Ecological Station (ML3, ML4 and ML5) in 2012, and Bom Jesus settlement (BJT0, BJT1 and BJT2) in 2013, in Roraima, Brazilian Amazon northernmost, related to the environmental variables density of trees with DBH > 10 (DEN), absolute dominance of trees with DBH > 10 (DOM), average vegetation height (ALV), number of glades (NCL) and number of water bodies (NCA).

Figures

Figure 1.

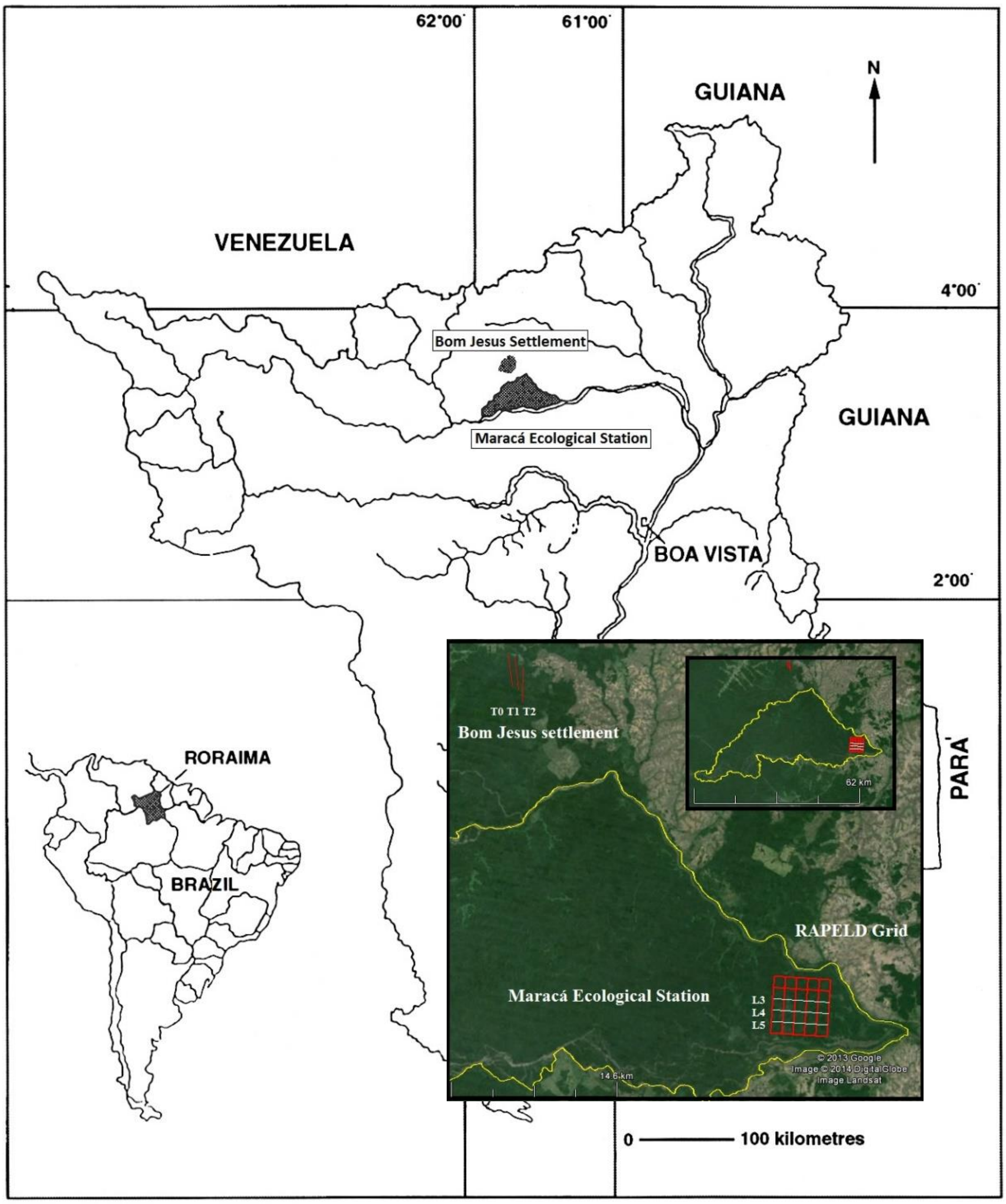
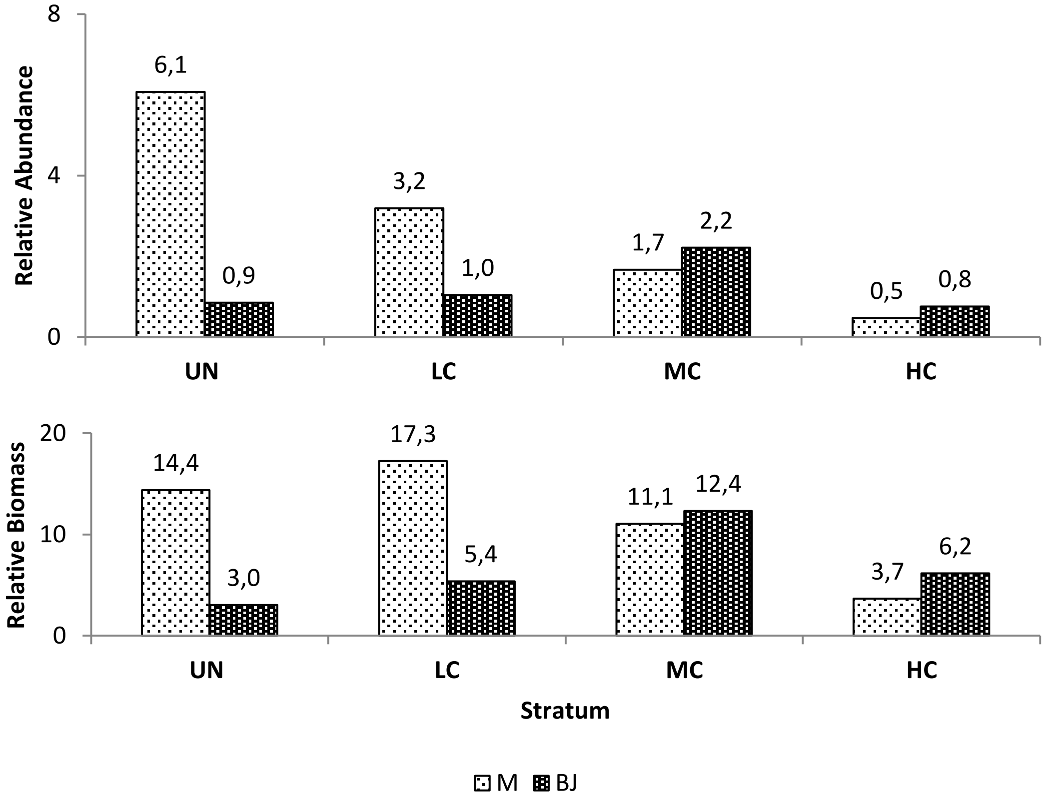


Figure 2.


Relative Abundance
8
4
0
6,1
0,9
3,2
1,0
1,7
2,2
0,5
0,8
UN
LC
MC
HC
Relative Biomass
20
10
0
14,4
3,0
17,3
5,4
11,1
12,4
3,7
6,2
UN
LC
MC
HC
Stratum
M
BJ

869 Figure 3.

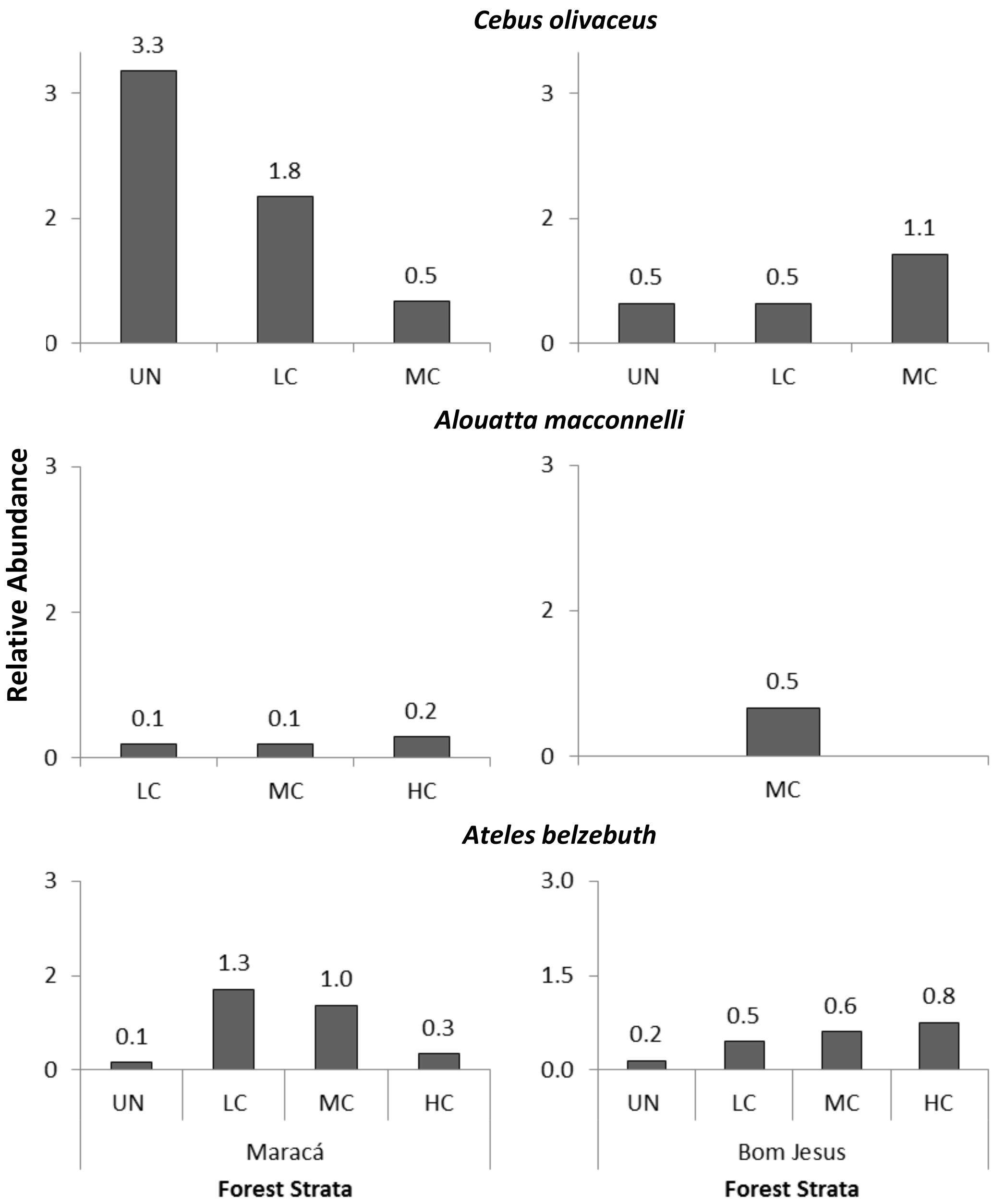
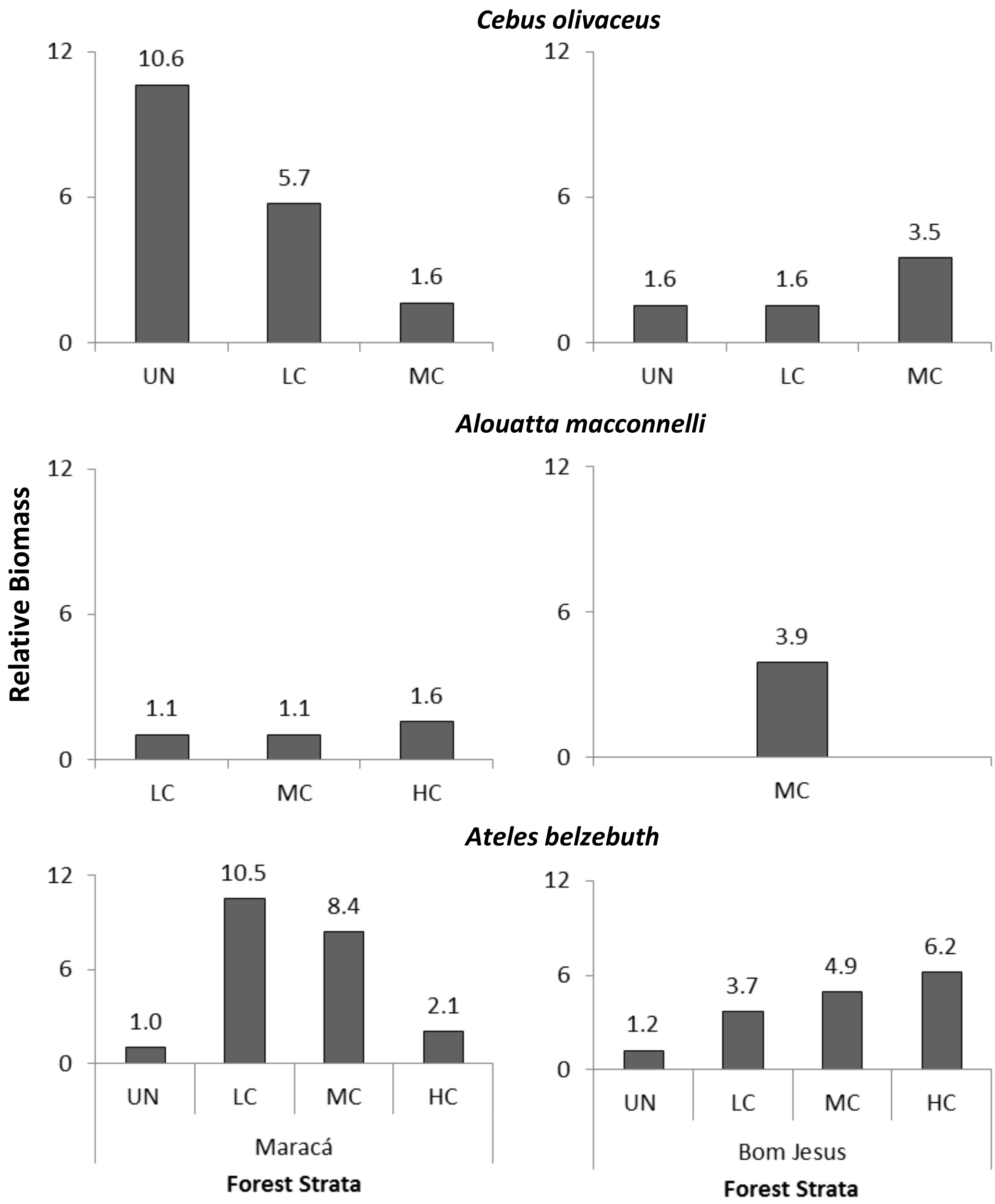
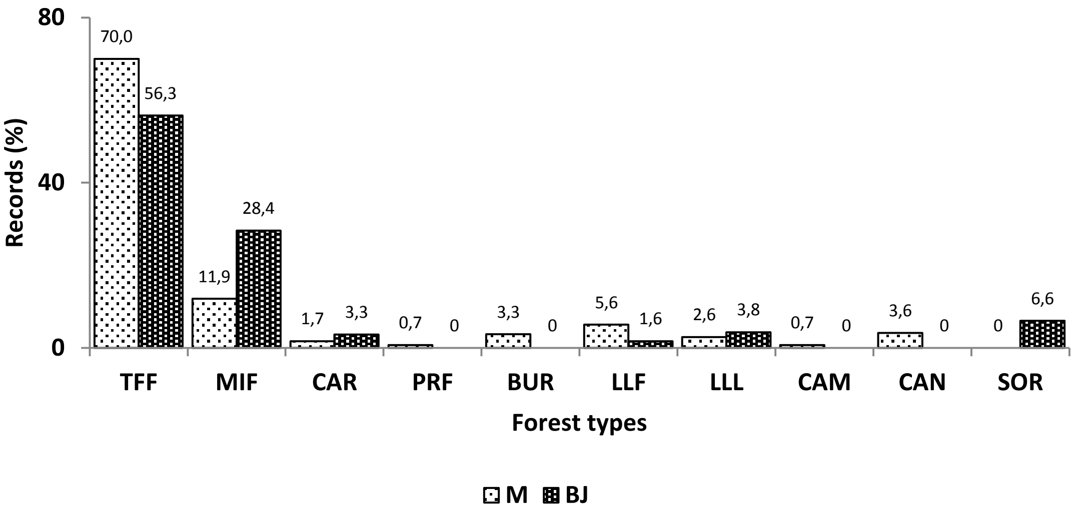

Cebus olivaceus
3.3
1.8
0.5
3
2
0
UN
LC
MC
1.1
0.5
0.5
3
2
0
UN
LC
MC
Alouatta macconnelli
Relative Abundance
3
2
0
0.1
0.1
0.2
LC
MC
HC
3
2
0
0.5
MC
Ateles belzebuth
3
2
0
0.1
1.3
1.0
0.3
UN
LC
MC
HC
Maracá
Forest Strata
3.0
1.5
0.0
0.2
0.5
0.6
0.8
UN
LC
MC
HC
Bom Jesus
Forest Strata

Figure 4.



