FILIPA ALEXANDRA DE ABREU PAULOS

ECOLOGIA COMPORTAMENTAL DE *Callithrix jacchus* (PRIMATES, CALLITRICHIDAE) EM AMBIENTE DE CAATINGA

RECIFE, 2015

FILIPA ALEXANDRA DE ABREU PAULOS

ECOLOGIA COMPORTAMENTAL DE *Callithrix jacchus* (PRIMATES, CALLITRICHIDAE) EM AMBIENTE DE CAATINGA

Dissertação de mestrado apresentada ao Programa de Pós-Graduação em Ecologia (PPGE) da Universidade Federal Rural de Pernambuco (UFRPE) como parte dos requisitos necessários para obtenção do título de mestre em Ecologia.

Orientadora: Dra. Nicola Schiel
(Universidade Federal Rural de Pernambuco)

Co-orientadores:
Dr. Daniel Pessoa
(Universidade Federal do Rio Grande Do Norte)

Dr. Antonio Souto
(Universidade Federal de Pernambuco)

RECIFE, 2015

ECOLOGIA COMPORTAMENTAL DE *Callithrix jacchus* (PRIMATES, CALLITRICHIDAE) EM AMBIENTE DE CAATINGA

FILIPA ALEXANDRA DE ABREU PAULOS

Dissertação de mestrado apresentada ao Programa de Pós-Graduação em Ecologia (PPGE) da Universidade Federal Rural de Pernambuco (UFRPE) como parte dos requisitos necessários para obtenção do título de mestre em Ecologia.

Dissertação apresentada e _____ em _____/_____/_____

Orientadora

_____

Prof[a] Dra. Nicola Schiel – UFRPE

Examinadores

_____

Dra. Tacyana Oliveira – UEPB

_____

Dra. Danise Alves – UFRPE

_____

Dr. Thiago Gonçalves-Souza – UFRPE

Suplente:

_____

Dr. Pabyton Cadena – UFRPE

Ficha Catalográfica

P331e Paulos, Filipa Alexandra de Abreu
Ecologia comportamental de *Callithrix jacchus* (Primates, Callitrichidae) em ambiente de Caatinga / Filipa Alexandra de Abreu Paulos. -- Recife, 2015.
85f. : il.

Orientadora : Nicola Schiel.
Dissertação (Mestrado em Ecologia) – Universidade Federal Rural de Pernambuco, Departamento de Biologia, Recife, 2015.
Inclui referência(s) e anexo.

1. Comportamento 2. Semiárido 3. Sagui-comum 4. Polimorfismo visual I. Schiel, Nicola, orientadora II. Título

CDD 574.5

DEDICATÓRIA

Dedico esta dissertação à kitty,

e a todos os saguis que acompanhei nesta jornada

EPÍGRAFE

“A grandeza de uma nação pode ser julgada

pelo modo que seus animais são tratados”

- Mahatma Gandhi

AGRADECIMENTOS

Agradeço primeiramente á minha mãe, por sempre acreditar em mim e apoiar minhas decisões mesmo não concordando com elas. Sem o seu apoio eu não estaria aqui defendendo esta dissertação. Ao meu irmão, pois apesar de ser desmiolado, também sempre me incentivou a ir mais longe e seguir o meu sonho. Agradeço à minha familia, em geral. Meus avós, tios, primos, e claro kitty de quem tanto sinto falta.

À minha orientadora, Dra. Nicola Schiel, por apesar de não me conhecer me ter aceito orientar mesmo eu estando ainda do outro lado do oceano. Por todos os ensinamentos, ajudas, contribuições, paciência e sermões durante todo o processo, que me ajudaram a crescer tanto profissionalmente como pessoalmente. Aos meus co-orientadores, Dr. Daniel Pessoa e Dr. António Souto, pelas suas contribuições valiosas no trabalho.

À Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) pela concessão da bolsa de estudos.

Ao Dr. Geraldo Baracuhy por nos ceder nosso local de estudo. E a todas as pessoas envolvidas naquela fazenda, pois foram um apoio bastante importante durante todo o tempo passado lá.

À coordenadora do curso de Pós-Graduação em Ecologia (PPGE), Paula Braga, por toda a ajuda prestada no momento da inscrição e matricula no curso, assim como pela disponibilidade total, quando eu ainda lá de Portugal enviava milhoes de e-mails com as minhas dúvidas e problemas. Muito obrigada! A todos os colegas da turma 2013.2, pelo companheirismo e ajuda inicial quando ainda me encontrava perdida pelo Brasil. Um especial obrigado á Joanny Martins, que foi a minha guia quando não sabia nem para onde ia e tinha um monte de burocracia para tratar. Problema de ser estrangeira!

A todos os meus colegas e amigos do Laboratório de Etologia Teórica e Aplicada (LETA). Obrigada pela amizade, pelas mesas redondas, pelas confraternizações e por toda a ajuda durante estes dois anos. Foi muito bom ter conhecido todos vocês! Um especial obrigado à Natasha Bittencourt, Shalana Castro, Fernanda de la Fuente, Marilian Boachá, Danise Alves e Rafaela Souza pela amizade que apesar de não ser de sempre, tenho a certeza que será para sempre, e por me fazerem sentir em casa mesmo

estando a milhares de km da minha cidade natal. Obrigada pelas conversas, apoio, carinho, e aprendizagens. Parece que terão de me aturar por mais uns anos.

Ao Mauro Vilar e mais uma vez à Rafaela Souza, por me mostrarem Recife, por me darem a conhecer esta cidade e todas as outras (principalmente Pipa). Por sempre me incluirem em todas as vossas saídas, mesmo eu negando, ahaha! Por todas as novas amizades que fiz à vossa conta, e por serem o meu pilar aqui no Brasil. Aprendi muito com vocês. Espero um dia poder retribuir toda a vossa hospitalidade =)

Por último, mas não menos importante, obrigada a todos os amigos de Portugal, pela amizade verdadeira que não muda apesar da distância. Um especial obrigado à Vânia Baptista, que para além de amiga é como um irmã e que mesmo longe continua perto, ajudando de todas as maneiras possiveis e imaginárias, ouvindo meus problemas e dúvidas existênciais e dando sempre suas contribuições para a melhoria deste trabalho.

Não poderia deixar de agradecer à parte mais importante desta dissertação, aos saguis. Eles que foram parte essencial deste estudo, pois sem a sua facil habituação à minha presença nada disto teria sido possível.

SUMÁRIO

Abreu, Filipa Alexandra de (MSc Ecologia) Universidade Federal Rural de Pernambuco. Julho de 2015. Ecologia comportamental de *Callithrix jacchus* (PRIMATES, CALLITRICHIDAE) em ambiente de Caatinga. Nicola Schiel (Orientadora); Daniel Pessoa e Antônio da Silva Souto (Co-orientadores).

RESUMO

Callithirx jacchus é um primata do Novo Mundo, com uma grande adaptabilidade a diversos ambientes, habitando desde Mata Atlântica à Caatinga. Este pequeno primata possui uma dieta onívoria e uma visão polimórfica, com dois fenótipos na população (tricromatas e dicromatas). A Caatinga é um ambiente semiárido que apresenta condições extremas, como altas temperaturas e baixas precipitações, impondo vários desafios aos animais que a habitam. Devido a estas condições ambientais, existe uma elevada escassez de recursos vegetais, estando estes disponíveis apenas em alguns períodos do ano. Por outro lado, há disponibilidade de insetos durante todo o ano. Dessa forma, o presente estudo tem como objetivo geral analisar a ecologia comportamental do sagui-comum de vida livre. Primeiramente investigamos os padrões comportamentais e a ecologia alimentar destes primatas nas estações chuvosa e seca. Posteriormente, comparamos o forrageio por insetos entre fêmeas e machos, investigando o efeito que os fenótipos têm nestas capturas. O estudo foi realizado na Fazenda Marimbondo, situada no munícipio de Cabaceiras, Paraíba. Durante 6 meses de estudo, observamos 19 indivíduos (5 grupos), através do método de observação comportamental animal focal associado ao método de *ad libitum*. Adicionalmente, registramos todos os eventos de exploração de recursos vegetais, assim como, todas as capturas de insetos. Com relação aos padrões comportamentais, observamos uma diferença significativa no tempo de descanso entre as duas estações, com aumento deste comportamento na estação seca. A respeito da ecologia alimentar, constatamos o consumo de alimentos alternativos tais como cladódio e flores de cactáceas entre outros. Ainda, observamos um consumo de várias presas animais, nomedamente presas insectívoras. Dentro deste consumo, observamos um maior número de capturas por parte de fêmeas, existindo apenas diferença significativa nas capturas de insetos totais e de coloração conspícua quando fêmeas lactantes estavam presentes na amostra. Por fim, verificamos um efeito do tamanho do inseto aliado à sua coloração nas capturas por machos dicromatas. Estes resultados sugerem que *C. jacchus* possui estratégias comportamentais ajustadas para sobreviver num ambiente como a Caatinga. Além

disso, as capturas de insetos parecem ser influenciadas tanto pela lactação como pelo fenótipo, sugerindo que na população em estudo este polimorfismo seja mantido por vantagem heterozigótica.
Palavras-chaves: sagui comum; padrões comportamentais; polimorfismo visual; semiárido.

Abreu, Filipa Alexandra de (MSc Ecologia). Federal Rural University of Permanbuco. July 2015. Behavioral ecology of *Callithrix jacchus* (PRIMATES, CALLITRICHIDAE) in Caatinga environment. Nicola Schiel (Supervisor); Daniel Pessoa e Antônio da Silva Souto (Co-supervisors).

ABSTRACT

Callithrix jacchus is a Neotropical primate, with a high adaptability to different environments, occuring in Atlantic Forest and Caatinga. These primates have an omnivorous diet and a polymorphic vision, with two phenotypes in the population (trichromatic and dichromatic). The Caatinga is a semiarid environment that presents extreme conditions such as high temperature and low rainfall, imposing several challenges to animals. Due to these conditions, plant resources are scarce and available only in certain periods of the year. Nonetheless, insects are available during all year. This study aimed to analyze the behavioral ecology of free-living commom marmosets in a Caatinga environment. First, we investigated the behavioral patterns and feeding ecology of these primates in the rainy and dry season. Later, we compared how colour vision affect insect prey capture between females and males. The study was conduted in the Fazenda Marimbondo, located near to Cabaceiras, Paraíba. During 6 months of study, we observed 19 individuals (5 groups), throught the focal animal sampling method associated with *ad libitium* method. Additionally, we recorded all the consumed plant items and animal prey captures. We observed a significant difference in the resting time between the two seasons, with an increase of this behavior during the dry season. Insectivorous preys were the most explored item by common marmosets, and alternative plant resources such as cactu's cladode were also consumed. Overall, within the insect consumption, we observed a significant higher number of captures performed by females and a significant higher number in conspicuous insects captures when lactating females were present. Finally, we found a size-coloration effect in the insect captures performed by males (dichromats). These results suggest that *Callithrix jacchus* adjust their behavioral patterns and feeding ecology to survive in a semiarid environment. Futhermore, the insects captures appear to be influenced by both lactation and colour vision, suggesting that the polymorphism in our population is maintained by heterozygous advantage.

Key-words: common marmoset; time budget; visual polymorphism; semiarid.

1. INTRODUÇÃO GERAL

Na Caatinga, um ambiente semiárido com altas temperaturas e baixa pluviometria (LEAL *et al.*, 2003), a escassez de recursos podem ser extremas. Sugere-se que mamíferos que nela habitam tendem a adquirir estratégias comportamentais de maneira a sobreviver a estas condições tão adversas (e.g. STREILEIN, 1982; ALBUQUERQUE *et al.*, 2012). Alguns estudos neste ambiente semiárido têm sido direcionados para primatas, devido à variação nas suas características morfológicas, ecológicas e comportamentais (EISENBERG & REDFORD, 1999). Assim, alguns autores revelam que estas estratégias comportamentais podem ser observadas nas mudanças temporais dos padrões comportamentais, como o caso de DE LA FUENTE *et al.* (2014), em que os primatas ajustaram seus comportamentos de acordo com a temperatura ao longo do dia. Outros mostram que estas estratégias são feitas quanto à alimentação, modificando a sua dieta (AMORA *et al.*, 2013) ou utilizando de ferramentas para obter o alimento (MOURA & LEE, 2004; MORAES *et al.*, 2014). No estudo conduzido por AMORA *et al.* (2013), os autores observaram um consumo de itens alimentares peculiares por parte de primatas, tal como folhas e frutas de cactáceas, enquanto os estudos de MOURA & LEE (2004) e MORAES *et al.* (2014) observaram o uso de ferramentas para obter alimento de espécies vegetais protegidas por espinhos ou de difícil acesso.

Com relação a dieta de primatas, estudos que tratem da visão de cores são de grande contribuição para a compreensão das técnicas de forrageio utilizadas por este grupo, visto que a seleção natural favoreceu a visão como principal meio de percepção do ambiente (KLEBER *et al.*, 2003). Os primatas do Novo Mundo possuem um tipo de visão característico em que machos e fêmeas homozigóticas possuem visão dicromática e que fêmeas heterozigóticas apresentam visão tricromática (JACOBS & NEITZ, 1987). As únicas exceções são os bugios (*Alouatta sp.*) e os macacos-da-noite (*Aotus sp.*), que são tricromáticos e monocromáticos, respetivamente (JACOBS *et al.*, 1996a; JACOBS *et al.*, 1996b). Relativamente a esta área, já foram realizados vários estudos (e.g. OSORIO & VOROBYEV, 1996; REGAN *et al.*, 2001; CAINE *et al.*, 2003, 2010; DOMINY *et al.*, 2003; SMITH *et al.*, 2003; OSORIO *et al.*, 2004; SAITO *et al.*, 2005; VOGEL *et al.*, 2007; MELIN *et al.*, 2007, 2012; PERINI *et al.*, 2009; FEDIGAN *et al.*, 2014) revelando que a maior vantagem do tricromatismo é a detecção de itens de coloração conspícua (OSORIO & VOROBYEV, 1996; CAINE & MUNDY, 2000; SMITH *et al.*, 2003). Por outro lado, os dicromatas têm vantagem no forrageio em locais com pouca luminosidade, possuem uma melhor visão espacial e têm uma maior

facilidade em detectar alimentos crípticos ou camuflados (REGAN *et al*., 2001; CAINE *et al.*, 2003, 2010; SAITO *et al*., 2005; MELIN *et al.*, 2007; FREITAG & PESSOA, 2012; SMITH *et al*., 2012). MORGAN *et al*. (1992) referem que estes indivíduos utilizam outras pistas acromáticas tal como brilho, forma ou textura ao invés da cor para detectar os objetos. No entanto, apesar da grande variedade de estudos a maioria é realizada em cativeiro, sendo poucos estudos direcionados para o gênero *Callithrix*.

Callithrix jacchus é um pequeno primata neotropical com visão polimórfica, possuindo uma grande distribuição geográfica (PONTES & CRUZ, 1995), destacando-se por conseguir sobreviver em uma grande variedade de ambientes, desde a Mata Atlântica à Caatinga (MODESTO & BERGALLO, 2008). O sagui-comum é uma espécie diurna, arborícola e que possui em seu grupo, normalmente apenas um par reprodutor (AURICCHIO, 1995). Alimentam-se de insetos durante todo o ano, particularmente de grilos, gafanhotos, cigarras, formigas e térmitas (STEVENSON & RYLANDS, 1988). Visto habitarem também a Caatinga, alguns estudos já foram realizados focando em partes distintas da sua ecologia (MOURA, 2007; AMORA *et al*., 2012; DE La FUENTE *et al*., 2014). Com relação ao seu polimorfismo visual, foram realizados alguns trabalhos nesta área, mas todos eles em cativeiro (TRAVIS *et al*., 1988; TOVÉE *et al*., 1992; WILLIAMS *et al.*, 1992; HUNT *et al.*, 1993; SHYUE *et al*., 1998; KAWAMURA *et al.*, 2001; SURRIDGE & MUNDY, 2002). No entanto, estudos comportamentais são ainda bastante escassos (FREITAG & PESSOA, 2012; MOREIRA *et al.*, 2015).

Assim, devido tanto à certa facilidade de habituação aos observadores, como à sua grande adaptabilidade a diversos ambientes e aos seus padrões de atividade diurnos, esta espécie foi utilizada como modelo para estudos ecológicos e comportamentais. O presente estudo foca na ecologia comportamental da espécie *Callithrix jacchus* em ambiente de Caatinga, tendo como objetivos: (1) Verificar como um primata sem aparente adaptação fisiológica consegue sobreviver em um ambiente semiárido como a Caatinga, observando para isso o "time-budget" de indivíduos nas duas estações (chuvosa e seca), assim como, a sua dieta ao longo de todo o estudo; (2) Observar o comportamento de forrageio por insetos de fêmeas e machos, tentando verificar de que forma esta captura é afetada pelos dois fenótipos existentes na população.