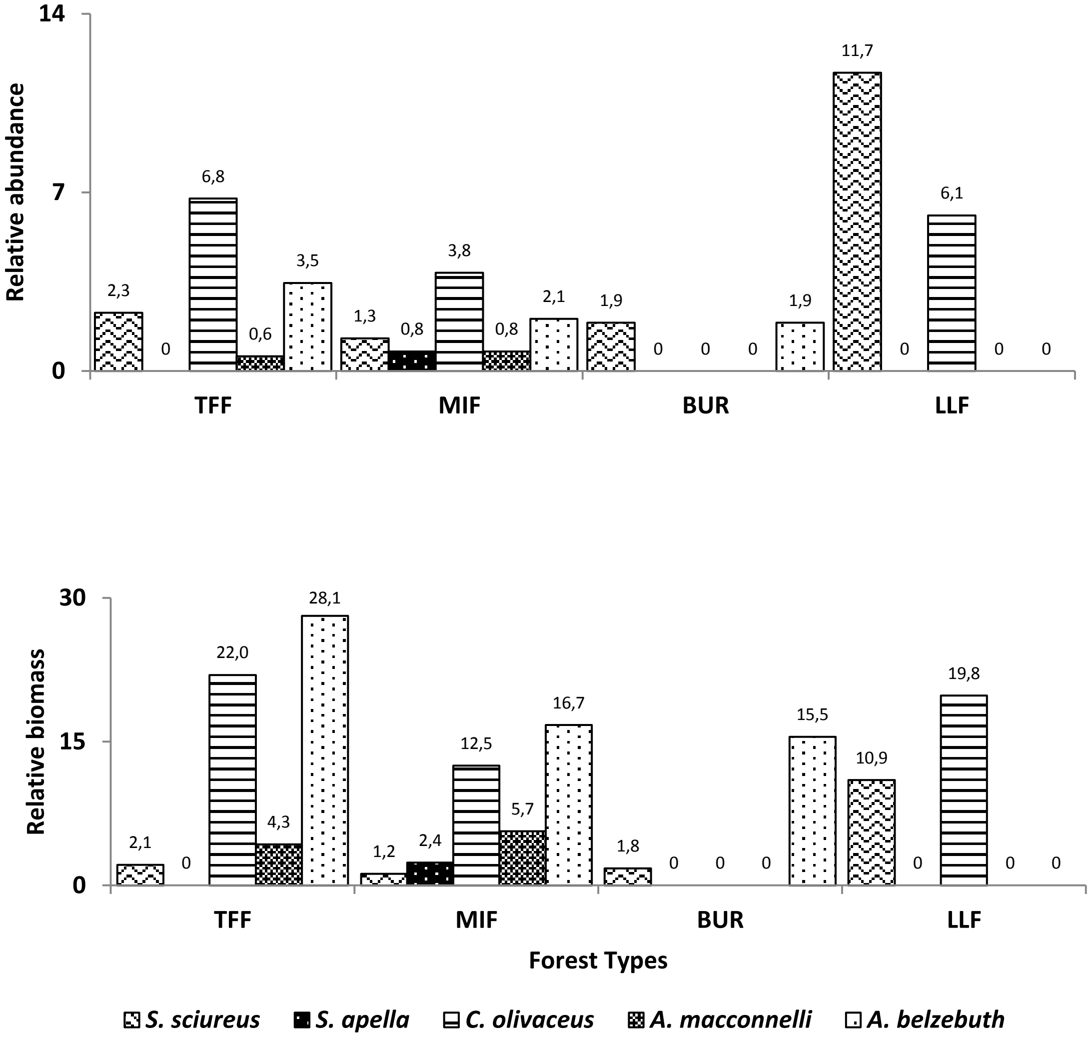
Cebus olivaceus
10.6
5.7
1.6
UN
LC
MC
1.6
1.6
3.5
UN
LC
MC
Alouatta macconnelli
Relative Biomass
1.1
1.1
1.6
LC
MC
HC
3.9
MC
Ateles belzebuth
1.0
10.5
8.4
2.1
UN
LC
MC
HC
Maracá
Forest Strata
1.2
3.7
4.9
6.2
UN
LC
MC
HC
Bom Jesus
Forest Strata

Figure 5.



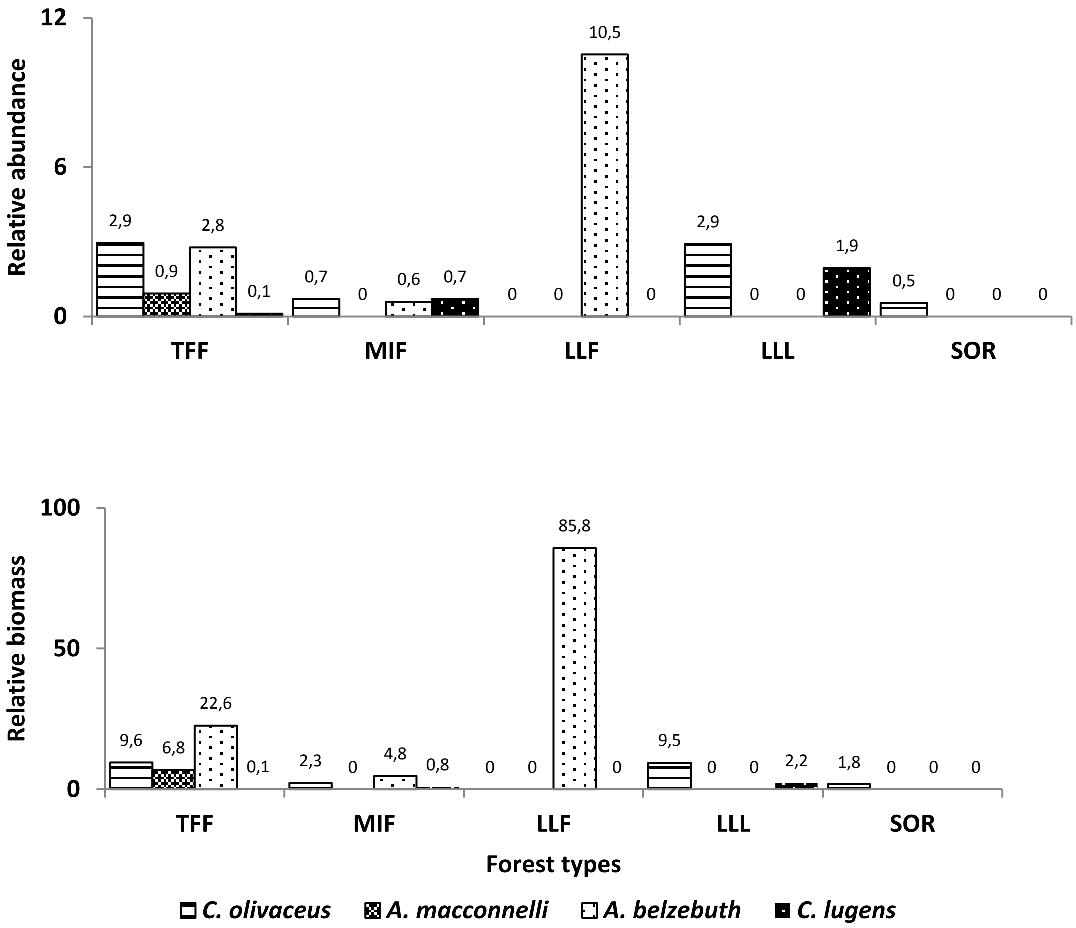
80
40
0
Records (%)
70,0
56,3
11,9
28,4
1,7
3,3
0,7
0
3,3
0
5,6
1,6
2,6
3,8
0,7
0
3,6
0
0
6,6
TFF
MIF
CAR
PRF
BUR
LLF
LLL
CAM
CAN
SOR
Forest types
M
BJ

Figure 6.



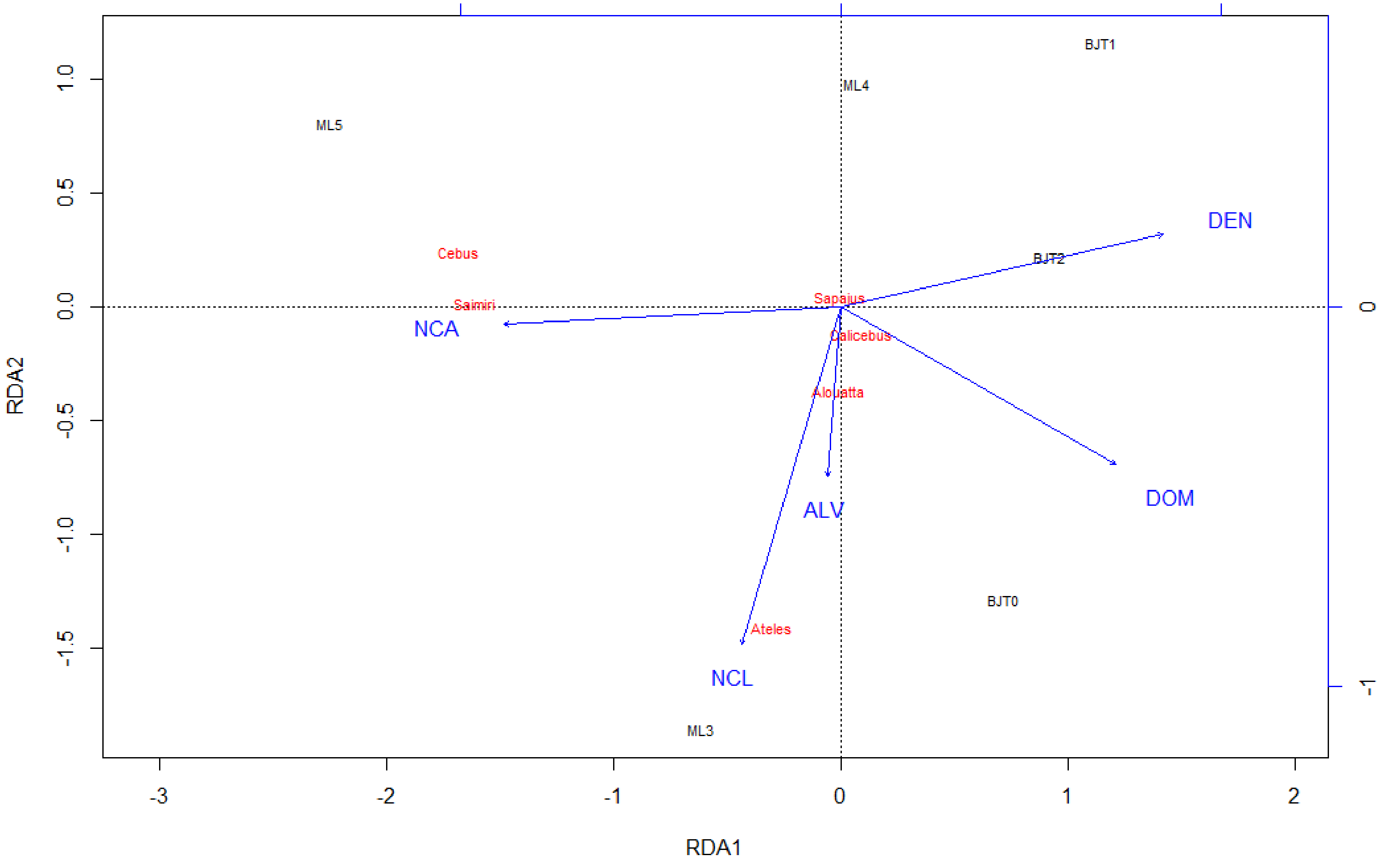
14
7
0
Relative abundance
2,3
0
6,8
0,6
3,5
1,3
0,8
3,8
0,8
2,1
1,9
0
0
0
1,9
11,7
0
6,1
0
0
TFF
MIF
BUR
LLF
30
15
0
Relative biomass
2,1
0
22,0
4,3
28,1
1,2
2,4
12,5
5,7
16,7
1,8
0
0
0
15,5
10,9
0
19,8
0
0
TFF
MIF
BUR
LLF
Forest Types
S. sciureus
S. apella
C. olivaceus
A. macconnelli
A. belzebuth

Figure 7.



Relative abundance
12
6
0
2,9
0,9
2,8
0,1
0,7
0
0,6
0,7
0
0
10,5
0
2,9
0
0
1,9
0,5
0
0
0
TFF
MIF
LLF
LLL
SOR
Relative biomass
100
50
0
9,6
6,8
22,6
0,1
2,3
0
4,8
0,8
0
0
85,8
0
9,5
0
0
2,2
1,8
0
0
0
TFF
MIF
LLF
LLL
SOR
Forest types
C. olivaceus
A. macconnelli
A. belzebuth
C. lugens

Figure 8.


BJT1
ML4
ML5
DEN
BJT2
Cebus
Saimiri
Sapajus
NCA
Callicebus
Alouatta
ALV
DOM
BJT0
Ateles
NCL
ML3
RDA2
RDA1
1.0
0.5
0.0
-0.5
-1.0
-1.5
-3
-2
-1
0
1
2
0
-1

5. CAPÍTULO 2

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Rodrigues, C. M. & Mendes Pontes, A. R. Primate community dynamics in three different periods over two decades at a Conservation Unity, northernmost Brazilian Amazon

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Primate community dynamics in three different periods over two decades at a Conservation Unity, northernmost Brazilian Amazon

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Abstract

Little is known about primate communities' structure in protected areas under a long-term assessment. Thus, we aim to assess the primate community into a protected area in three different periods, over two decades, in order to verify differences in abundance parameters along the years, and test primate community variance in habitat structure among the periods and species associations with the forests types. We carried out the study at Maracá Ecological Station in 1992, 1997/1998 and 2012 by using linear transect method and also calculated diversity parameters, average group size, relative abundance and biomass of the primate assemblage and by primate species. We found no significant evidence of population fluctuation among the periods assessed. Within each period, *S. sciureus* was obtained the largest group sizes, *C. olivaceus* presented the highest relative abundance and *A. belzebuth* obtained the highest relative biomass. Overall primate abundance and biomass was higher in seasonally flooded forests, followed by terra firme forest. The main associations found among species and forest type were for *A. belzebuth* and buritizal forest, *S. sciureus* and low seasonally flooded florests, and *C. olivaceus* together with *S. apella* and terra firme and mixed forests. The variance in primate community structure at Maracá was probably related to the each primate species' guild, resource availability and water presence as a consequence of dry season and subsequent drought. Conservation unities assessment is critical to understand primate ecology, and how primate communities behave in a long term process, ensuring an improvement and better results of conservation strategies.