2. FUNDAMENTAÇÃO TEÓRICA

2.1 Caatinga

A Caatinga é o único domínio morfoclimático restrito ao território brasileiro compreendendo uma área de aproximadamente 800.000 km^2, representando 70% da região do Nordeste e 11% do território nacional (ANDRADE-LIMA, 1981). Este ambiente apresenta características climáticas extremas tais como alta radiação solar, baixa nebulosidade, alta temperatura média anual, umidade relativa baixa e precipitações baixas (LEAL *et al*., 2003). A temperatura média anual varia entre 24 a 28º C e a precipitação média anual varia entre 240 e 1.500 mm (PRADO, 2003). Esta precipitação é bastante invulgar/sazonal, sendo reduzida a períodos curtos do ano, normalmente três meses (NIMER, 1979).

Considerada como "Floresta Branca" (PRADO, 2003), este ambiente é composto predominantemente por florestas arbóreas ou arbustivas baixas de espécies vegetais decíduas apresentando espinhos, microfilia e características xerofíticas. Estas características permitem às plantas sobreviverem em períodos longos de estiagem, quando a umidade do solo é extremamente baixa (LEAL *et al*., 2003; ANDRADE *et al*., 2005; ALBUQUERQUE *et al*., 2012). A Caatinga possui cerca de 1500 espécies de plantas diferentes (ALBUQUERQUE *et al.*, 2012), sendo as famílias mais representativas desta região: Fabaceae/Leguminosae, Cactaceae, Bromelacieae, Euphorbaceae (LEAL *et al.*, 2003). Entres estas, as mais representadas e também endêmicas deste ambiente são Fabaceae/Leguminosae (QUEIROZ, 2002) e Cactaceae (TAYLOR & ZAPPY, 2002). No entanto, a composição florística das caatingas não é uniforme e varia de acordo com o volume das precipitações, da qualidade dos solos entre outros fatores (BARBOSA *et al*., 2003), podendo ser observadas variações fisionômicas a distâncias relativamente curtas (escala local) (AMORIM *et al.*, 2005).

2.1.1 Fauna

Estudos com invertebrados são escassos neste ambiente. Entre esta fauna, a classe Insecta é uma das que contêm maior número de espécies, estando dividida em 26 ordens (GULLAN & CRANSTON, 2005). Neste ambiente, são poucos os estudos sobre sazonalidade e abundância desta classe, sendo que os realizados apresentam resultados bastante semelhantes, relatando que os insetos são mais abundantes em épocas chuvosas e próximo a açudes, onde a vegetação é mais verde (VASCONCELLOS *et al*., 2010;

SILVA & LIMA, *no prelo*). Segundo vários autores as ordens mais comuns em ambientes na Caatinga são Diptera, Hymenoptera e Coleoptera (VASCONCELLOS *et al*., 2010; OLIVEIRA *et al*., 2013; SILVA & LIMA, *no prelo*). Tal como a maioria dos animais, estes insetos possuem estratégias de fuga a predação, sendo estas, camuflagem e apresentação de coloração críptica, mimetismo (coloração aposemática) ou procurando locais de difícil acesso para predadores (EDMUNDS, 1974).

Relativamente á fauna vertebrada, os estudos têm crescido nos últimos anos. Desta forma, aves, repteis, peixes e mamíferos têm sido alvo de vários estudos em ambiente semiárido, aumentando assim o conhecimento sobre a sua diversidade neste tipo de ambiente (ALBUQUERQUE *et al*., 2012). Dentro deste sub-filo, os mamíferos são os que apresentam uma menor diversidade (ALBUQUERQUE *et al.*, 2012), sendo conhecidas cerca de 156 espécies, 12 destas endêmicas do semiárido brasileiro (ALBUQUERQUE *et al*., 2012). Pelo facto de a Caatinga ser geologicamente recente (AB'SÁBER, 1974), este grupo não possui adaptações fisiológicas para viver em ambientes de condições tão severas (STREILEIN, 1982). Contudo vários autores têm demonstrado o desenvolvimento de estratégias comportamentais possibilitando a sua existência em ambiente semiárido (e.g. STREILEIN, 1982; MENDES *et al.*, 2004; FREITAS *et al.*, 2005). Estes estudos mostram, em geral, que as estratégias utilizadas pelos animais são através de mudanças no seu "time-budget", isto é, evitando as horas de maior temperatura e calor para realizar as suas atividades diárias (ROCHA, 1995; DE LA FUENTE *et al.*, 2014), ou mudanças na sua dieta, visto a escassez de recursos ser bastante comum no semiárido (e.g. MOURA & LEE, 2004; AMORA *et al*., 2013; MORAES *et al.*, 2014). Com relação aos primatas, são conhecidas algumas espécies que habitam a Caatinga (e.g. *Callithrix jacchus, Callithrix pennicillata, Sapajus libidinosus, Sapajus flavius, Alouatta ululata*) havendo consequentemente, estudos direcionados para a sua ecologia nestas condições (e.g. MOURA & LEE, 2004; MOURA, 2007; FERREIRA *et al*., 2009; MORAES *et al*., 2014, AMORA *et al*., 2013, DE LA FUENTE *et al*., 2014).

2.2 Visão em primatas

A visão dos vertebrados requer a presença de fotorreceptores, bastonetes e cones, e de mecanismos neurais que descodificam os sinais visuais (JACOBS *et al*., 1996a,b). O tipo de visão está relacionada com o número de cones existentes na retina e o seu pico de absorção (DOMINY *et al.*, 2003; FREITAG & PESSOA, 2012). Desta forma, um

organismo tricromático possui três tipos de cones, sendo cada um sensível a determinado tipo de comprimento de onda (JACOBS, 1994). Os cones S (do inglês "short") possuem pigmentos com pico de sensibilidade para a cor azul, isto é, comprimentos de onda curtos (CAINE *et al.*, 2003). Os cones M e L (do inglês "middle" e "long") apresentam os seus picos de sensibilidade para a cor verde (comprimentos de onda médios) e cor vermelha (comprimentos de onda longos), respetivamente (CAINE *et al*., 2003; SURRIDGE *et al.*, 2003). Os indivíduos de visão dicromata, pelo contrário, possuem apenas dois tipos de cones. O cone sensível ao comprimento de onda curto (cone S) e o cone sensível ao comprimento de onda médio ou longo (M ou L) (GOSH *et al.*, 1997).

Entre os primatas, os primatas do Velho Mundo possuem tricromacia uniforme com visão similar à dos seres humanos (ONISHI *et al*., 1999). Já nos Platyrhini (Primatas do Novo Mundo) existe polimorfismo visual, em que os machos são obrigatoriamente dicromatas e as fêmeas podem apresentar dicromatismo ou tricromatismo (JACOBS & NEITZ, 1987). Isto acontece, pois a codificação dos comprimentos de onda médio e longo se dá no mesmo *locus* do cromossomo X (MOLLON *et al*., 1984), ao contrário do que acontece em Primatas do Velho Mundo, em que a codificação se processa em diferentes *loci*. Já o comprimento de onda mais curto (S) é codificado no autossoma 7, estando presente em todos os primatas (HUNT *et al*., 1993). Assim, as fêmeas heterozigóticas para esse gene irão possuir visão tricromática enquanto que as fêmeas homozigóticas são dicromatas (MOLLON *et al*., 1984; JACOBS & NEITZ, 1987; TRAVIS *et al*., 1988). De acordo com JACOBS & DEEGAN (2005) 60% das fêmeas apresentam tricromatismo e apenas 40% apresentam dicromatismo. Ainda, em cada tipo de visão podem ser encontrados até seis diferentes fenótipos dentro de uma mesma população, isto é, três tipos de dicromatas e três tipos de tricromatas com picos de absorção diferenciados (OSORIO *et al*., 2004; PESSOA *et al.*, 2012). Porém, dentro da mesma infraordem existe o gênero *Alouatta*, nos quais todos os indivíduos são tricromatas, e o gênero *Aotus* em que só existe monocromatismo, isto é, todos os animais possuem apenas o comprimento de onda mais curto (JACOBS *et al.*, 1996a; JACOBS *et al.*, 1996b).

A visão polimórfica nos primatas do Novo Mundo é ainda uma incógnita. O seu surgimento levanta várias hipóteses (JACOBS *et al*., 1996a; GILAD *et al*., 2004; MATSUI *et al*., 2010), sendo as mais aceitas a hipótese da frugivoria e a hipótese da folivoria. A primeira defende que a tricromacia se mantêm devido ao fato de esta

conseguir discriminar frutas maduras entre as folhagens verdes das árvores (OSORIO & VOROBYEV, 1996; REGAN *et al*., 2001). Já a hipótese da folivoria refere que a tricromacia é favorecida devido a discriminação de folhas maduras sob uma folhagem velha e castanha (KREMERS *et al*., 1999) e de folhas jovens e de tom avermelhado entre as folhagens verdes (DOMINY & LUCAS, 2001; DOMINY *et al*., 2003). Assim, é considerada como principal vantagem dos indivíduos tricromatas a discriminação de objetos de cores conspícuas (e.g. CAINE & MUNDY, 2000; SMITH *et al*., 2003). Em contrapartida, estudos recentes realizados por CAINE *et al.* (2003, 2010), SAITO *et al*. (2005), MELIN *et al*. (2007) e SMITH *et al.* (2012) relatam vantagens dos dicromatas sobre os indivíduos tricromatas. Estes estudos mostram que este fenótipo tem facilidade em forragear em locais de baixa luminosidade, tem uma melhor visão espacial e detetam com mais facilidade itens camuflados ou com coloração críptica, já que utilizam outras pistas, como brilho, textura e forma (MORGAN *et al*.,1992).

Relativamente à permanência deste polimorfismo em primatas do Novo Mundo, apenas recentemente se tem debatido sobre essa questão. O fato deste polimorfismo se manter ao longo de 14 milhões de anos sugere que haja uma vantagem adaptativa para indivíduos com visão tricromática. São conhecidas duas hipóteses gerais: a hipótese da vantagem heterozigótica e a hipótese da seleção por frequência negativa (MOLLON *et al*., 1984). Estas hipóteses tentam explicar como o balanço da seleção afeta a frequência dos dois fenótipos (BOISSINOT *et al*., 1998; SURRIDGE *et al*., 2003). A hipótese da vantagem heterozigótica sugere que fêmeas tricromatas tenham um "fitness" mais elevado que as fêmeas dicromatas e por isso este polimorfismo se mantêm (SURRIDGE & MUNDY, 2002). Já a segunda hipótese indica que este polimorfismo se mantém, pois a seleção favorece o fenótipo com menor frequência, no caso o tricromatismo. Ainda, este tipo de seleção pode ser dividido em divergência de nicho e associação por benefício mútuo. A divergência de nicho sugere que estes dois fenótipos ocupam diferentes nichos, aumentando assim o "fitness" tanto dos dicromatas como dos tricromatas, enquanto que a associação por benefício mútuo refere que o aumento na diversidade de fenótipos, aumenta o "fitness" dos dois (BUNCE, 2015). No entanto, estudos mostrando o efeito que estas duas hipóteses têm no polimorfismo em primatas são ainda escassos e sem resultados concretos (DOMINY *et al*., 2003; SMITH *et al*., 2003; VOGEL *et al*., 2007; HIWATASHI *et al*., 2010; FEDIGAN *et al*., 2014).

2.3 Espécie em estudo: *Callithrix jacchus*

Callithrix jacchus é um primata do Novo Mundo da família Callitrichidae (HERSHKOVITZ, 1977), sendo popularmente conhecido como sagui-comum, sagui-de-tufo-branco ou sagui-estrela (AURICHIO, 1995). Habitam naturalmente no Nordeste do Brasil (SOUSA & PONTES, 2008), possuindo uma grande adaptabilidade a diferentes ambientes podendo ser encontrados desde a Mata Atlântica a Caatinga (PONTES & CRUZ, 1995). São animais sociais, vivendo em grupos de 3 a 15 indivíduos, formados por adultos, juvenis e infantes (STEVENSON & RYLANDS, 1988). A reprodução deste primata neotropical é típica dos callithriquideos, existindo normalmente apenas um par reprodutor, com uma fêmea e macho dominantes em cada grupo, gerando filhotes gêmeos duas vezes por ano (AURICCHIO, 1995). Isto acontece, pois tanto a fêmea reprodutora como o macho reprodutor suprimem a fertilidade dos outros indivíduos (fêmeas e machos) do grupo (STEVENSON & RYLANDS, 1988). No entanto, poliandria e poliginia podem ocorrer nesta espécie (FERRARI & LOPES FERRARI, 1989). A gestação dos filhotes é de 140 a 150 dias, nascendo com cerca de 10 a 15% do tamanho da progenitora (TARDIF *et al*., 2001). Além disso, estas fêmeas possuem estro logo após o parto (ABBOTT *et al*., 1993). Todos estes fatores levam a que a gestação, assim como a lactação, exijam da fêmea reprodutora um grande gasto energético (NIEVERGELT & MARTIN, 1999; TARDIF *et al*., 2004). Normalmente, o cuidado parental é dividido pelos membros do grupo (FAULKES *et al*., 2009), no entanto, durante as primeiras semanas de vida dos infantes a fêmea é a mais presente neste cuidado (FERRARI & LOPES FERRARI, 1989).

O padrão de atividades da espécie é vasto, tendo sido descrito por STEVENSON & POOLE (1976). De acordo com MAIER *et al.* (1982), estes primatas têm um período de atividade de cerca de 12 horas, sendo os comportamentos de deslocamento, interação com outros membros do grupo e forrageio os mais comuns realizados durante o dia (ALONSO & LANGUUTH, 1989). Os saguis-comuns são onívoros (STEVENSON & RYLANDS, 1988) e a sua dieta é variada, alimentando-se de frutas, folhas, sementes, insetos, aracnídeos, pequenos lagartos, sapos, filhotes e ovos de aves (RYLANDS & de FARIA, 1993). Apesar da sua falta de dimorfismo sexual, estes animais apresentam algumas diferenças sexuais no que diz respeito ao forrageio por alimento (e.g. MICHELS, 1998; BOX *et al.*, 1999; YAMAMOTO *et al.*, 2004). Estudos indicam que fêmeas não só têm mais sucesso na procura, detecção e captura de alimento (e.g. MICHELES, 1998; YAMAMOTO *et al*., 2004), como também têm prioridade no

acesso a este alimento (e.g. TARDIF & RICHTER, 1981; LOPES *et al*., 1997). No geral, esta espécie passa boa parte do seu tempo procurando por presas, sendo ortópteros (grilos e gafanhotos), himenópteras (formigas), isópteros (térmitas), hemípteras (cigarras) e lepidópteras (normalmente, larvas de borboletas e mariposas) as presas insetívoras mais consumidas (STEVENSON & RYLANDS, 1988). A estratégia de forrageio destes animais é considerada vantajosa visto que normalmente os insetos capturados têm coloração críptica, ficando camuflados sob o substrato (STEVENSON & RYLANDS, 1988; SCHIEL *et al*., 2010). Estes insetos além de se camuflarem, evitam a predação colocando-se em locais de difícil acesso como buracos ou possuindo mimetismo, com colorações aposemáticas (EDMUNDS, 1974).

Assim como nos demais primatas do Novo Mundo, *Callithrix jacchus* também possui dimorfismo visual. Para esta espécie foram realizados estudos genéticos (WILLIAMS *et al.,* 1992; HUNT *et al.,* 1993), microespectofotometricos e comportamentais (TOVÉE *et al*., 1992), comprovando assim que este polimorfismo existe tal como na maioria das espécies desta infraordem. Outros estudos mostraram que os picos de absorção destes animais são de 430 nm, 543 nm, 556 nm e 563 nm (SURRIGDE & MUNDY, 2002). Trabalhos mais antigos foram também realizados nesta área, no entanto todos mostraram valores de picos de absorção próximos aos descritos (TRAVIS *et al*., 1988; SHYUE *et al*., 1998; KAWAMURA *et al.*, 2001). Em um estudo mais recente realizado por FREITAG & PESSOA (2012), focou-se nos efeitos da luminosidade na detecção de itens alimentares de diferentes cores sob um substrato verde por machos dicromatas. Estes chegaram a conclusão que em uma luminosidade intermediária, os dicromatas conseguiam identificar mais facilmente itens de cor laranja. Recentemente, MOREIRA e colaboradores (2015), mostraram que fêmeas reprodutoras utilizam pistas visuais da pele da zona sexual (sinais acromáticos/cromáticos e luminosidade) para indicar a altura do parto para os outros indivíduos do grupo. No entanto, são inexistentes os estudos em ambiente natural para esta espécie. A dificuldade de se controlar todas as variáveis faz com que a grande maioria destes estudos seja feita em laboratório.