Keywords: Primate Community fluctuations, Maracá Ecological Station, habitat structure, relative abundance and biomass, Brazilian Amazon Northernmost.

Introduction

Conservation unities play an important role in primate conservation by providing an environment free from human threats, allowing species establishment and long-term survival (Peres 1991). Nevertheless, even under no anthropogenic pressure, primate diversity can vary in time (Milton 1982) and space (Kasecker 2006; Mittermeier and

Van Roosmalen 1981; Peres 1994a) due mainly to several intrinsic aspects of the areas. Regarding to time influence, primate communities can experience changes along the same year or among years within the same region, species in these areas are likely to change its abundances rather than richness (Lwanga et al. 2011).

Seasonality is one of the most important factors determining primate structure in an area (Emmons 1984). Some primate species' (e.g. *Aotus trivirgatus*, *Alouatta seniculus*, *Ateles belzebuth* and *Sapajus apella*) density and biomass can be affected and increase with wet season, whereas for others (e.g *Cebus olivaceus* and *Saimiri sciureus*), theses parameters tend to decline (Mendes Pontes 2000). The same pattern was found for velvet monkeys in Amboseli national Park, Kenya (Lee and Hauser 1998).

Spatial variation of primate diversity can be large scale, for instance, Central Amazonian forests are known for its highly diverse primate communities (Kasecker 2006; Peres 1993; 1997; 1999), and on the other hand, the forests in the Guyana Shield, northernmost Amazonia, are less diverse (Lehman 2000; 2004; Mendes Pontes et al. 2012; Nunes et al. 1988). Habitat heterogeneity is a short scale variation in space, which plays an important role on primate community structure, in other words, the more heterogeneous is the habitat the more primate species are expected (Lehman 2004).

Additionally, habitat heterogeneity allows sympatric species live together with little competition among them (Mendes Pontes 1997; Warner 2002). Generalist species are able to exploit more habitat types (Mittermeier and Roosmalen 1981) and forest strata (Chagas and Ferrari 2010), which is possible due their behavioral flexibility (Fragaszy et al. 1990), compared to the specialist species.

Habitat complexity is attached to heterogeneity, and essential for primate diversity, as well (August 1983). The more tree species, lianas and the lower the mean percentage of large trees per quadrant, more structurally complex is the habitat (Schwarzkopf and Rylands 1989). Large-bodied primate species prefer terra firme forests with large trees and high strata (Lehman et al. 2006), while smaller ones prefer lowland seasonally flooded forest and lower and dense forest strata (Mittermeier and van Roosmalen 1981; Warner 2002).

The adjustment in numbers into the primate community is probably a consequence of the amount of resource available (Mendes Pontes 2000), which can be shaped according both plant richness and fruit availability (Puertas and Bodmer 1993; Spironello 1991). The floristic variation tends to increase in areas with higher amount of rainfall and soil fertility, as well as, the habitat productivity (Gentry and Emmons 1987), which is directly connected to primate distribution and abundance (Defler 1996; Stevenson et al. 2000).

Low tree species diversity, abundance and fruit production have been influence biogeographic patterns of primates in Guyana (Lehman 2004). Specialist primate species are more vulnerable than generalists and the frugivorous species are reduced in areas with poor soils, whereas the folivorous are not affected (Emmons 1984). Primate species prefer areas with high abundance of fruits, and what may delimit the segregation of the species groups would be the foraging methods when resources are scarce, like in dry season (Brum 2011).

Primate diversity is also influenced by the presence of rivers barriers (Puertas and Bodmer 1993) and the seasonal rainfall with subsequent increase of water levels (Ayres and Clutton-Brock 1992; Desbiez et al. 2010), causing local flooding, may create obstacles for small primates (Bennett et al. 2001) and affect primate species ranging patterns (Bennett et al. 2001; Lehman 2000; Peres 1997), for instance, spider monkeys (*Ateles* sp.) and bearded sakis (*Chiropotes* sp.) (Johns and Skorupa 1987).

Finally, extreme climate events may also shape and change wildlife distributions and densities (Desbiez et al. 2010). Drastic shifts is forests can be caused by climatic changes (e.g. *El Niño*), which may affect those forests essential for frugivorous communities (Hannah et al. 2002). Severe droughts can either affect tree survival or fruit production, and consequently, primate diversity (Barlow and Peres 2004; Wright et al. 1999).

Thus, we propose to assess the diurnal primate community's dynamics into a protected area in three different years along a 20 years' time span to test whether primate abundances vary amongst forest type within the same area and which forest type are associated with the primate species, since conservation strategies will need to be revisited in order to allow a better understanding population dynamics, and how changes in the environment can affect the species.

Methods

Study site

Maracá Ecological Station

Maracá Ecological Station is a Conservation Unity created in 1981, and placed between Alto Alegre and Amaraji counties, northern Roraima, comprising 101 312 hectares (BRASILIA 1981). The Unity is situated between Santa Rosa north channel and Maracá south channel (Figure 1a) arisen from the bifurcation of the Uraricorea River, and, therefore, is called Maracá Island (Milliken and Ratter 1990).

The whole Island belongs to the Guyana Shield, which is a South America Plate craton formed by an old rock (Hammond 2005), its ground in the east is flat with small ripples (about 130 m), while the western ripples can reach 400 m, furthermore, the soil is acid, sandy, dry and poor in nutrients (Thompson et al. 1992).

The Ecological Station presents a well determined wet (April to September) and dry (October to March) seasons (Mendes Pontes 1994; 2000; Thompson et al. 1992). Temperature can range from 20 to 40 ºC (Mendes Pontes 1994), and rainfall can be under 100 mm during dry season (Sombroek 2001) and, can reach up to 2000 mm during the wet season (Barbosa and Ferreira 1997; Mendes Pontes 1994).

The vegetation is constituted 95% by seasonal forest and smaller portions of savanna and seasonally flooded areas with short vegetation and palm trees (Milliken and Ratter 1990), and, the predominant forest types are terra firme forest and mixed forest (Mendes Pontes 2000). The fauna at the Unity presents low abundance and densities (Haugaausen and Peres 2005; Mendes Pontes 2004; Mendes Pontes et al. 2010), where, only six primate species were recorded in the area, which are, the red howler monkey (*Alouatta macconnelli*), the white-belied spider monkey (*Ateles belzebuth*), the brown capuchin monkey (*Sapajus apella*), the cairara monkey (*Cebus olivaceus*), the squirrel monkey (*Saimiri sciureus*) and the nocturnal monkey (*Aotus trivirgatus*) (IUCN 2013).

A RAPELD grid is inserted into Maracá Ecological Station, which was created by the regional center of the Biodiversity Research Program (PPBio) and concluded in

March, 2006. The RAPELD system aims the standardization of data collecting, for long term ecological research (PELD), besides allows rapid assessments (RAP – *Rapid Assessment Program*) (Magnusson et al. 2005).

Sampling Design

The samplings were carried out in three periods 1992, 1997/1998 and 2012. In 1992 and 1998 we used the matrix data used in the Mendes Pontes (1994) and (2004) publications, respectively, and we collected the data for 2012 sampling.

1992 and 1997/1998 samplings

The primates surveys were carried out in one line transect measuring 12.2 km (Table 1). The trail begins at the easternmost point of the island and extends towards northwest up to 9 km, and then towards the center of the island. It was about 1 meter width and was marked each 50 meters with paint mark on the trees in order to indicate positions (Mendes Pontes 1994). The surveys from 1992 were performed at the entire trail length, while in 1997/1998, the total length used in the sampling was 10 km (Figure 1b).

2012 sampling

We carried out primates surveys in three line transects of the PPBio grid measuring 5 km each (trails L3, L4 and L5). The trails from the grid are 1 km far from each other, moreover, every 50 meters is marked with tags made of pipe with a metal plaque on the top, which contains the name of the trail and the distance of the point in meters (Figure 1c).

For the three periods, the trails were totally cleaned of debris to minimize disturbance while walking.

Primate surveys

We only considered data collected during the dry season for the years 1992 (Outubro to December 1992), 1997/1998 (October to December 1997 and January to March 1998) and 2012 (October to December 2012). The surveys, in the three years, were performed by using the line transect method (Buckland et al. 1993; Burnham et al. 1980). Each trail were traveled by two people simultaneously (the researcher and the guide) at an average speed of 1.5 km/h with regular stops (each 20 or 30 minutes) in order to find primate evidences.

The surveys in 1992 were carried out along the entire length of the trail per day, and they started at 05:45 h and they ended up at 17:45 h. In 1997/1998, the sampling was divided between the two main forests (terra firme and mixed forest, 5 km each). The surveys in terra firme forest started at 06:00 h and they ended up at 11:00 h. The surveys in mixed forest started at 07:00 h and they ended up at 12:00 h (Mendes Pontes 2000). In 2012, we started the surveys at 05:30 h and they ended up at 16:30 h.

Data in the three periods were collected in both directions along the trails, however, in order to access the most standardized data possible, we considered the data corresponding to about 10 km walked/day. Therefore, we used data only from one direction walked along the trail from 1992 sampling (12.2 km walked/day), and both directions from 1997/1998 and 2012 samplings (totaling 10 km walked/ day).

For each primate sighting gathered the following data were collected: (a) primate species, (b) date, (c) time, (d) animal-observer distance, (e) angle from the trail to the animal, (f) location on the trail and assumed direction, (g) forest type, (g) age, (h) sex, (i) animal activity, (j) vertical stratum height according to Van Roosmalen (1985) and Mendes Pontes (1997), which were, ground, understory (0-15 m), lower canopy (15-20 m), middle canopy (20-25 m), high canopy (25-30 m) and emergent canopy (> 30 m), (k) occasional polyspecific relationships and (l) total distance walked.

Habitat structure: Phytophysiognomies or habitat types

The forest types were identified during the surveys and classified according to Milliken and Ratter (1990) and Mendes Pontes (1994; 1997; 1999; 2000).

1992 and 1997/1998 sampling

The transect was divided in two mains unflooded habitat types: terra firme forest (closed canopy forest with high trees) and mixed forest (similar to terra firme with occurrence of pau-roxo trees). Nevertheless, it was identified four smaller habitat types inserted along the trail which were pau-roxo forest (predominating *Peltogyne gracilipes* Leg. Caesalphiniacea), buritizal (predominating *Mauritia flexuosa* Arecaceae), carrasco (very shrubby and multi trunked form with small trees) and low forest with dwarf pau-roxo (km 11.2 to km 11.55 not assessed in 1997/1998) (Figure 2). For details see Mendes Pontes (1994; 2000).

2012 sampling

Nine forest types were identified along the three trails surveyed at Maracá, which were, terra firme forest, mixed forest, carrasco, pau-roxo forest, buritizal, lowland forest (seasonally flooded forest with shorter trees than terra firme and mixed forest), liana lowland forest (seasonally flooded forest with shorter trees than terra firme and mixed forest and plenty of lianas), campinarana (open canopy with short and slim trees, subjected to flood in the wet season) and campina (open area with sparse up to 5 m trees and very sandy soil).

Data analysis

In order to assess the primate community structure in the three years areas we calculated the follow parameters: (a) sighting rate (groups/10 km walked) which consists on the number of primate records or groups, multiplied by 10 and divided by total kilometers walked in the area, (b) average group size (individuals/ group), which consists on the number of individuals of a species divided by the number of groups, (c) primate relative abundance (individuals/ 10 km walked) which is the product between sighting rate and average group size (Chiarello 1999), and (d) relative biomass (kg/10 km walked) which is product between relative abundance and average species body mass (Galetti et al. 2009) (mean species body mass calculated from data available in Eisenberg and Redford 1999; Emmons and Feer 1997).

We calculated overall primate diversity by using Shannon-Wiener diversity index, and, species evenness by using Smith and Wilson Index of Specie Evenness.

Before testing the differences between data among study sites, we performed a *Shapiro-Wilk Test* in order to assess whether data group presented normal distribution, if not, we picked up the correspondent non-parametric test.

We performed FRIEDMAN Test in order to verify whether there were differences in the kilometers walked in the habitat types among the three years, which could lead in a biased result.

Aiming to calculate expected primate records and individuals number by habitat type, we created a data matrix and used the Chi-square expected formula:

$$\mathrm{E} = \frac{\Sigma\,(\text{line values}) \times \Sigma\,(\text{column values})}{\Sigma\,(\text{all values})}$$

After, we carried out a *Mann-Whitney U Test* in order to verify possible differences between observed and expected data.

We performed the ANOVA or FRIEDMAN Test (if data presented non normal distribution), in order to test whether overall average group size, relative abundance and relative biomass variations among the periods were significant. We also carried out *Bray-Cutis Index* in order to verify whether there were any similarities amongst the years studied at Maracá Ecological Station regarding to relative abundance, relative biomass and average size group.

We executed a FRIEDMAN Test aiming to verify possible differences regarding to overall primate relative abundance, biomass and average size group by forest types amongst the years. Moreover, we tested possible differences in species relative abundance, relative biomass and average size group by habitat type at the studied years by using NPMANOVA test (Non-Parametric MANOVA).

We performed a *Correspondence Analysis* in order to verify possible associations among habitat types and primate species with the software PAST 2.17c.

We used the software R Project to run the ANOVA and FRIEDMAN tests. To run *Shapiro-Wilk Test* and *Mann-Whitney U Test* we used BIOSTAT 5.0 software and to run NPMANOVA, we used PAST 2.17c software. Overall, we assumed $P < 0.05$ (two-tailed) to indicate significant values.

Results

Samplings, species recorded and phytophysiognomies

In 1992, at Maracá Ecological Station, were gathered 143 primate records; in 1997/1998, 139 primate records and in 2012, 82 primate records (Table 1). The diurnal species recorded at Maracá island in the three periods were: the squirrel monkey (*Saimiri sciureus*), the brown capuchin monkey (*Sapajus apella*), the cairara monkey (*Cebus olivaceus*), the red howler (*Alouatta macconnelli*) and the white-belied spider monkey (*Ateles belzebuth*).

We found no significant differences in mileage walked along the three years assessed at Maracá (FRIEDMAN: F=4.6667, df=2, P=0.097). Terra firme and mixed forest were the most traveled habitat type (Table 2). The expected values for the amount of primate records (Table 3) and the amount of individuals recorded, by habitat type (Table 4), at the Conservation Unity in 1992, 1997/1998 and 2012 did not differ significantly from observed records.

Species abundances

Average group size

The variations in primate groups size amongst the years at Maracá Ecological Station did not differ significantly (FRIEDMAN: F=5.2, df=2, P=0.074). Squirrel monkey presented the higher mean group size in the three years, whereas the lower mean were recorded to the red howler (Table 5).

Relative abundance

We found no significant differences in species relative abundance among the three studied years, as well (ANOVA: F=1.210, df=2, P=0.3327). *Cebus olivaceus* was the most abundant species in the three periods. *S. sciureus* was the second most abundant species in 1992 and 1997/1998, whereas, in 2012, *A. belzebuth* obtained the second position in species relative abundance. *Sapajus apella*, on the other hand, presented the lowest abundances values in the whole study. (Table 6).

Relative Biomass

No significant variances in relative biomass amongst the three periods was found (ANOVA: F=0.7746, df=2, P=0.5138). The white-belied spider monkey obtained the highest relative biomass among the three assessed years, followed by the cairara. The brown capuchin monkey, as well, showed the lowest values from the species recorded, this time in relative biomass (Table 6).

By performing the Bray-Cutis index, we found a similarity between the years 1997/1998 and 2012 regarding to the dependent variables relative abundance, relative biomass and average group size. The year 1992 presented similarity with 2012 regarding relative abundance of primate species and with 1997/1998 regarding to relative biomass and average group size (Table 7).

Diversity parameters and species evenness

The Shanon-Wiener index found in 1992, for Maracá Ecological Station was 1.35, in 1997/1998 was 1.29 and in 2012 was 1.21. In 1992, species evenness corresponded to 0.53, and in 2012 and 1997/1998 was respectively 0.28 and 0.25.

Species *vs.* Phytophysiongnomies

During 1992, overall primate relative abundance was higher at liana lowland forest, whereas, relative biomass was higher at lowland forest. In 1997/1998, carrasco obtained higher primate abundance and pau roxo forest obtained higher primate biomass. During 2012, lowland forest presented the highest values of abundance at lowland forest and values of biomass at terra firme forest (Figure 3).

In the periods assessed, squirrel monkeys, cairaras and white-belied spider monkeys were recorded in, at least, four form the seven phytophysiongnomies which presented primate records. From these, terra firme forest and mixed forest were the only habitat types in which whole five primate species were recorded.

The variance, we found, in relative abundance, relative biomass and average group size by species in each habitat types recorded at Maracá Ecological Station amongst the three periods were not significant (Table 8).

Species relative abundance vs. Phytophysiongnomies

S. sciureus and *C. olivaceus* were, respectively, the two most abundant species at terra firme forest in 1992 and 1997/1998. In 2012, on the other hand, the highest relative abundances were recorded for *C. olivaceus* and *A. belzebuth*. At the mixed forest, we recorded the highest relative abundance values for *A. belzebuth* in 1992 and *C. olivaceus* in 1997/1998 and 2012 (Figure 4).

At lowland forest *S. sciureus* and *C. olivaceus* presented the highest abundance values in 1992 and 2012. Still regarding to this habitat type, in 1997/1998, only the red howler was recorded. Primates were recorded at the liana lowland forest only in 1992, and the squirrel monkey was the most abundant species. At the buritizal, we only recorded the red howler in the three years, presenting the highest relative abundance in 1992. Pau roxo forest and carrasco only obtained primate records in 1997/1998. At the last one, only the squirrel monkey was recorded, whereas, at pau roxo forest we recorded the white-belied spider monkey and the cairara. We recorded *S. apella* only in terra firme forest (in 1992 and 1997/1998) and mixed forests (in 1992 and 2012) (Figure 4).

Species relative biomass vs. Phytophysiongnomies

We recorded the highest relative biomass for *A. belzebuth* at terra firme forest, mixed forest and buritizal in 1992, 1997/1998 and 2012, and at pau roxo forest in 1997/1998. *C. olivaceus* was the second species which the most contributed in biomass at terra firme forest in 1992, 1997/1998 and 2012, and at mixed forest in 2012. At this lest habitat type, *A. macconnelli* presented the highest relative biomass in 1992 and 1997/1998. In each year assessed, the species with the highest relative biomass varied at the lowland forest. The whit-belied spider monkey obtained more relative abundance in 1992, whereas the red howler obtained the highest value in 1997/1998 and cairara in 2012. The squirrel monkey showed the highest relative biomass in 1992 (Figure 5).

Species average group size vs. Phytophysiongnomies

We recorded the biggest mean groups sizes of *S. sciureus* at terra firme forest in the three years studied, at lowland forest in and liana lowland forest in 1992, at mixed forest and carrasco in 1997/1998 and finally in the buritizal in 2012. In 1997/1998, *C. olivaceus* obtained the biggest mean group size at pau roxo forest. In 1992, *S. apella* presented its biggest average group size at mixed forest and in 2012, at the same forest type; *A. macconnelli* obtained the biggest mean group size (Figure 6).

The correspondence analysis between primate species and the phytophysiognomies recoded at the Maracá Ecological Station showed that, regarding to relative abundance, the squirrel monkey was associated with the lower forests in 1992 (lowland forest and liana lowland forest), in 2012 (lowland forest) and in 1997/1998 (carrasco). The brown capuchin monkey and cairaras were tightly associated with mixed forest and terra firme forest in 2012, moreover, *C. olivaceus* was also associated with the buritizal in the same year. The white-belied spider monkey was more associated with pau roxo forest and buritizal in 1997/1998. The red howler did not show any evident association with the phytophysiognomies (Figure 7). See the eigenvalues and percentage results of the Axis from the correspondence analysis in the Table 10.

Regarding to relative biomass, *A. belzebuth* biomass was tightly more associated with buritizal forests along the three years assessed and at pau-roxo forest in 1997/1998. The biggest values of relative biomass from *S. apella* and *C. olivaceus* were mainly associated to terra firme and mixed forest, whereas, *S. sciureus* presented a slight association with the shorter forest (lowland forest, liana lowland forest and carrasco). Once more, the red howler did not show any evident association with the phytophysiognomies (Figure 8). See the eigenvalues and percentage results of the Axis from the correspondence analysis in the Table 9.

Discussion

Primate community structure

Differences in primate community structure are more remarkable when is taken in account different regions and their particular features (Bennett et al. 2001; Cordeiro 2008; Kasecker 2006; Mendes Pontes 1999; Peres 1988), however, within a same region with similar vegetation structure, the primate community can also presents variations (Brum 2011; Lehman 2000; Mendes Pontes 1997).

Studies regarding population fluctuations into protected areas are scarce. Data from Kibale National Park, Ngogo, shows a primate population variance along 33 years, where some species showed a decline in population, while others had an increasing in the population (Lwanga et al. 2011). The hypothesis mentioned for population variances were mainly disease, predation, changes in habitat and habitat selectivity, population fissions, competition and fruit production. In addition, the author says that primate communities in protected areas are likely to change its abundances rather than richness.

Within Amazonia Forest, primate richness is largely well represented at the Central forest, where, the number of species can vary from 13 up to 16 sympatric species (Haugaasen and Peres 2005; Peres 1993; 1997; 1999). On the other hand, the areas from Amazonian River basin (Guyana Shield region) are known to be poor in diversity, and primate richness consists in 2 up to 9 species (Alves 2012; Lehman 2000; 2004; Mendes Pontes et al. 2012; Nunes et al.1988, Thoisy et al. 2005).

Our records corroborate the low richness recorded in Guyana Shield areas, and the number of species at Maracá Island, remained basically the same along the three years assessed, which were the same species recorded in others studies performed at the Unity (Cordeiro 2008; Mourthé 2012; Nunes et al. 1988).

The soil fertility influences directly the plant community, and productivity which influence biogeographic patterns of primate species (Defler 1996; Gentry and Emmons 1987; John et al. 2007; Lehman 2004). The Guyana Shield presents soils poor in nutrients (Thompson et al. 1992), sandy and acids with low concentrations of extractable nitrogen and phosphorus (Nascimento et al. 1997). On the other hand, despite Central Amazonian forest be composed by poor soils, as well, it is covered by an organic matter layer coming from the own forest and the nutrients available in this layer are recycled by microscopic organisms such as, bacteria and fungus, which, added up to high temperature levels and relative humidity throughout the year, guarantee the sustainability of the forest (Ferreira et al. 2002).

Specie group size showed no significant variations along the years, although overall species group size tended to decline along the periods. *Saimiri sciureus* presented the biggest group size into the three periods (10.62 ± SD 1.24 ind/group), and was almost the same value to that recorded in the Conservation Unity in 2008 (10.6 ind/group) (Cordeiro 2008), but lower than that recorded in Viruá Natinal Park (21.29 ind/group) (Alves 2012; Melo 2012). *Alouatta macconnelli* presented a low average group size (3.01 ± SD 0.65 ind/group), the same value found in others studies at Maracá (Cordeiro 2008) and Viruá National Park (Alves 2012; Melo 2012).

Variances in primate group size among areas are mainly related to distribution and density of the food resource and the amount of effort groups must do in order to find adequate food supplies (Milton and May 1976). In addition, primarily frugivorous species which depends on food available in patches tend to form small groups when food is scarce (Chapman and Chapman 2000).

Primate's assemblage relative abundance and biomass among the periods were not significant, despite the considerable variance for *Saimiri sciureus, Cebus olivaceus and Ateles belzebuth* along the three years. Furthermore, theses parameters were much more similar between the periods of 1997/1998 and 2012.

Into the Guyana Shield, primate relative abundance and biomass recorded at Viruá National Park, in Roraima (28.2 ind/10 km walked and 77.4 kg/10 km walked, respectively), were higher compared to the values found in this study (Alves 2012; Melo 2012). Moreover, protected areas and even disturbed areas from French Guyana presented an average primate assemblage's relative abundance higher than 1997/1998 and 2012 (Thoisy et al. 2005).

Cebus olivaceus was the most abundant species, and, together with *Ateles belzebuth* were responsible for the highest contribution for primate biomass within each period, although large-bodied species (e.g. *Ateles* and *Alouatta*) are known for contributing to the major proportion of the total primate biomass in protected areas (Freese et al. 1982).

Sapajus apella obtained the lowest relative abundance and biomass into each studied year. In a study performed in 1988 at Maracá Ecological Station, the species presented a low sighting rate (Nunes et al. 1988) and in other studies at the same area, it was not recorded (Cordeiro 2008; Mourthé 2012). Mourthé (2012, pers. com.) suggests that this species may be in an extinction process by competition with *Cebus olivaceus*.

Alouatta macconnelli group size, abundance and biomass remained basically the same in the periods. Probably, as the red howler is primarily folivorous species and leaf resources tend to be less temporally and spatially restricted than fruit (Chapman 1987), in circumstances where frugivorous species tend to be affected, folivorous remain unaffected (Emmons 1984).

Differences among biogeographic patterns in the primates are likely to be associated to the low tree species diversity and abundance, low fruit production (Lehman 2004; Stevenson 2001) and seasonality (Emmons 1984).

Environmental structure and habitat use

Phytophysiognomy structure can be a determinant factor to primate distribution (Alves 2012; August 1983; Peres 1997; 1999), however, differences in primate's assemblage abundance and biomass by habitat type among the years presented no significant differences, as well as, variances in species' abundance and biomass by habitat type. In 1992 and 1997/1998 primate species were recorded in, at least, five habitat types, while in 2012, they were recorded only in four forests.

Overall, primate biomass and abundance was higher at seasonally flooded forests, such as lowland forest, liana lowland forest and buritizal, and at terra firme forest. Though, in 1997/1998, primates were more evenly distributed and relative biomass was higher at pau roxo forest and buritizal.

Primates may exploit the habitat in many different ways, and the number of species in an area is influenced by the way species share the main dimensions of the niche (Lehman 2004). They prefer areas with high abundance of fruits, species foraging methods may delimit the segregation of the species groups when resources are scarce, like in dry season (Brum 2011). In habitats with higher fruit availability, animals require smaller home ranges (Hanya et al. 2006).

Animals must forage over an area large enough in order to supply their energetic and nutritional requirements (Milton and May 1976). Areas which are rapidly depleted and presents low density and scattered distribution of resource, species which have large groups are obligated to visit many areas in order to move between resource clumps, whereas, those areas is likely to support species which tend to form small groups (Milton and May 1976).

The squirrel monkey was mainly associated with the lower forests, and, at lowland forest (and liana lowland forest in 1992, as well) and terra firme forest primate abundance was mainly represented by *Saimiri sciureus* and *Cebus olivaceus*. In Surinam forests, *Saimiri* sp. was the only species that was not found most often in high forest, more than 50% of all species' observations were in liana forest (Mittermeier and Van Roosmalen 1981).

Despite the decrease in *S. sciureus'* relative abundance and biomass along the years have not been significant, declining patterns in insectivorous species may be associated to the decreasing of herbivorous insects in poor soils areas (Emmons 1984). Moreover, Maracá Ecological Station does not present well-defined forest floors (Mendes Pontes 1997) and in forest with poor soils the understory varies dramatically, because it is sensitive to changes in rainfall, whereas in the canopy, changings are weaker (Gentry and Emmons 1987).

We found *C. olivaceus* in five from the nine forest types recorded in Maracá Island in the three years together, which may be a reflex of their flexibility (Fragaszy et al. 1990). This species was more associated to terra firme forest, although, *C. olivaceus* biomass was also high at lowland forest in 1992 and 2012. Studies have shown that *C. olivaceus* occurred mainly at high forests, while *Sapajus apella* were more generalist regarding habitat use (Cordeiro 2008; Mittermeier and Van Roosmalen 1981), although we found *Sapajus* apella, only in terra firme and mixed forest.

Ateles sp. is generally found almost exclusively in high forests (Mittermeier and Van Roosmalen 1981) such as terra firme forest (Lehman et al. 2006). We also recorded *Ateles belzebuth* at terra firme forest, however, we found higher relative abundance and biomass of white-handed spider monkey in seasonally flooded areas, such as, buritizal in 1992 and 1997/1998, and lowland forest in 1992, although it has been suggested that spider monkeys (*Ateles* sp.) are sensitive to flooding (Johns and Skorupa 1987).

Buritizal forest had an outstanding importance for *Ateles belzebuth* relative biomass. Abundance of *C. olivaceus* was also correlated to buritizal forest, but only in 1997/1998. The hypothesis is that fruits of some species of palm tree are available throughout the year and represent an important fruit source for frugivores during the dry season when ripe fleshy fruits of non-palm trees become rare or nonexistent (Peres 1994b; Spironello 1991).

Terra firme forests in Guyana are characterized by having low densities of palm species (Ahumada et al. 1998; Terborgh and Andresen 1998) and higher densities in flooded than non-flooded forests (Davis and Richards 1934; Terborgh and Andresen 1998). *Cebus* sp. may select habitats that contain the highest densities of palms (Spironello 1991), however, probably in order to avoid *Ateles belzebuth*, which has dominated buritizal areas in the three periods, cairaras exploited terra firme forest and lowland forest, mainly in the years with the species had low record at the buritizal (1992 and 2012).

Terra firme forests tend to be under extremely tight nutrient budgets because they rest upon nutrient-poor Ultisol soils. The Ultisol soils of Amazonia are very similar to the soils of the Guyana Shield (Peres 1999) found at Maracá. The author found that total primate density and biomass in floodplain forests were twice that of terra firme forests. Concomitantly, terra firme forests in Guyana have low levels of floral diversity and abundance of plant families that are valuable food resources for primates (Terborgh and Andresen 1998; Lehman 2000).

The occurrence of flooding forests probably plays an important role in small mammals' distributions and abundance (Bennett et al. 2011; Lehman 2000; Peres 1997). *Cebus* sp. can determine the home range and core areas according to the water source distribution (Campos and Fedigan 2009), and *Saimiri sciureus* is likely to favors flooded areas (Kasecker 2006). Furthermore, mammals' species are correlated to habitat complexity but not with habitat heterogeneity, which is associated with an increase of potential food resources in these areas (August 1983). Complex habitat have high mean number of trees, high mean number of lianas, low mean percentage large trees per quadrat, and streams (Schwarzkopf and Rylands 1989), this features are related mainly to seasonally flooded forests.