Estudos que visem ecologia comportamental em ambiente semiárido ou a forma como o polimorfismo visual afeta o forrageio de insetos são ainda escassos no gênero *Callithrix,* e consequentemente, em saguis-comuns. Assim, devido à alta facilidade com que *C. jacchus s*e habitua à presença humana, à sua ampla distribuição além da sua atividade diurna, este pequeno primata neotropical foi utilizado como modelo de estudo.

REFERÊNCIAS BIBLIOGRÁFICAS

ABBOTT, D. H., BARRET, J., GEORGE, L. M. Comparative aspects of the social suppression of reproduction in female marmosets and tamarins. 1993. In: Rylands, A. B. (ed.) Marmosets and Tamarins. Systematics, Behaviour, and Ecology. Oxford University Press, Oxford, pp. 152–163.

AB'SABER, A. N. O domínio morfoclimático semiárido das caatingas brasileiras. Universidade de São Paulo, Instituto de geografia, São Paulo, 1974.

ALBUQUERQUE, U. L., ARAÚJO, E. L., EL-DEIR, A. C. A., LIMA, A. L. A., SOUTO, A., BEZERRA, B. M., FERRAZ, E. M. N., FREIRE, E. M. X., et al. Caatinga revisited: Ecology and conservation of an important seasonal dry forest. *The Scientific World Journal*, 2012. doi:10.1100/2012/205182.

ALONSO, C., LANGGUTH, A. Ecologia e comportamento de *Callitrhix jacchus* (Primates: Callitrichidae) numa ilha de floresta atlântica. *Revista Nordestina de Biologia*, 6(2):105-137, 1989.

AMORA, T. D., BELTRÃO-MENDES, R. & FERRARI, S. F. Use of alternative plant resources by common marmoset (*Callithrix jacchus*) the semi-arid Caatinga scrub forests of Northeastern Brazil. *American Journal of Primatology*, 75: 333-341, 2013.

AMORIM, I. S., SAMPAIO, E. V. S. B., ARAÚJO, E. L. Flora e estrutura da vegetação arbustivo-arbórea de uma área de caatinga do Seridó, RN, Brasil. *Acta Botânica Brasiliensis,* 19 (3): 615-623, 2005.

ANDRADE-LIMA, D. The caatingas dominium. *Revista Brasileira de Botânica*, 4: 149-163, 1981.

ANDRADE, L. A., PEREIRA, I. M., LEITE, U. T. & BARBOSA, M. R. V. Análise da cobertura de duas fitofisionomias de caatinga, com diferentes históricos de uso, no município de São João do Cariri, Estado da Paraíba. Revista Cerne, v.11, n.3, p. 253-262, 2005.

AURICCHIO, P. Primatas do Brasil. São Paulo: Ed. Terra Brasilis. pp.168, 1995.

BARBOSA, D., BARBOSA, M., LIMA, L. Fenologia de espécies lenhosas da Caatinga. 2003. In: LEAL, I. R., TABARELLI, M., SILVA, J. M. C. (Eds) Ecologia e conservação da Caatinga, Universidade Federal de Pernambuco (UFPE), Recife, Brazil, pp. 657–693.

BOISSINOT, S., TAN, Y., SHYUE, S., SCHNEIDER, H., SAMPAIO, I., NEISWANGER, K., HEWETT-EMMETT, D. & LI, W. Origins and antiquity of x-linked triallelic color vision systems in New World monkeys. *Proceedings of the National Academy of Science USA*, 95: 13749-13754, 1998.

BOX, H., YAMAMOTO, M. E., LOPES, F. A. Gender differences in marmosets and tamarins: responses to food tasks. *International Journal of Comparative Psychology*, 12 (2): 59-70, 1999.

BUNCE, J. A. Incorporating ecology and social system into formal hypothesis to guide field studies of color vision in primates. *American Journal of Primatology*, 77: 516-526, 2015.

CAINE, N. G. & MUNDY, N. I. Demonstration of a foraging advantage for trichromatic marmosets (*Callithrix geoffroyi*) dependent on food color. *Proceedings of a Royal Society of London B*, 267: 439-444, 2000.

CAINE, N. G., SURRIDGE, A. L. & MUNDY, N. I. Dichromatic and trichromatic *Callithrix geoffroyi* differ in relative foraging ability for red-green color-camouflaged and non-camouflaged food. *International Journal of Primatology*, 24 (6): 1163-1175, 2003.

CAINE, N. G., OSORIO, D. & MUNDY, N. I. A foraging advantage for dichromatic marmosets (*Callithrix geoffroyi*) at low light intensity. *Biology Letters*, 6: 36-38, 2010.

DE LA FUENTE, M. F. C., SOUTO, A., SAMPAIO, B. & SCHIEL, N. Behavioral adjustments by a small neotropical primate (*Callithrix jacchus*) in a semiarid Caatinga environment. *The Scientific World Journal,* 2014. doi:10.1155/2014/326524.

DOMINY, N. J. & LUCAS, P. W. Ecological importance of trichromatic vision to primates. *Nature*, 410: 363-366, 2001.

DOMINY, N. J., GARBER, P. A., BICCA-MARQUES, J. C. & AZEVEDO-LOPES, M. A. Do female tamarins use visual cues to detect fruit rewards more successfully than do males? *Animal Behaviour*, 66: 829-837, 2003.

EDUMUNDS, M. Defense in animals: a survey of antipredator defenses. Harlow, Longman Group Limited, 357pp, 1974.

EISENBERG, J.F.; REDFORD, K.H. Mammals of the Neotropics: The Central Neotropics. Ecuador, Peru, Bolivia, Brazil. Chicago: University of Chicago Press. v. 3, p. 624, 1999.

FAULKES, C. G., ARRUDA, M. F., MONTEIRO DA CRUZ, M. A. O. Genetic structure within and among populations of common marmoset, *Callithrix jacchus*: Implications for cooperative breeding. In: FORD, S. M., PORTER L. M., DAVIS, L. C. (Ed.) The smallest anthropoids. The marmoset/callimico radiation. Springer. p. 486, 2009.

FEDIGAN, L. M., MELIN, A. D., ADDICOTT, J. F., KAWAMURA, S. The heterozygote superiority hypothesis for polymorphic color vision is not supported by long-term fitness data from wild neotropical monkeys. *PLoS ONE*, 9(1): e84872, 2014.

FREITAG, F. B. & PESSOA, D. M. A. Effect of luminosity on color discrimination of dichromatic marmosets (*Callithrix jacchus*). *Journal of Optical Society of America*, 29 (2), 2012.

FREITAS, R. R., ROCHA, P. L. B., SIMÕES-LOPES, P. C.Habitat structure and small mammals abundance in one semiarid landscape in the Brazilian Caatinga. *Revista Brasileira de Zoologia*, 22 (1): 119-129, 2005.

FERRARI, S. F., LOPES FERRARI, M. A. A re-evaluation of the social organization of the Callitrichidae, with reference to the ecological differences between genera. *Folia Primatologica*, 52: 132 – 147, 1989.

FERREIRA, R. G., JERUSALINSKY, L., SILVA, T. C. F., FIALHO, M. S., ROQUE, A. A., FERNANDES, A., ARRUDA, A. On the occurrence of Cabus flavius (Schreber 1774) in the Caatinga, and the use of semi-arid environments by Cebus species in the Brazilian state of Rio Grande do Norte. *Primates*, 2009. doi: 10.1007/s10329-009-0156-z.

GILAD, Y., WIEBE, V., PRZEWORSKI, M., LANCET, D. & PAABO, S. Loss of olfactory receptor genes with the acquisition of the full trichromatic vision in primates. *Plos Biology*, 2 (1): 0120-0125, 2004.

GOSH, K. K., MARTIN, P. R. & GRUNERT, U. Morphological analysis of the blue cone pathway in the retina of the new world monkey, the marmoset *Callithrix jacchus*. *The Journal of Comparative Neurology*, 379: 211-225, 1997.