Primate species fed mainly on fruit pulp along the year, but they may change their diet during the dry season due to the low productivity of fruit (Peres 1994a). In Maracá during 2009 and 2010 *Ateles belzebuth* sighting rates were related to fruit availability during the shortage of fruit, whereas *Alouatta macconnelli* and *Cebus olivaceus* did not follow this pattern (Mourthé 2012). *A. macconnelli*'s was associated to seasonally flooded areas, as recorded by Peres (1997), and mixed forest.

We found no significant evidence of population fluctuation over a twenty-year range, but, what may explain the variance observed in primate abundance and biomass among the periods? This difference is probably caused by influence of temperature and the amount of rainfall into the years. According to Desbiez et al. (2010), population fluctuations of certain species are closely associated with water due to the drought. It has been showed that severe drought events have influence on tree survival and fruit production (Barlow and Peres 2004; Hannah et al. 2002; Wright et al. 1999) which affect mainly primate frugivorous species (Wiederholt and Post 2010).

The maximum temperature in 1992 ranged 32-34 ºC while 1997/1998 and 2012 maximum temperature ranged 34-36 ºC (CPTEC/INPE 2014). The average amount of rainfall, in the three months assessed in this study, was higher in 2012 (October to December), 1998 (January to March), and 1992 (October to December) with 91, 83 and 72 mm of precipitation, respectively (CPTEC/INPE 2014).

The period of 1997/1998 presented a severe drought, and at the capital of the State of Roraima, the amount of rainfall was only 8% from the expected (Rebello et al. 1998), with about 21 mm of precipitation (CPTEC/INPE 2014). The drought in this period was an effect of the strongest El Niño event along more than 60 decades (Climate Prediction Center 2014; Rebello et al. 1998). Nevertheless, the climatic shifts were not enough to induce significant changes in primate structure, but may explain the variance found in the three periods.

Long term assessment of protected areas is quite important to understand how habitat structure and climatic changes affect primate communities under no anthropogenic influence, and then, with this knowledge, create conservation strategies better adapted to the needs, and specific responses of the primate species.

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Tables

Table 1. Trails length, total effort and primate record of the three years assessed at Maracá Ecological Station, in Roraima, Brazil.

		2012	1997/1998	1992
Trail length (km)		5 (n=3)	12.2	12.2
Effort (km)	**Average distance walked/day (km)**[1]	10 ± 0[2]	9.53 ± 1.57[3]	11.84 ± 0.76[4]
	Total Diurnal	300	600.9	449.95
Total primate records		342	706	1004

[1]Mean ± Standard Deviation.
[2] Replicated surveys (round trip).
[3] Replicated surveys (round trip).
[4] Non-replicated surveys (one way).

Table 2. Forest type proportion (%) by trail and distance (in kilometers) traveled at each forest types recorded at Maracá Ecological Station, State of Roraima, Brazil, in 1992, 1997/1998 and 2012. Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF), Liana Low Land Forest (LLL), Campina (CAM) and Campinarana (CAN).

Forest Types	**1992**		**1997/1998**		**2012**	
	%	**km**	**%**	**km**	**%**	**km**
TFF	45.0	171.08	45.0	269.08	68.6	205.7
MIF	47.0	248.4	47.0	281.68	13.0	38.98
CAR	1.2	4.41	1.2	7.19	1.6	4.72
PRF	1.8	6.84	1.8	11.34	0.7	2
BUR	3.4	12.96	3.4	21.38	3.5	10.52
LLF	1.1	3.99	1.1	6.51	6.6	19.68
LLL	0.6	2.28	0.6	3.72	1.7	5
CAM	0	0	0	0	0.7	2
CAN	0	0	0	0	3.8	11.4
TOTAL		499.95		600.9		300

Table 3. Observed (O) and Expected (E) primate records at Maracá Ecological Station, State of Roraima, Brazil, by forest type in 1992, 1997/1998 and 2012. Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF), Liana Low Land Forest (LLL), Campina (CAM) and Campinarana (CAN).

Forest Types	**1992**			**1997/1998**			**2012**		
	[1]KM	**O**	**E[2]**	**[1]KM**	**O**	**E[2]**	**[1]KM**	**O**	**E[2]**
TFF	171.1	64	51.1	269.1	68	86.7	205.7	95	89.2
FMI	248.4	12	25.0	281.7	59	42.4	39.0	40	43.6
CAR	4.4	0	0.2	7.2	1	0.4	4.7	0	0.4
FPR	6.8	0	0.7	11.3	3	1.1	2.0	0	1.2
BUR	13.0	2	2.5	21.4	7	4.2	10.5	2	4.3
FBA	4.0	4	1.8	6.5	1	3.1	19.7	3	3.1
FBC	2.3	0	0.7	3.7	0	1.1	5.0	3	1.2
CAM	0	0	0	0	0	0	2	0	0
CAN	0	0	0	0	0	0	11.4	0	0
U (OxE)[3]	U=34; P=0.5660			U=37; P=0.7573			U=37; P=0.6267		

[1]KM – Kilometers walked by habitat type.
[2]Expected values (E) calculated by the Chi-square formula: $E = [\Sigma \text{ (line valeus)} \times \Sigma \text{ (column values)}] \div \Sigma \text{ (total values)}$.
[3]Mann-Whitney U Test used in order to verify significant differences between O and E.

Table 4. Observed (O) and Expected (E) number of individuals recorded at Maracá Ecological Station by forest type, State of Roraima, Brazil, in 1992, 1997/1998 and 2012. Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF), Liana Low Land Forest (LLL), Campina (CAM) and Campinarana (CAN).

Forest Types	**1992**			**1997/1998**			**2012**		
	KM[1]	**O**	**E[2]**	**KM[1]**	**O**	**E[2]**	**KM[1]**	**O**	**E[2]**
TFF	171.1	269	232.7	269.1	402	480.3	205.7	725	683.0
MIF	248.4	34	83.3	281.7	245	172.0	39.0	221	244.6
CAR	4.4	0	2.3	7.2	14	4.8	4.7	0	6.8
PRF	6.8	0	2.7	11.3	16	5.5	2.0	0	7.8
BUR	13.0	4	7.7	21.4	27	15.8	10.5	15	22.5
LLF	4.0	35	10.3	6.5	2	21.3	19.7	25	30.3
LLL	2.3	0	3.0	3.7	0	6.2	5.0	18	8.8
CAM	0	0	0	0	0	0	2	0	0
CAN	0	0	0	0	0	0	11.4	0	0
U (OxE)[3]	U=33; P=0.5078			U=39; P=0.8946			U=36; P=0.6911		

[1]KM – Kilometers walked by habitat type.
[2]Expected values (E) calculated by the Chi-square formula: E=[Σ(line values)*Σ(column values)]/Σ(total).
[3]Mann-Whitney U Test used in order to verify significant differences between O and E.

Table 5. Average group size (individuals/group), and species records (N) for diurnal primate species recorded at Maracá Ecological Station by forest type, State of Roraima, Brazil, in 1992, 1997/1998 and 2012. Mean ± Standard Deviation; (FRIEDMAN: F=5.2, gl=2, P=0.074).

Species	**1992**		**1997/1998**		**2012**	
	N	**ind/gr**	**N**	**ind/gr**	**N**	**ind/gr**
Saimiri sciureus	9	11.41 ± 3.81	21	11.90 ± 4.06	29	8.56 ± 4.47
Sapajus apella	1	8.00 ± 3.23	1	4	5	3
Cebus olivaceus	44	6.35 ± 3.87	66	3.95 ± 3.91	54	3.77 ± 4.25
Alouatta macconnelli	7	3.20 ± 3.75	17	3.71 ± 4.21	15	2.14 ± 3.89
Ateles belzebuth	21	6.05 ± 3.57	34	3.76 ± 3.91	40	3.86 ± 4.25
TOTAL	82	7.02 ± 3.87[1]	139	5.08 ± 4.06[1]	143	4.17 ± 4.23[1]

[1]Overall primate average group size.

Table 6. Primate species relative abundance (RA – individuals/10 km walked) and biomass (RB – kg/10 km walked) for diurnal primate species recorded at Maracá Ecological Station by forest type, State of Roraima, Brazil, in 1992, 1997/1998 and 2012.

Species	**1992**		**1997/1998**		**2012**	
	RA	**RB**	**RA**	**RB**	**RA**	**RB**
Saimiri sciureus	7.36	6.91	4.16	3.91	2.57	2.41
Sapajus apella	0.89	2.76	0.07	0.21	0.10	0.31
Cebus olivaceus	7.62	24.77	4.34	14.12	5.53	17.98
Alouatta macconnelli	1.07	7.84	1.05	7.71	0.50	3.68
Ateles belzebuth	5.38	43.83	2.13	17.36	2.70	22.01
Overall primate species	22.31	86.12	11.75	46.10	11.40	46.39

Table 7. Comparison of relative abundance (groups/10 km walked), relative biomass (kg/ 10 km walked) and average group size (individuals/group) of primates, by using Bray-Curtis Similarity Index, among the years 1992, 1997/1998 and 2012 at Maracá Ecological Station, State of Roraima, Brazil.

Years	Relative abundance	Relative biomass	Average group size
1992 x 1997/1998	0.68976	0.66929	0.84454
1992 x 2012	0.67616	0.70023	0.75719
1997/1998 x 2012	0.83024	0.84236	0.87276

Table 8. Variance of the parameters relative abundance (groups/10 km walked), relative biomass (kg/ 10 km walked), by primate species, among each phytophysiognomies recorded at Maracá Ecological Station (Terra firme forest, mixed forest, carrasco, pau-roxo forest, buritizal, lowland forest, liana lowland forest, campina and campinarana) in the years of 1992, 1997/1998 and 2012, State of Roraima, Brazil. Significance test based on FRIEDMAN.

Species	**Relative abundance**	**Relative biomass**	**Average group size**
Saimiri sciureus	F=0.2222; df=2; P=0.8948	F=0.2222; df=2; P=0.8948	F=0; df=2; P=1
Sapajus apella	F=0.2222; df=2; P=0.8948	F=0.2222; df=2; P=0.8948	F=0.6667; df=2; P=0.7165
Cebus olivaceus	F=0; df=2; P=1	F=0; df=2; P=1	F=1.5556; df=2; P=0.4594
Alouatta macconnelli	F=1.5; df=2; P=0.4724	F=1.5; df=2; P=0.4724	F=1.7222; df=2; P=4227
Ateles belzebuth	F=2.6667; df=2; P=0.2636	F=2.6667; df=2; P=0.2636	F=2.6667; df=2; P=0.2636

Table 9. Correspondence Analysis results for relative abundance and relative biomass of primate species recorded at Maracá Ecological Station among habitat types (Terra firme forest, mixed forest, carrasco, pau-roxo forest, buritizal, loeland forest, liana lowland forest, campina and campinarana) in 1992, 1997/1998 and 2012, State of Roraima, Brazil.

	Relative Abundance		**Relative Biomass**	
	Eigenvalues	**% from total**	**Eigenvalues**	**% from total**
Axis 1	0.52	52.86	0.53	53.76
Axis 2	0.27	27.34	0.27	27.40
Axis 3	0.16	16.40	0.16	16.26
Axis 4	0.03	3.40	0.03	2.58

Figures Labels

Figure 1. (A) Location of the study area Maracá Ecological Station, State of Roraima, Brazil (Modified from Mendes Pontes 1997). (B) Location of the trail (12.2 km) surveyed at Maracá Ecological Station in 1992 and 1998. (C) Location of the PPbio RAPELD grid and the three 5 km trails (L3, L4 and L5) surveyed at Maracá Ecological Station in 2012. (Pictures taken from Google Earth).

Figure 2. Location of the two main forests, Terra Firme and Mixed forest, and the other three minor habitats, Buritizal, Pau-Roxo, and Carrasco forest, along the 10-km study transect, in eastern Maracá, Roraima, Braziian Amazonia (Figure from Mendes Pontes 2000).

Figure 3. Overall relative abundance (individuals/10 km walked) and biomass (kg/10 km walked) of diurnal primates recorded at Maracá Ecological Station in 1992, 1997/1998 and 2012, State of Roraima, Brazil, by habitat types with primate presence. Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-Roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF) and Liana Low Land Forest (LLL).

Figure 4. Relative abundance (individuals/10 km walked) of diurnal primate species recorded at Maracá Ecological Station in 1992, 1997/1998 and 2012 in State of Roraima, Brazil, by habitat types with primate presence. Terra Firme Forest (TFF),

Mixed Forest (MIF), Carrasco (CAR), Pau-Roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF) and Liana Low Land Forest (LLL).

Figure 5. Relative biomass (kg/10 km walked) of diurnal primate species recorded at Maracá Ecological Station in 1992, 1997/1998 and 2012 in State of Roraima, Brazil, by habitat types with primate presence. Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-Roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF) and Liana Low Land Forest (LLL).

Figure 6. Average group size (individuals/group) of diurnal primate species recorded at Maracá Ecological Station in 1992, 1997/1998 and 2012 in State of Roraima, Brazil, by habitat types with primate presence. Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-Roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF) and Liana Low Land Forest (LLL).

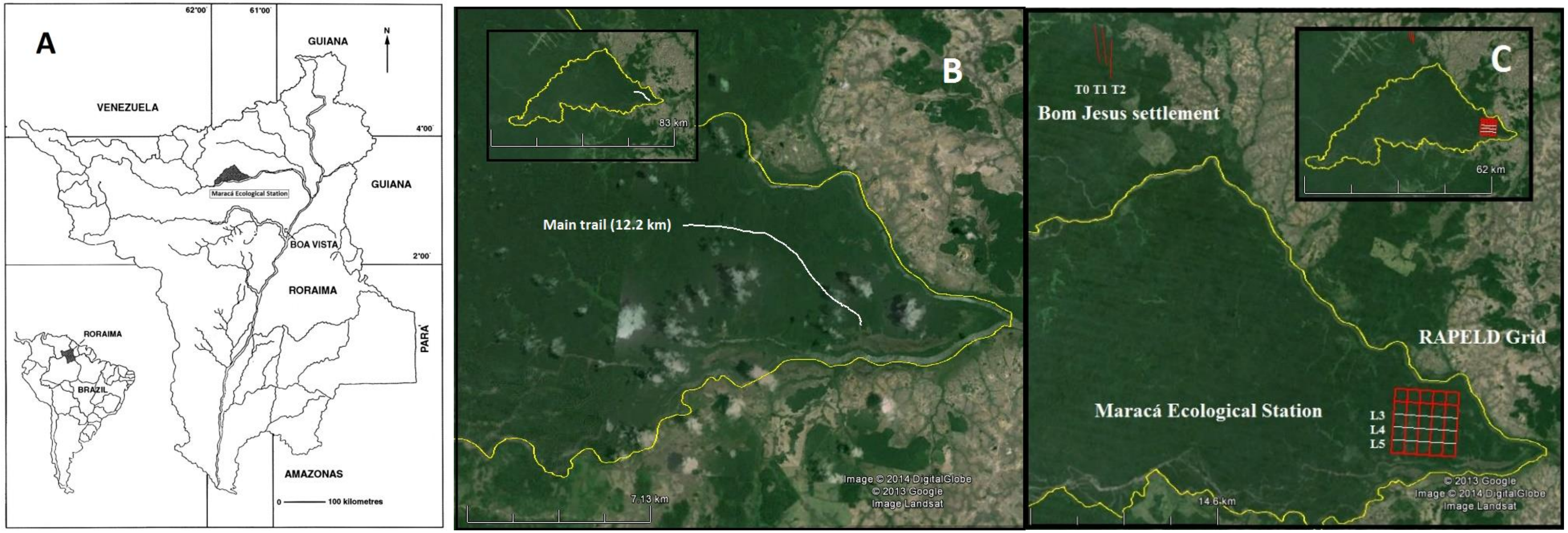
Figure 7. Correspondence Analysis for relative abundance (individuals/10 km walked) regarded to the habitat types recorded at of Maracá Ecological Station in 1992 (blue point), 1997/1998 (red point) and 2012 (green point) in State of Roraima, Brazil, by habitat types with primate presence. Primate Species: *Saimiri sciureus* (Ss), *Sapajus apella* (Sa), *Cebus olivaceus* (Co), *Alouatta macconnelli* (Am) e *Ateles belzebuth* (Ab). Habitat types: Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-

Roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF) and Liana Low Land Forest (LLL).