GULLAN, P. J. & CRANSTON, P. S. The insects: an outline of entomology. Blackwell Publishing Ltd (Third Eds), 2005.

HIWATASHI, T., OKABE, Y., TSUTSUI, T., HIRAMATSU, C., MELIN, A. D., OOTA, H., SCHAFFNER, C. M., AURELI, F., FEDIGAN, L. M., INNAN, H. & KAWAMURA, S. An explicit signature of balancing selection of color-vision

variation in New World monkeys. *Molecular Biological Evolution*, 27: 453-464, 2010.

HERSHKOVITZ, P. Living New World monkeys (Platyrrhini), with an introduction to primates, vol. 1. Chicago University Press, Chicago, 1977.

HUNT, D. V., WILLIAMS, A. J., BOWMAKER, J. K. & MOLLON, J. D. Structure and evolution of the polymorphic photopigment gene of the marmoset. *Vision Research*, 33 (2): 147-154, 1993.

JACOBS, G. H. Variations in primate color vision: mechanisms and utility. *Evolutionary Anthropology*, 3: 196-205, 1994.

JACOBS, G. H. & NEITZ, J. Inheritance of color vision in a New World monkey (*Saimiri sciureus*). *Proceedings of the National Academy of Science*, 84: 2545-2549, 1987.

JACOBS, G. H., NEITZ, M., DEEGAN, F. & NEITZ, J. Trichromatic colour vision in new world monkey. *Nature*, 382, 1996A.

JACOBS, G. H., NEITZ, M. & NEITZ, J. Mutations in S-cone pigment genes and the absence of colour vision in two species of nocturnal primates. *Proceedings of the Royal Society of London B*, 263: 705-710, 1996B.

JACOBS G.H. & DEEGAN II, J.F. Polymorphic New World monkeys with more than three M/L cone types. *Journal of Optical Society of America A*, 22(10): 2072-2080, 2005.

KAWAMURA, S., HIRAI, M., TAKENAKA, O., RADLWIMMER, F. B. & YOKOYAMA, S. Genomic and spectral analyses of long to middle wavelength-sensitive visual pigments of common marmoset (*Callithrix jacchus*). *Gene*, 269: 45-51, 2001.

KLEBER, A., VOROBYEV, M., OSORIO, D. Animal colour vision-behavioural tests and physiological concepts. *Biological Reviews*, 78: 81-118, 2003.

KREMERS, J., SILVEIRA, L. C. L., YAMADA, E. S. & LEE, B. B. The ecology and evolution of primate colour vision. 1999. In: GEGENFURTNER, K. R. & SHARPE, L. T. (Eds.). Color vision: from genes to perception. Cambridge, England: Cambridge University Press, 123-142pp.

LEAL, I., TABARELLI, M. & SILVA, J. M. C. Ecologia e conservação da Caatinga. Edição Universitária da UFPE: 822pp, 2003.

LOPES, F. A., YAMAMOTO, M. E., MEDEIROS, I. S., DELGADO, K. V. C. A influência do estado reprodutivo da fêmea na competição por alimento no sagüí comum (*Callithrix jacchus*). *Anais de Etologia*, 15:35-46, 1997.

MAIER, W., ALONSO, C., LANGGUTH, A. Field observations on *Callithrix jacchus jacchus*. *L. Z. Saugetierkunde*, 47: 334-346, 1982.

MATSUI, A., GO, Y. & NIIMURA, Y. Degeneration of olfactory receptor gene repertories in Primates: No direct link to full trichromatic vision. *Molecular Biological Evolution*, 27(5): 1192-1200, 2010.

MELIN, A. D., FEDIGAN, L. M., HIRAMATSU, C., SENDALL, C. L. & KAWAMURA, S. Effects of colour vision phenotype on insect capture by a free-ranging population of white-faced capuchins, *Cebus capuchins*. *Animal Behaviour*, 73: 205-214, 2007.

MELIN, A. D., FEDIGAN, L. M., HIRAMATSU, C. & KAWAMURA, S. Polymorphic color vision in white-faced capuchins (Cebus *capucinus*): Is there foraging niche divergence among phenotypes? *Behavioral Ecology and Sociobiology*, 62: 659-670, 2008.

MELIN, A. D., FEDIGAN, L. M., HIRAMATSU, C., HIWATASHI, T., PARR, N. & KAWAMURA, S. Fig foraging by dichromatic and trichromatic *Cebus capucinus* in a tropical dry forest. *International Journal of Primatology*, 30: 753-775, 2009.

MELIN, A. D., FEDIGAN, L. M., YOUNG, H. C. & KAWAMURA, S. Can color vision variation explain sex differences in invertebrate foraging by capuchin monkeys? *Current Zoology*, 56: 300-312, 2010.

MELIN, A. D., HIRAMATSU, C., FEDIGAN, L. M., SCHAFFNER, C. M., AURELI, F., KAWAMURA, S. Polymorphism and adaptation of primate colour vision. 2012. In: PONTAROTTI, P. (Ed.). Evolutionary Biology: mechanisms and trends. Springer-Verlab, Berlin.

MENDES, L., ROCHA, P., RIBEIRO, M., PERRY, S., OLIVEIRA, E. Differences in ingestive balance of two populations of Neotropical Thrichomys apereoides (Rodentia, Echimyidae), *Comparative Biochemistry and Physiology A*, vol. 138, pp. 327–332, 2004.

MICHELS, A. N. Sex differences in food acquisition and aggression in captive commom marmosets (*Callithrix jacchus*). *Primates*, 39(4): 549-556, 1988.

MODESTO, T. C., BERGALLO, H. G. Ambientes diferentes, diferentes gastos do tempo entre atividades: o caso de dois grupos mistos do exótico *Callithrix* spp. na

Ilha Grande, RJ, Brasil. *Neotropical Biology and Conservation*, v. 3, n. 3, p. 112-118, 2008.

MOLLON, J. D., BOWMAKER, J. K. & JACOBS, G. H. Variations of colour vision in a new world primate can be explained by polymorphism of retinal photopigments. *Proceedings of the Royal Society of London B*, 222: 373-399, 1984.

MORGAN, M. J., ADAM, A. & MOLLON, J .D. Dichrimats detect colour-camouflaged objects that are not detected by trichromats. *Proceedings of the Royal Society of London B*, 248: 291-295, 1992.

MORAES, B. L. C, SOUTO, A., SCHIEL, N. Adaptability in stone use by capuchin monkeys (*Sapajus libidinosus*). *American Journal of Primatology*, 76: 967-977, 2014. doi:10.1002/ajp.22286.

MOREIRA, L. A. O., OLIVERIA, D. G. R, SOUSA, M. B. C, PESSOA, D. M. A. Parturition signaling by visual cues in female marmosets (*Callithrix jacchus*). *PLos ONE*: e0129319, 2015. doi: 10.1371/journal.pone.0129319.

MOURA, A. C., LEE, P. Capuchin stone tool use in Caatinga dry forest. *Science*, 306: 1909, 2004. doi:10.1126/science.1102558

MOURA, A. Primate group size and abundance in the Caatinga Dry Forest, Northeastern Brazil. *International Journal of Primatology*, 28: 1279-1297, 2007.

NIMER, E. Climatologia do Brasil. IBGE, 421 p. Paraíba, Governo do Estado. Atlas Geográfico da Paraíba. Secretaria de Educação, UFPB. João Pessoa, p.100, 1979.

NIEVERGELT, C. M., MARTIN, R. D. Energy intake during reproduction in captive common marmosets (*Callithrix jacchus*). *Physiology & Behavior*, 65 (4/5):849-854, 1999.

OLIVEIRA, I. B. R., MOURA, J. Z., MOURA, S. G., BRITO, W. C., SOUSA, A. A., SANTANA, J. D. P. & MAGGIONI, K. Diversidade da entomofauna em uma área de caatinga no município de Bom Jesus-PI, Brasil. *Cientifica*, 41 (2): 150-155, 2013.

ONISHI, A., KOIKE, S., IDA, M., IMAI, H., SHICHIDA, Y., TAKENAKA, O., HANAZAWA, A., KONATSU, H., MIKAMI, A., GOTO, S., SURYOBROTO, B., KITAHARA, K. & YAMAMORI, T. Dichromatism in macaque monkeys. *Nature*, 402: 139-140, 1999.

OSORIO, D. & VOROBYEV, M. Colour vision as an adaptation to frugivory in primates. *Proceedings of the Royal Society of London*, 263: 593-599, 1996.

OSORIO, D., SMITH, A. C., VOROBYEV, M. & BUCHANAN-SMITH, H. M. Detection of fruit and selection of primate visual pigments for color vision. *The American Naturalistic*, 164 (6): 696-708, 2004.

PERINI, E. S., PESSOA, V. F. & PESSOA, D. M. A. Detection of fruit by cerrado's marmoset (*Callithrix penicillata*): modeling color signals for different background scenarios and ambient light intensities. *Journal of Experimental Zoology*, 311A: 289-302, 2009.

PESSOA, D.M.A, PERINI, E. S., PESSOA, V. F. Deteção de alvos naturais pelo sagui-do-cerrado (Callithrix penicillata): avaliação do papel da visão de cores. A primatologia no Brasil. In: A Primatologia no Brasil, Vol. 11, Belo Horizonte, Anais do Congresso Brasileiro de Primatologia, 2012, pp. 01-18.

PONTES, A. & CRUZ, M. Home range, intergroup transfers, and reproductive status of common marmosets *Callithrix jacchus* in a forest fragment in North-eastern Brazil. *Primates*, 36 (3): 335-347, 1995.

PRADO, D. As caatingas da América do Sul. In: LEAL, I.R.; TABARELLI, M.; SILVA. J.M.C. (eds.), Ecologia e conservação da caatinga. Recife, Brasil: Editora Universitária, Universidade Federal de Pernambuco, p 3–73, 2003.

QUEIROZ, L.P.. Distribuição das espécies de Leguminoseae na caatinga. 2002. In: SAMPAIO, E. V. S. B., GIULIETTI, A. M., VIRGÍNIO, J. & GAMARRA-ROJAS, C. F. L. (ed.) Vegetação e flora das caatingas. APNE / CNIP, Recife, PE. pp141-153.

REGAN, B. C., JULLIOT, C., SIMMEN, B., VIÉNOT, F., CHARLES-DOMINIQUE, P. & MOLLON, J. D. Fruits, foliage and the evolution of primate colour vision. *Philosophical Transactions of the Royal Society B*, 356: 229-283, 2001.

ROCHA, P. L. B. *Proechimys yonenagae*, a new species of spiny rat (Rodentia: Echimyidae) from fossil sand dunes in the Brazilian Caatinga. *Mammalian*, 59 (4): 537– 549, 1995.

RYLANDS, A. B. & de FARIA, D. S. Habitats, feeding ecology, and home range size in the genus Callithrix, 1993. In: RYLANDS, A. B., editor. Marmosets and tamarins: systematic, behaviour and ecolgy. New York: Oxford University Press, p.262-272.

SAITO, A., MIKAMI, A., KAWAMURA, S., UENO, Y., HIRAMATSU, C., WIDAYATI, K. A., SURYOBROTO, B., TERATOMO, M., MORI, Y., NAGANO, K., FUJITA, K., KUROSHIMA, H. & HASEGAWA, T. Advantage

of dichromats over trichromats in discrimination of color-camouflaged stimuli in nonhuman primates. *American Journal of Primatology*, 67: 425-436, 2005.

SCHIEL, N., SOUTO, A., HUBER, L. & BEZERRA, B. Hunting strategies in wild common marmosets are prey and age dependent. *American Journal of Primatology*, 71: 1-8, 2010.

SHYUE, S., BOISSINOT, S., SCHNEIDER, H., SAMPAIO, I., SCHNEIDER, M. P., ABEE, C. R., WILLIAMS, L., HEWETT-EMMETT, D., SPERLING, H. G., COWING, J. A., DULAI, K. S., HUNT, D. M. & LI, W. Molecular genetics of spectral tuning in new world monkey color vision. *Journal of Molecular Evolution*, 46: 697-702, 1988.

SILVA, J. K. S. M. & LIMA, A. D. A. Entomofauna e sazonalidade de insetos em vegetação de caatinga e floresta ciliar no semi-árido Paraibano. *Scientia Plena, in press.*

SMITH, A. C., BUCHANAN-SMITH, H. M., SURRIDGE, A. K., OSORIO, D. & MUNDY, N. I. The effect of color vision status on the detection and selection of fruits by tamarins (*Saguinus spp.*). *Journal of Experimental Biology*, 206: 3159-3165, 2003.

SMITH, A. C., SURRIDGE, A. K., PRESCOTT, M. J., OSORIO, D., MUNDY, N. I. & BUCHANAN-SMITH, H. M. Effect of colour vision status on insect prey capture efficiency of captive and wild tamarins (*Saguinus* spp.). *Animal Behaviour*, 83: 479-486, 2012.

SOUSA, M. & PONTES, M. Variação temporal diurna de comportamentos afiliativos de sagui comum (*Callithrix jacchus*) machos vivendo em ambiente natural. *Revista Brasileira de Zoociências*, 10(1): 7-12, 2008.

STEVENSON, M. F. & POOLE, T. B. An ethogram of the commom marmoset (*Callitrhix jacchus jachhus*): general behavior repertoire. *Animal Behavior*, 24: 428-451.

STEVENSON, M. F. & RYLANDS, A. B. 1988. The marmosets, Genus *Callithrix*. In: Mittermeier RA, Rylands AB, Coimbra-Filho AF, Da Fonseca GAB. (Ed.) 1988. Ecology and behavior of Neotropical primates. Washington DC: World Wildlife Foundation. 2:131-222.

STREILEIN, K. E. Ecology of small mammals in the semiarid Brazilian Caatinga. II. Water relations. *Annual Carnegie Musuem*, 51(6): 109–126, 1982.

SURRIDGE, A. K. & MUNDY, N. I. Trans-specific evolution of opsin alleles and the maintenance of trichromatic colour vision in Callitrichine primates. *Molecular Ecology*, 11: 2157-2169, 2002.

SURRIDGE, A. K., OSORIO, D. & MUNDY, N. I. Evolution and selection of trichromatic vision in primates. *Elsevier*, 18 (4), 2003.

TARDIF, S.D., RICHTER, C. B. Competition for a desired food in family groups of the common marmoset (*Callithrix jacchus*) and the cotton-top tamarin (*Saguinus oedipus*). *Laboratory Animal Science*, 1(31): 52-55, 1981.

TARDIF, S. D., POWER, M., OFTEDAL, O. T., POWER, R. A., LAYNE, D. G. Lactation, maternal behavior and infant growth in common marmoset monkeys (*Callithrix jacchus*): effects of maternal size and litter size. *Behavioral Ecology Sociobiology*, 51: 17-25, 2001.

TARDIF, S. D., POWER, M., LAYNE, D., SMUCNY, D., ZIEGLER, T. Energy restriction initiated at different gestational ages has varying effects on maternal weight gain and pregnancy outcome in common marmosets monkeys (*Callithrix jacchus*). *British Journal of Nutrition*, 92: 841-849, 2004.

TAYLOR, N.P. & D. ZAPPI. Distribuição das espécies de Cactaceae na caatinga. 2002. In: SAMPAIO, E. V. S. B., GIULIETTI, A. M., VIRGÍNIO J. & GAMARRA-ROJAS, C. F. L. (ed.) Vegetação e flora das caatingas. APNE / CNIP, Recife, PE. pp123-125.

TOVÉE, M. J., BOWMAKER, J. K. & MOLLON, J. D. The relationship between cone pigments and behavioural sensitivity in a new world monkey (*Callithrix jacchus jacchus*). *Vision Research*, 32 (5): 867-878, 1992.

TRAVIS, D. S., BOWMAKER, J. K. & MOLLON, J. D. Polymorphism of visual pigments in a callitrichid monkey. *Vision Research*, 28 (4): 481-490, 1988.

VASCONCELLOS, A., ANDREAZZE, R., ALMEIDA, A. M., ARAUJO, H. F. P., OLIVEIRA, E. S. & OLIVEIRA, U. Seasonality of insects in the semi-arid caatinga of northeastern of Brazil. *Revista Brasileira de Entomologia*, 54 (3): 471-476, 2010.

VOGEL, E. R., NEITZ, M. & DOMINY, N. J. Effect of color vision phenotype on the foraging of wild-faced capuchins, *Cebus capuchins*. *Behavioral Ecology*, 18: 292-297, 2007.

WILLIAMS, A. J., HUNT, D. M., BOWMAKER, J. K. & MOLLON, J. The polymorphic photopigments of the marmoset: spectral tuning and genetic basis. *The EMBO Journal*, 11 (6): 2039-2045, 1992.