Figure 8. Correspondence Analysis for relative biomass (kg/10 km walked) regarded to the habitat types recorded at of Maracá Ecological Station in 1992 (blue point), 1997/1998 (red point) and 2012 (green point) in State of Roraima, Brazil, by habitat types with primate presence. Primate Species: *Saimiri sciureus* (Ss), *Sapajus apella* (Sa), *Cebus olivaceus* (Co), *Alouatta macconnelli* (Am) e *Ateles belzebuth* (Ab). Habitat types: Terra Firme Forest (TFF), Mixed Forest (MIF), Carrasco (CAR), Pau-Roxo Forest (PRF), Buritizal Forest (BUR), Low Land Forest (LLF) and Liana Low Land Forest (LLL).

Figures

Figure 1.



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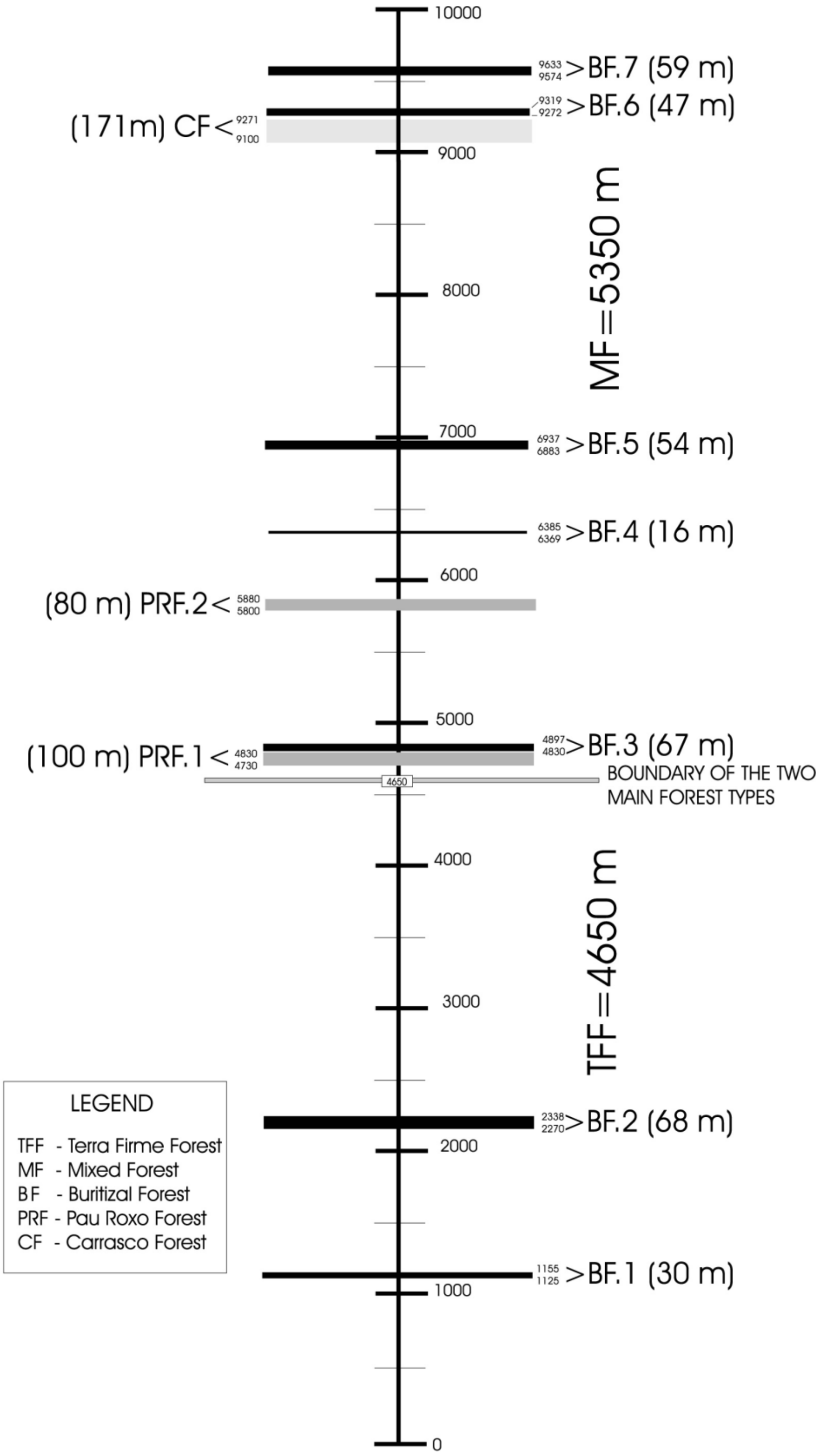
10000
9633
9574
>BF.7 (59 m)
9319
9272
>BF.6 (47 m)
(171m) CF<
9271
9100
9000
MF=5350 m
8000
7000
6937
6883
>BF.5 (54 m)
6385
6369
>BF.4 (16 m)
6000
(80 m) PRF.2<
5880
5800
5000
4897
4830
>BF.3 (67 m)
(100 m) PRF.1<
4830
4730
4650
BOUNDARY OF THE TWO
MAIN FOREST TYPES
4000
TFF=4650 m
3000
LEGEND
TFF - Terra Firme Forest
MF - Mixed Forest
BF - Buritizal Forest
PRF - Pau Roxo Forest
CF - Carrasco Forest
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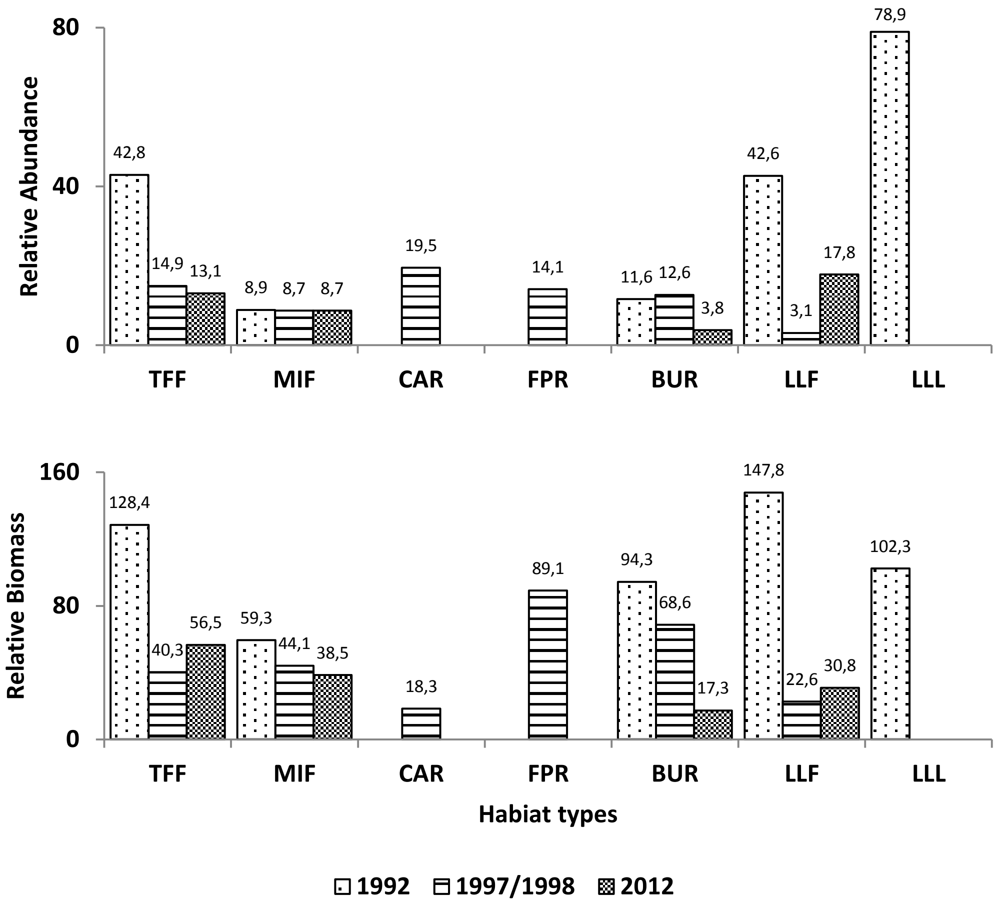
2270
>BF.2 (68 m)
2000
1155
1125
>BF.1 (30 m)
1000
0

Figure 3.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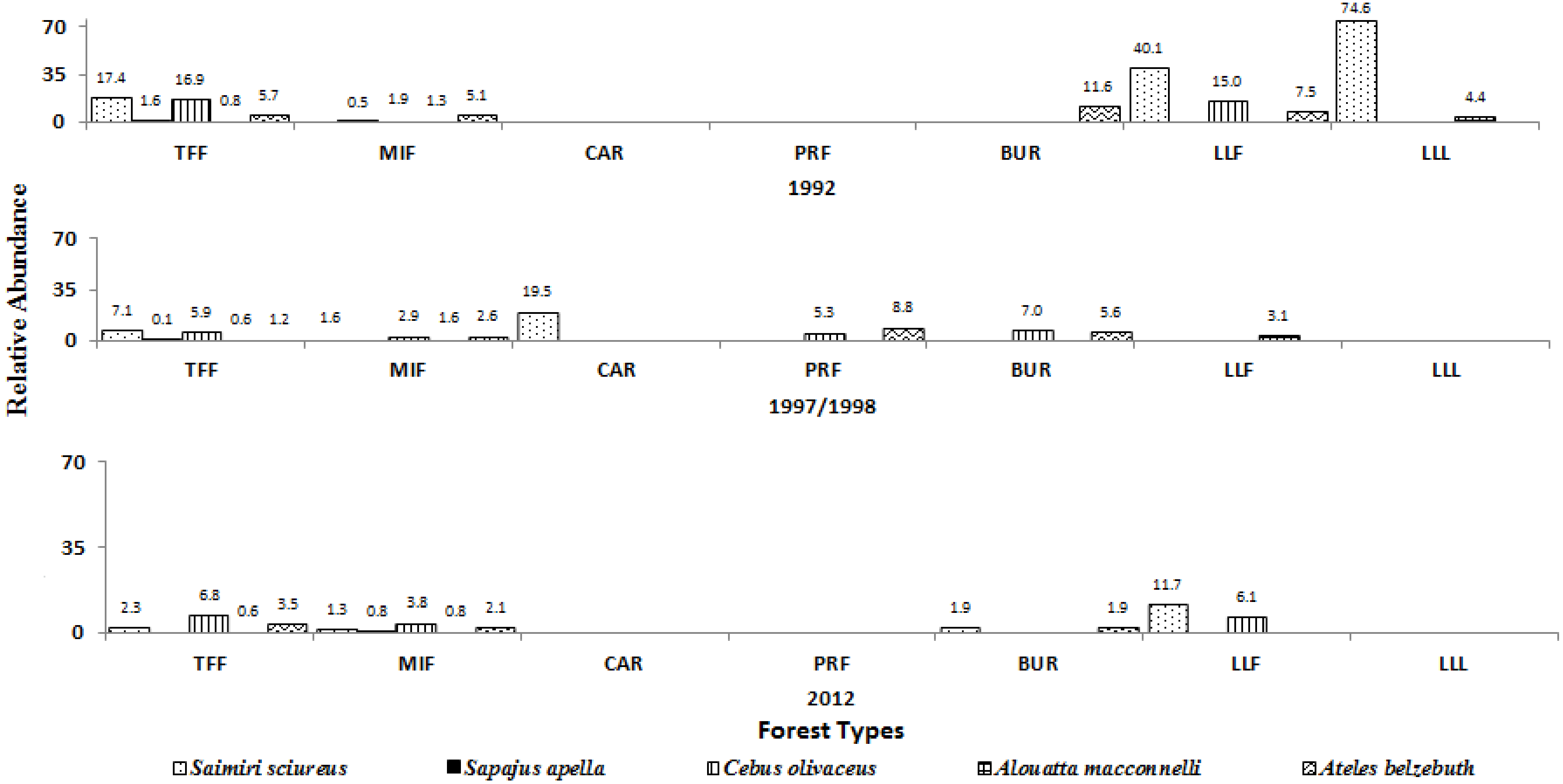
13,1
8,9
8,7
8,7
19,5
14,1
11,6
12,6
3,8
42,6
3,1
17,8
78,9
TFF
MIF
CAR
FPR
BUR
LLF
LLL
Relative Biomass
160
80
0
128,4
40,3
56,5
59,3
44,1
38,5
18,3
89,1
94,3
68,6
17,3
147,8
22,6
30,8
102,3
TFF
MIF
CAR
FPR
BUR
LLF
LLL
Habiat types
1992
1997/1998
2012

892 Figure 4.



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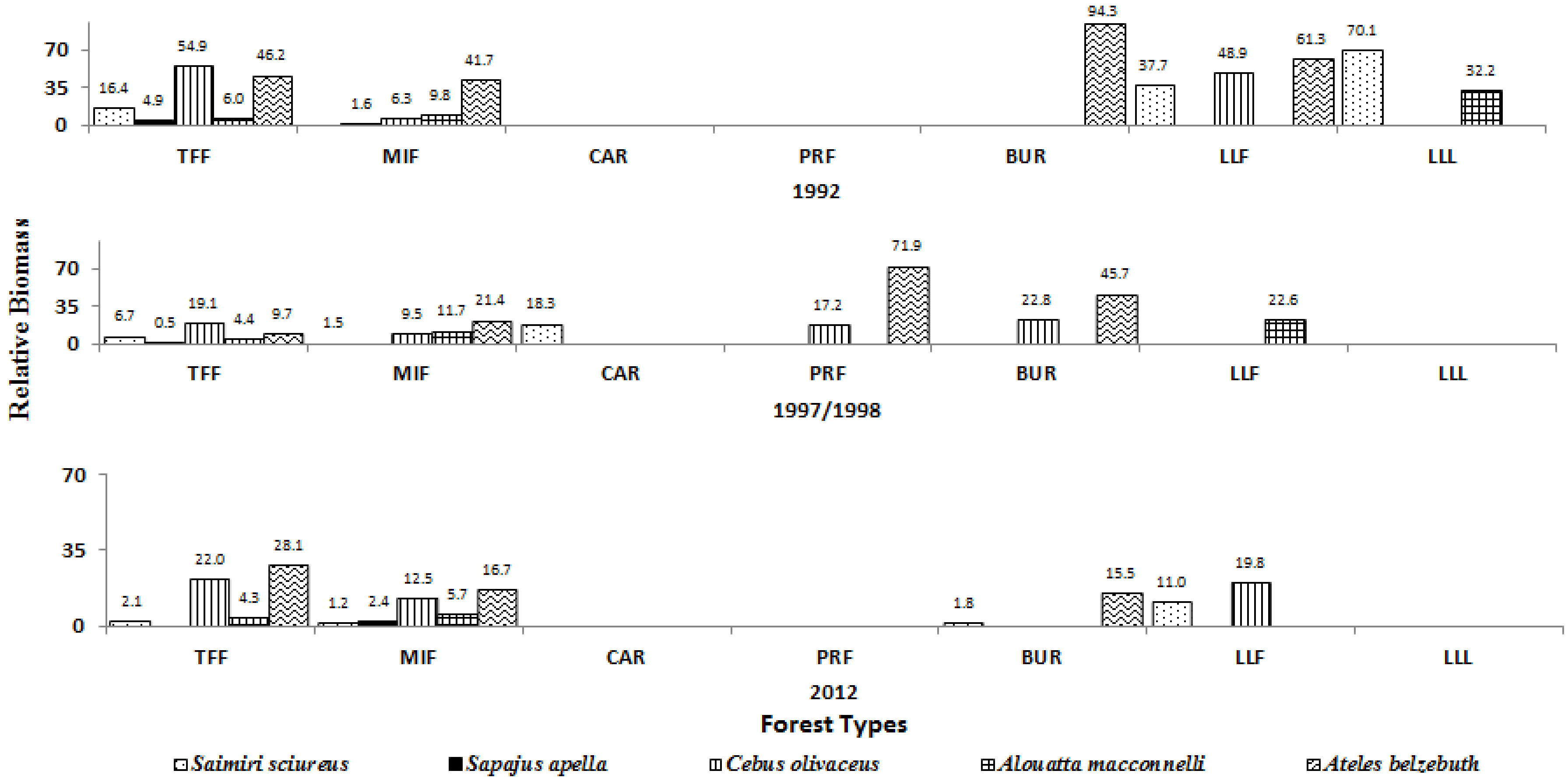

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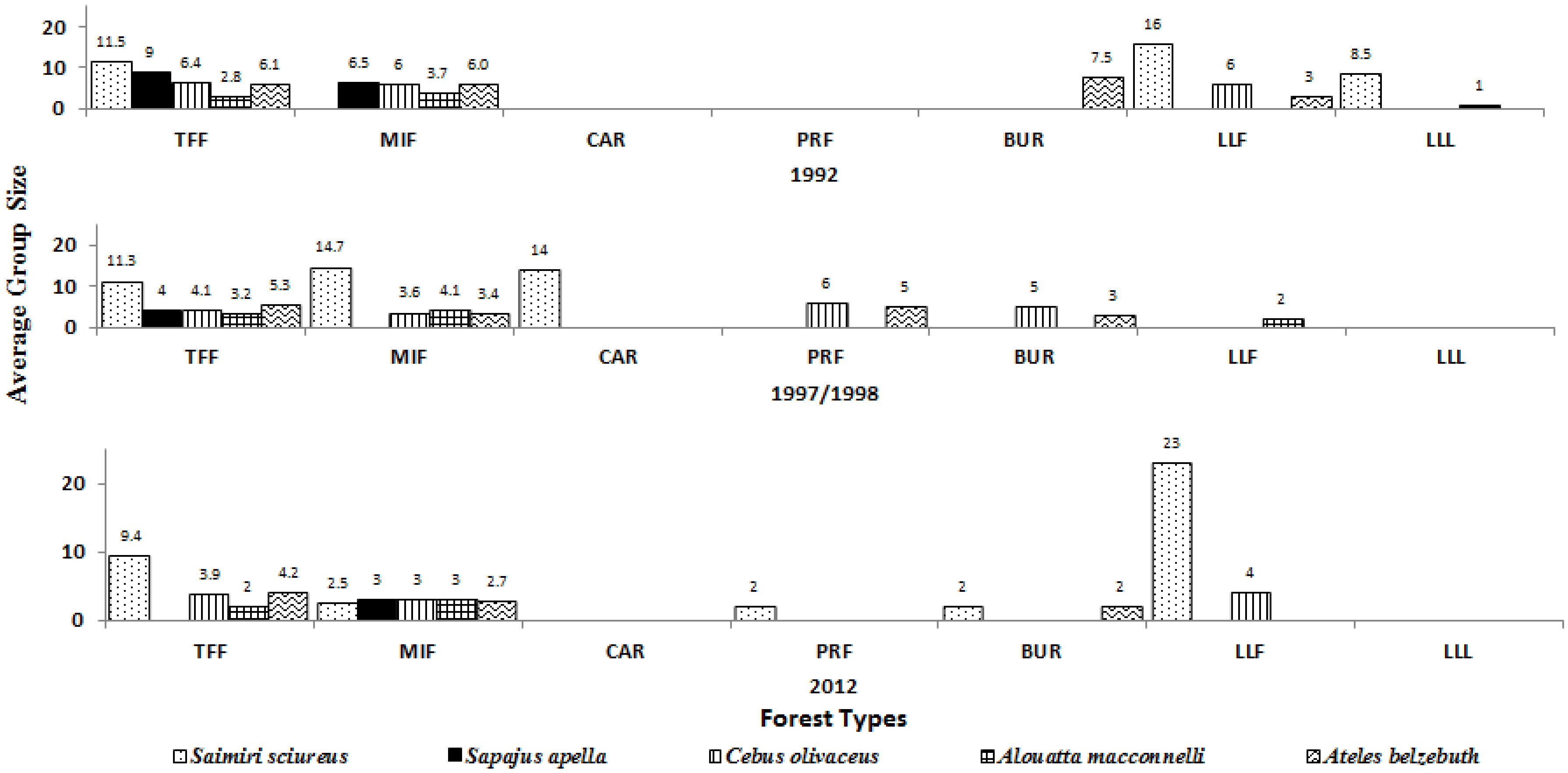

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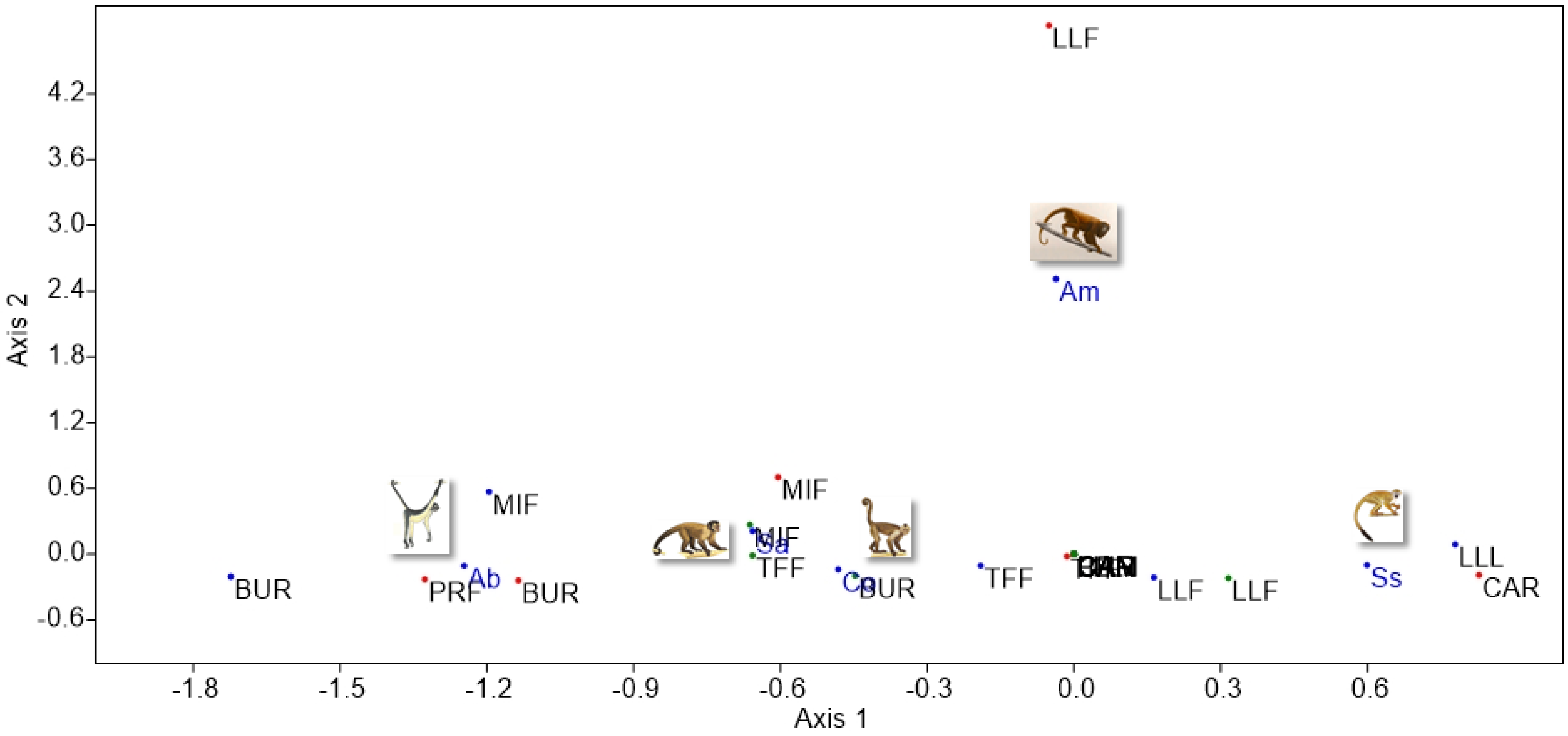

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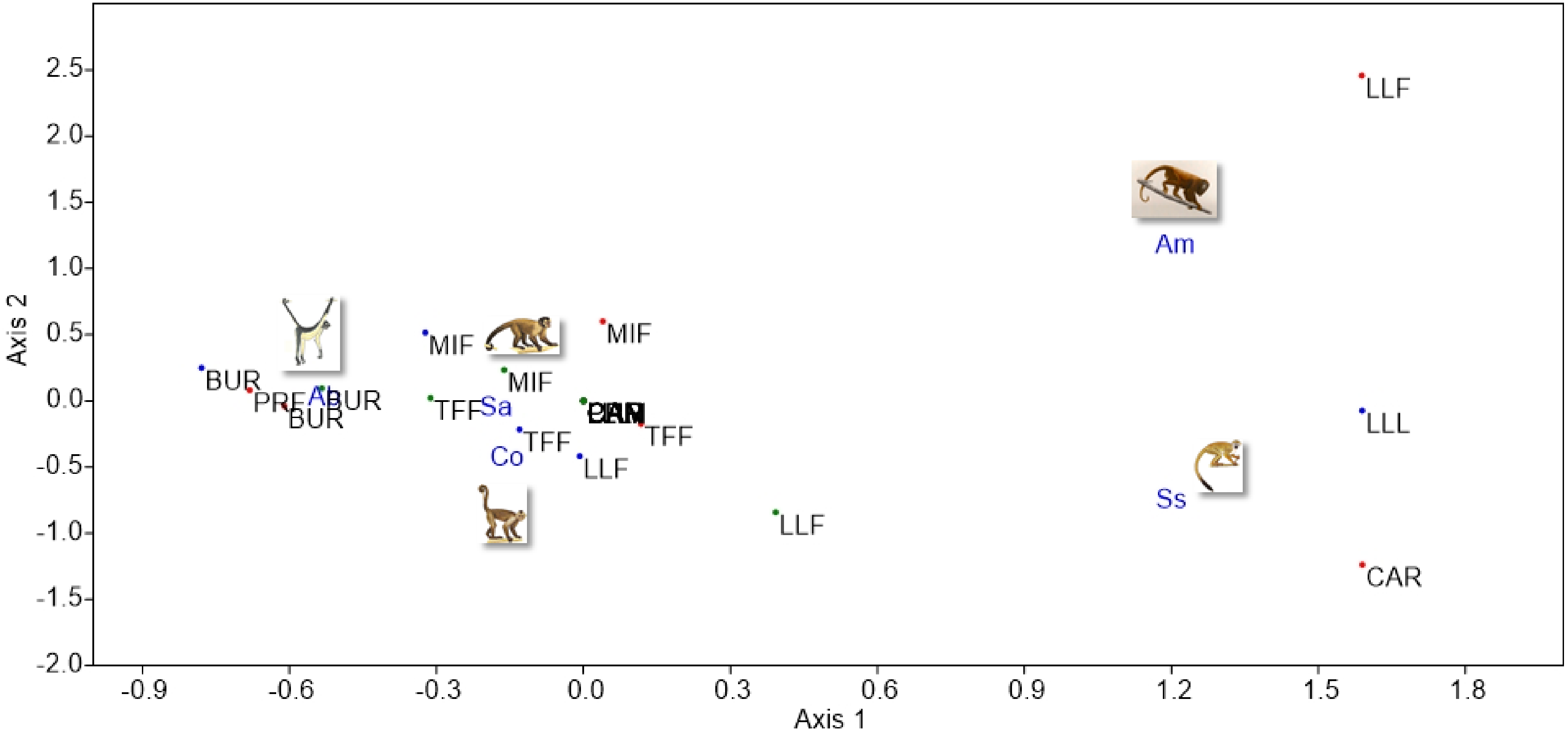
Figure 8.



Axis 2
Axis 1
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2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-0.9
-0.6
-0.3
0.0
0.3
0.6
0.9
1.2
1.5
1.8
LLF
Am
MIF
MIF
BUR
MIF
BUR
TFF
Sa
TFF
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Co
LLF
LLL
Ss
LLF
CAR

6. CONCLUSÃO

O presente estudo mostrou que as comunidades de primatas da Estação Ecológica de Maracá e do assentamento humano Bom Jesus não diferiram signiticativamente entre os parâmetros de abundância, além de que a caça ainda não está influenciando na estrutura dessa comunidade.

A abundância relativa das espécies que acessam os estratos mais altos (20-30 m) na área impactada é maior do que na área protegida.

Também observamos que a abundância de *Saimiri sciureus* estava diretamente relacionada com a área basal total de árvores com DAP >10, com o DAP >10 médio e com a presença de água. *Alouatta macconnelli* e *Ateles belzebuth* estavam relacionados com o número de clareiras e *Callicebus lugens* esteve negativamente relacionado com a presença de água.

Em relação à dinâmica da população de primatas na Estação Ecológica Maracá não foi encontrado variações significativas entre o tamanho médio de grupo, abundância e biomassa relativa das espécies de primatas nos três anos estudados. Contudo pode-se observar uma similaridade entre os períodos 1997/1998 e 2012 em relação a esses parâmetros.

Foi encontrada uma associação entre biomassa e abundância relative de *Ateles belzebuth* com os buritizais, de *Sapajus apella* e *Cebus olivaceus* com floresta de terra firme e floresta mista, e de *Saimiri sciureus* com as florestas baixas.

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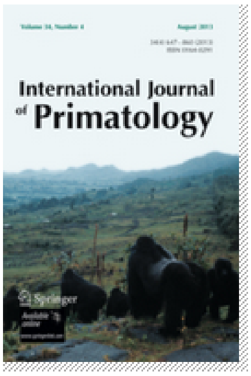

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- Use the active voice, not the passive.

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- Do not repeat values presented in tables in the text.

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Number pages consecutively. Use continuous line numbers starting on the first page. Do not use footnotes. Double-space the text throughout. Leave a line between paragraphs, or indent the first line of a paragraph, so that it is clear to the reader when one paragraph ends and the next begins.

Do not use field functions.

Use tab stops or other commands for indents, not the space bar.

Use the table function to make tables, not spreadsheets.

Use the equation editor or Math Type for equations. Define all variables used in an equation.

Use abbreviations sparingly. If you invent new ones, they will be familiar to you, but not to your reader, who will need to go back and look them up. Define all abbreviations at first mention (abstract and main text) and use them consistently thereafter. Abbreviations that are self-explanatory are more useful to the reader than those that are not (e.g., “wet season” rather than “period 1”).

The text should be clear, readable, and concise. Manuscripts should be well presented, with correct grammar, spelling and punctuation. You should not expect reviewers and editors to make corrections to the English. Authors who are native English speakers must take responsibility for checking the submission for errors. Authors whose first language is not English should ask a native English speaker with experience in writing for scientific journals to verify their use of English prior to submission and confirm this in the letter to the Editor. If the English is unsatisfactory, we will return the manuscript for correction without review.

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Avoid colloquialisms and jargon.

Do not capitalize threat categories such as threatened, endangered, critically endangered.

Be consistent with the use of tense. In general, use past tense for the Methods (what you did), the Results (what you found) and Discussion.

Avoid beginning sentences with “Author (year) found…”. This is usually better phrased as “The finding you wish to highlight (Author, year).”

Use the active voice throughout, not the passive. In other words, employ I/we in relating what you did, observed, etc. Every sentence should have an explicit subject. Use I or we as appropriate for the number of actors.

Avoid parenthetic instructions to readers. In other words, avoid embedded fragments such as (see Darwin, 1859 for fuller discussion on the origin of species). The citation (Darwin, 1959) is sufficient to direct the reader to a fuller source of information on a topic.

Refer to Figures and Tables by number in the text and indicate their approximate position. Do not write “Statistics are presented in Table 1”; instead summarise the content of the figure or table and cite it parenthetically, for example: There was a significant difference in body mass between the sexes (Figure 2)”.

Insert a space between numbers and the unit of measure (6 m, 14 mL).

Use no more than three levels of headings. Do not number headings.

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1. Papers of similar length and topic in a recent issue of the International Journal of Primatology
2. Planning, Proposing and Presenting Science Effectively (by Jack P. Hailman and Karen B. Strier, Cambridge University Press, 1997)
3. Scientific Style and Format. The Council of Biology Editors Manual for Authors,

Editors and Publishers (Cambridge University Press).

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Use strepsirrhine, not prosimian. Give the latin name for a species the first time you mention the common name, both in the abstract and in the main text. Thereafter, be consistent in your use of latin or common name. Linnaean nomina and common names of species should use the lexicons in Grubb et al. (IJP 24(6): 1301-1357, 2003) and Brandon-Jones (IJP 25(1); 97-164, 2004) for Old World monkeys and apes and Colin Grove's Primate Taxonomy (2001, Smithsonian Institution Press) for New World monkeys, tarsiers and strepsirrhines, unless your subject is a new species. Do not use Linnaean nomina adjectivally; write "habitats of *Pan paniscus*," not "*Pan paniscus* habitats."

Do not abbreviate taxa except within a paragraph wherein you have already written out the same taxon. For example, "*Pan troglodytes* and *P. paniscus* live in Africa." is acceptable, but "*P. troglodytes* and *P. paniscus* live in Africa." is not acceptable.

Avoid nicknames such as chimps for chimpanzees, orangs for orangutans, ringtails for ringtailed lemurs.

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The title page should include:

The name(s) of the author(s).

A concise and informative title. We do not encourage journalistic or colloquial titles.

The affiliation(s) and address(es) of the author(s).

The e-mail address, telephone and fax numbers of the corresponding author.

ABSTRACT AND KEYWORDS

Abstract

This should constitute a single paragraph of not more than 250 words that is complete without reference to the text.

Do not use acronyms or complex abbreviations. The abstract must summarize the entire paper, including the general context, your aim, a concise account of the methods, a clear description of the most important results, and a brief presentation of the conclusions, including broad conclusions for Primatology, in that order.

Avoid vague statements such as: "We discuss the implications of our findings". Instead give a brief summary of that discussion.

The abstract should not contain unexplained abbreviations or terms. It should not normally contain citations, but if it does, then these should be included in full, as not all readers are able to access the full text.

Check that all the information in the abstract actually appears in the text of the paper.

Keywords

Provide 4 to 6 keywords which can be used for indexing purposes. These should not repeat the title.

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The Introduction should put your study into context. It should begin broadly, with the general context of your study, and focus down to the specific question that you address. It is not normally appropriate to begin with your study species. Begin with a brief summary of current understanding of the question that you address. Avoid listing articles but providing no information about their content. Cite reviews where appropriate, rather than long lists of articles.

Review the literature that reports previous research on the subject, highlighting why the question is important and what is not yet known. Then introduce your model system (e.g., your study species), and describe why it is a particularly suitable choice to advance our knowledge of the question in hand. No further general context should appear after this point. Lead up to a clear statement of your aim and explain your approach to the question and rationale succinctly. The introduction should normally finish with clear predictions regarding the outcomes of your study.

Reports in IJP should be self-contained. It is not usually appropriate to refer to larger research programs if you do not report the results of these studies.

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The Methods should describe clearly how you carried out your study, including a description of your study site, details of the study subjects, study design and data collection, laboratory analysis and statistical analysis, as appropriate. Provide details of how you collected all data reported in the Results but do not include additional data collection for which you do not actually report findings. Define all terms. Use sub-headings to organize the content.

Data collection and laboratory analyses should be described in sufficient detail such that other researchers could repeat your work. This may involve repeating material from previous publications. Include how you summarized data (means, etc) and report variability (SEM, SD, etc), any transformations used and all statistical tests with reference to the particular questions that they address (e.g., “We compared the mean body mass of males and females using …”). Include the probability level at which you determined significance.

Do not include results in the methods, with the exception of preliminary results that were used to design your study.

Describe how you tested your predictions in the same order as you introduced them, to help the reader.

ETHICAL NOTE

Address the ethical considerations of your study in a separate subsection of the Methods headed Ethical Note. Identify any ethical implications of the experimental design and procedures, and specify any licenses acquired to carry out the work.

Describe procedures that were taken to minimize the welfare impact on subjects, including choice of sample sizes, use of pilot tests and predetermined rules for intervention, where relevant. Include any steps taken to enhance the welfare of subjects. If the study involved keeping wild animals in captivity, state for how long the animals were captive and whether, where and how they were returned to the wild. If you use radio-telemetry, give details of capture methods, and include how you removed the collar at the end of the study.

Where relevant, include a statement that (1) the research complied with protocols approved by the appropriate Institutional Animal Care Committee (provide the name of the committee); and that (2) the research adhered to the legal requirements of the country in which the research was conducted.

Please consult relevant guidelines, including "Guidelines for the treatment of animals in behavioural research and teaching" in ANIMAL BEHAVIOUR, 2006, 71, 245–253 253 and the

ARRIVE guidelines for the Reporting of In Vivo Experiments in Animal Research published in PLoS Biology 8 (6): e1000412. doi:10.1371/journal.pbio.1000412.

RESULTS

The results section should report your findings succinctly in a logical sequence. It should not contain introductory material, methods or discussion. Support your statements with data.

Present data in tables or figures where appropriate. Summarize the findings in words, and refer to the table or figure, but do not repeat values presented in tables.

Do not repeat the same data in both a table and a figure.

Report summary rather than raw data.

Present means and standard deviation/standard error in the format X ± SD/SE unit (i.e., mean body weight = 6.38 ± SD 1.29 kg or mean head-trunk length = 425 ± SE 3.26 mm).

Present ranges as range: 15-29.

Write sample sizes as N=731.

Write numbers less than 1 as 0.54 not as .54.

Present all P values, including non-significant outcomes, using an exact probability value whenever possible. Thresholds are acceptable for highly significant values (e.g., P ‹ 0.001).

Capitalize the P value (P) and sample size (N). Write degrees of freedom in lower case (e.g. df= 4). For example: ANOVA: F = 2.26, df = 1, P = 0.17.

Results should include the name of the statistical test, followed by a colon, the test statistic and its value, degrees of freedom or sample size (depending on which is most appropriate for that test), and the P value, with indication if it is one- or two-tailed (unless you address this issue in the methods). These entries should be separated by commas, e.g. Wilcoxon signed-ranks test: Z=3.82, P‹0.001, N=20; ANOVA: F=2.26, df=1, P=0.17.

Ensure that you include information concerning biological, as well as statistical, significance by presenting summary statistics or a figure.

DISCUSSION

The Discussion should summarize and interpret your main findings and place them in the context of what was already known. It should link back to the question(s), hypotheses and predictions in the Introduction, examine whether the findings support the hypotheses and compare your findings with those of previous studies. The Discussion should not repeat the results, but may summarise them. It should not include further results that are not reported in the Results section. Include discussion of any limitations to your study.

Begin the Discussion with a summary of your findings. There is no need to repeat your aim.

It is often useful to address each major finding in a separate paragraph, comparing your results with previous studies, and giving potential explanations for any differences. Future directions should be precise and detail the exact information required to improve our understanding of the question further.

A paragraph that does not refer to your results does not (usually) belong in your discussion.

End with the broader implications of your results for Primatology (not only for your study taxon).

ACKNOWLEDGMENTS

Acknowledgments should include sources of support, grants, disclaimers, names of those who contributed but are not authors, etc. The names of funding organizations should be written in full.

Remember to acknowledge comments from reviewers and editors in any revision. This includes comments on previous drafts submitted to other journals.

REFERENCES

Citations

Cite references in the text by name and year in parentheses, e.g.:

Negotiation research spans many disciplines (Thompson 1990).

This effect has been widely studied (Abbott 1991; Barakat et al. 1995; Kelso and Smith 1998; Medvec et al. 1993).

Avoid beginning sentences with “Author (year) found…”. This is usually better phrased as “The finding you wish to highlight (Author, year).”

Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished Works should only be mentioned in the text. Do not use footnotes or endnotes as a substitute for a reference list.

Reference list entries should be alphabetized by the last names of the first author of each work.

Examples:

Harris, M., Karper, E., Stacks, G., Hoffman, D., DeNiro, R., Cruz, P., et al. (2001). Writing labs and the Hollywood connection. *Journal of Film Writing*, 44, 213–245.

Slifka, M. K., & Whitton, J. L. (2000) Clinical implications of dysregulated cytokine production. *Journal of Molecular Medicine*, doi:10.1007/s001090000086

Calfee, R. C., & Valencia, R. R. (1991). *APA guide to preparing manuscripts for jornal publication*. Washington, DC: American Psychological Association.

O'Neil, J. M., & Egan, J. (1992). Men's and women's gender role journeys: Metaphor for healing, transition, and transformation. In B. R. Wainrib (Ed.), *Gender Issues Across the Life Cycle* (pp. 107–123). New York: Springer.

Abou-Allaban, Y., Dell, M. L., Greenberg, W., Lomax, J., Peteet, J., Torres, M., & Cowell, V. (2006). Religious/spiritual commitments and psychiatric practice. Resource document. American Psychiatric Association. http://www.psych.org/edu/other_res/lib_archives/archives/200604.pdf. Accessed 25 June 2007.

Journal names and book titles should be italicized.

For authors using End Note, Springer provides an output style that supports the formatting of in-text citations and reference list.

End Note style (zip, 3 kB)

TABLES

Number all tables using Arabic numerals (Table 1, 2, 3).

Cite all tables in text in consecutive numerical order.

Supply a table caption (title) for each table, explaining the components of the table. Include the study taxon, site and dates, where relevant.

The reader should be able to interpret tables without referring to the text. Define all abbreviations and terms in the caption, using the same terminology as used in the text.

Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.

Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

Do not split tables into separate sections (e.g., Table 1a and Table 1b). Make separate tables (Table 1, Table 2) or combine data under the same columns or rows.

FIGURES

Number all figures using Arabic numerals (Fig. 1, 2, 3).

Cite all figures in the text in consecutive numerical order.

Denote figure parts using lowercase letters (a, b, c, etc.).

If your article includes an appendix containing figures, continue the consecutive numbering of the main text. Do not number the appendix figures, "A1, A2, A3, etc.".

Avoid unnecessary gridlines and rectangular frames.

Label all axes and include units of measure in the label. Use a sensible number of decimal places in tick labels and ensure all numbers along an axis have the same number of significant figures (1.0, 1.5, 2.0 not 1, 1.5, 2). Do not repeat % in the axes label and the tick labels.

Match typeface and type size among figures. On a plot, ensure that the axis labels are similar in size.

Ensure that maps include a scale and compass direction.

Number figures in online appendices (Electronic Supplementary Material) separately.

Figure Captions

Each figure should have a concise caption describing accurately what the figure shows.

Include the captions in the text file of the manuscript, not in the figure file. Include the study taxon, site and dates, where relevant.

The reader should be able to interpret figures without referring to the text. Define all abbreviations and terms in the caption, using the same terminology as used in the text.

Figure captions begin with the term Fig. in bold type, followed by the figure number, also in bold type.

Do not include punctuation after the number, or at the end of the caption.

Identify all elements found in the figure in the figure caption; and use boxes, circles, etc., as coordinate points in graphs.

Identify previously published material by giving the original source in the form of a reference citation at the end of the figure caption.

ARTWORK AND ILLUSTRATIONS GUIDELINES

For the best quality final product, we recommend that you submit all of your artwork in na electronic format. Your art will then be produced to the highest standards. The published work will directly reflect the quality of the artwork provided.

Electronic Figure Submission

Indicate which graphics program was used to create the artwork.

For vector graphics, the preferred format is EPS; for halftones, please use TIFF format. MS Office files are also acceptable.

Vector graphics containing fonts must have the fonts embedded in the files.

Name your figure files with "Fig" and the figure number, e.g., Fig1.eps.

Line Art

Definition: Black and white graphic with no shading.

Do not use faint lines and/or lettering and check that all lines and lettering within the figures are legible at final size.

All lines should be at least 0.1 mm (0.3 pt) wide.

Scanned line drawings and line drawings in bitmap format should have a minimum resolution of 1200 dpi.

Vector graphics containing fonts must have the fonts embedded in the files.

Halftone Art

Definition: Photographs, drawings, or paintings with fine shading, etc.

If any magnification is used in the photographs, indicate this by using scale bars within the figures themselves.

Halftones should have a minimum resolution of 300 dpi.

Combination Art

Definition: a combination of halftone and line art, e.g., halftones containing line drawing, extensive lettering, color diagrams, etc.

Combination artwork should have a minimum resolution of 600 dpi.

Color Art

Figures will be produced in black & white in the print version and in color in the electronic version free of charge. The cost for reproducing color in the print version is $1150 per article.

If color is necessary and funding is unavailable, please contact the Editor-in-Chief. If black and white will be shown in the print version, ensure that the main information will still be visible. Many colors are not distinguishable from one another when converted to black and white. A simple way to check this is to make a xerographic copy to see if the necessary distinctions between the different colors are still apparent.

If the figures will be printed in black and white, do not refer to color in the captions.

Color illustrations should be submitted as RGB (8 bits per channel).

Figure Lettering

To add lettering, it is best to use Helvetica or Arial (sans serif fonts).

Keep lettering consistently sized throughout your final-sized artwork, usually about 2–3 mm (8–12 pt).

Variance of type size within an illustration should be minimal, e.g., do not use 8-pt type on an axis and 20-pt type for the axis label.

Avoid effects such as shading, outline letters, etc.

Do not include titles or captions within your illustrations.

Figure Placement and Size

When preparing your figures, size figures to fit the column width.

For most journals the figures should be 39 mm, 84 mm, 129 mm, or 174 mm wide and not higher than 234 mm.

Accessibility

To give people of all abilities and disabilities access to the content of your figures, please make sure that:

All figures have descriptive captions (blind users can then use a text-to-speech software or a text-to-Braille hardware).

Patterns are used instead of or in addition to colors for conveying information (color-blind users would then be able to distinguish the visual elements).

Any figure lettering has a contrast ratio of at least 4.5:1.