YAMAMOTO, M. E., DOMENICONI, C., BOX, H. Sex differences in commom marmosets (*Callithrix jacchus*) in response to an unfamiliar food task. *Primates*, 45: 249-254, 2004.

Artigo 1

Feeding ecology and behavioral adjustments: flexibility of a small neotropical primate (*Callithrix jacchus*) to survive in a semiarid environment

Artigo submetido à Mammal Research – fator de impacto: 1.20

(Normas para publicação Anexo I)

Feeding ecology and behavioral adjustments: flexibility of a small neotropical primate (*Callithrix jacchus*) to survive in a semiarid environment

Filipa Abreu[1]; María Fernanda Castellón De la Fuente[1]; Nicola Schiel[1]; Antonio Souto[2*]

[1]Department of Biology, Federal Rural University of Pernambuco, Recife, Brazil.
[2]Department of Zoology, Federal University of Pernambuco, Recife, Brazil.

*Corresponding author:
Antonio Souto
Department of Zoology
Federal University of Pernambuco
Avenida Professor Morais Rego, 1235
CEP: 50670-901. Cidade Universitária
Recife, Pernambuco, Brasil
E-mail: asouto.labet@gmail.com
Phone number: 0055 81 21268353

Acknowledgments The authors thank Dr. Geraldo Baracuhy for providing the Fazenda Marimbondo to conduct the research. We thank the valuable contributions and suggestions of Dr. Elcida de Lima Araújo. The present study was founded by a master Grant from the Coordination for the Improvement of Higher Education Personnel (CAPES) awarded to Filipa Abreu.

Abstract

We aimed to investigate how a small neotropical primate (*Callithrix jacchus*; the common marmoset) manages to survive under the harsh conditions that a semiarid environment imposes. The study was carried out in a 400 ha-area of Caatinga in the Northeast of Brazil. During a six-month period we collected data on the diet of 19 individuals of common marmosets (distributed in five groups) and estimated their behavioral time budget during both the dry and rainy seasons. Resting significantly increased during the dry season. No significant differences were detected regarding to the other behaviors. In relation to the diet, we recorded the consumption of prey items like insects, spiders and small vertebrates. We also observed the consumption of plant items, including prickly cladodes, which is something new for this species. Cladode exploitation required perceptual and motor skills to safely access the food resource. Our findings show that common marmosets can survive under challenging conditions in part because of adjustments in its behavior, and in part because of changes in their diet. It is also worth pointing out that the common marmoset is diurnal and relatively easy to accustom to human presence, which makes it a good model to better understand how a mammal without unique physiological adaptations can survive in a semiarid environment.

Keywords: Behavior, Time budget, Caatinga, Diet, Cacti

Introduction

The Caatinga, a Brazilian savanna, is a semiarid region localized in the Northeast of Brazil and occupies an area of approximately 800,000 km^2 (Araújo et al. 2007). This type of environment is characterized by a climate with high solar radiation, high temperatures, low humidity rates and irregular precipitation limited to a few months of the year (three to six consecutive months), which results in periodic and severe droughts (Prado 2003; Araújo et al. 2007; Albuquerque et al. 2012). The woody vegetation is low and present deciduous trees with thorns, microphyll leaves and xerophytic characteristics, as well as cacti, bromeliads and a rich diversity of herbaceous species (Prado 2003; Araújo et al. 2007; Albuquerque et al. 2012). According to Barbosa et al. (2003), the phenology of many plant species in the Caatinga is controlled by precipitations. Therefore, due to both climatic seasonality and rain distribution, fleshy fruit represents a relatively scarce resource throughout the dry season (Barbosa et al. 2003; Amorim et al. 2009).

The harsh conditions of semiarid environments, in general, impose significant challenges for mammals in terms of heat stress, thermoregulation, available water, and limited resource availability (Diaz and Ojeda 1999; Albuquerque et al. 2012). In spite of that, at least 156 species of mammals, 12 of which endemic, inhabit the Caatinga (Albuquerque et al. 2012). The recent geological origin of this environment (Ab'Sáber 1974) may have prevented pronounced physiological adaptations in mammals, as found in other dry regions (Streilein 1982). Behavioral adaptations have been suggested to be crucial to overcome the constraints and limitations of this environment (Streilein 1982; Albuquerque et al. 2012; De la Fuente et al. 2014); nevertheless, the potential behavioral adjustments that mammals exhibit to survive in the Caatinga are still poorly known. To this regard, Rocha (1995) reported that the endemic rodent *Trinomys yonenagae* digs holes in dunes during the hottest hours of the day. Moura and Lee (2004) and Moraes et al. (2014) suggested that harsh environmental conditions can be a factor leading capuchin monkeys to use tools to gain access to hard-to-obtain and hard-to-process food. Besides these aspects, feeding ecology may be adjusted as a strategy to survive in environments (or during seasons) with limited resources (Marshall and Wrangham 2007). Therefore, some mammals inhabiting the Caatinga include uncommon food items in their diets (cacti by capuchin monkeys: Moraes et al. 2014; fruit, flower of cacti and leaves by common marmoset: Amora et al. 2013).

The relatively low number of behavioral and ecological studies focused on mammals in the extended Caatinga may be due to its adverse environmental conditions, which usually involves physical hardship and endurance. Difficulties also derive from the elusive nature and/or night habits of many animals inhabiting this environment (e.g. wild cats, rodents, bats, etc.). However, a small primate such as the common marmoset (*Callithrix jacchus*) presents characteristics, which make it a viable alternative to these kinds of studies in semiarid environments.

Common marmoset is native to different environments in the Northeast of Brazil, including the Caatinga (Stevenson and Rylands 1988; Rylands and Faria 1993). It has an omnivorous diet, which consists mainly of fruit, insects, gum and small vertebrates (Rylands and Faria 1993; Schiel et al. 2010), and may even include mollusc in the humid Atlantic Forest (Souto et al. 2007) and leaves in the Caatinga (Amora et al. 2013). Moreover, it is worth pointing out that teeth and ceca of the common marmoset are adapted for the exploitation of exudates (Nash 1986; Stevenson and Rylands 1988), which is a food

resource available throughout the year since it can be found in the stems of trees (Araújo et al. 2007). Besides, common marmoset is a diurnal animal able to get used to human presence, a factor that facilitates its study, as documented in several studies conducted in the Atlantic Forest in the last few decades (Maier et al. 1982; Alonso and Langguth 1989; Souto et al. 2007; Bezerra and Souto 2008; Pesendorfer et al. 2009; Schiel et al. 2010; Gunhold et al. 2014)

Nevertheless, despite these advantages, scarce is the information about how these small mammals cope with the difficult conditions of the Caatinga. In fact, although the only two studies on the common marmoset in a semiarid environment are certainly important, they have some limitations. The research conducted by Amora et al. (2013) was restricted to the use of alternative plants as food resources. Furthermore, the sample ranged "from two to four individuals", which may limit the generalization of the findings. De la Fuente et al. (2014) investigated the adjustments of some behavioral patterns of 12 individuals in response to temperature fluctuation throughout the day. Unfortunately, this study does not provide information on the behavioral time budget of the animals under study.

Hence, the two main objectives of the present study were: (i) to investigate the diet of 19 individuals of common marmosets (distributed in five groups), and (ii) to estimate the behavioral time budget of these animals during both the dry and rainy seasons of the Caatinga. Moreover, we described the behavioral strategies used by common marmosets to achieve their goals. Lastly, but not less important, we compared our data with those obtained in previous studies conducted in the humid environment of the Atlantic Forest (Maier et al. 1982; Alonso and Langguth 1989; Souto et al. 2007; Schiel et al. 2010). With our research we intend to contribute to a better understanding of the importance of behavioral adjustments for the survival of mammals in semiarid environments.

Materials and Methods

Study area

This study was carried out in the Caatinga at the Fazenda Marimbondo (7º31'42" S – 36º17'50" W), localized in state of Paraíba, Northeast of Brazil. This place features the typical vegetation of semiarid environments, high temperatures and the lowest rainfall index of the Brazilian semiarid region (for further information please see: Nascimento and Alves 2008; De la Fuente et al. 2014). During the study period, the mean precipitation in the rainy season (May to July) was 61.8 mm, whereas the mean precipitation in the dry season (September to November) was 13.6 mm (Fig. 1) (INMET 2015).

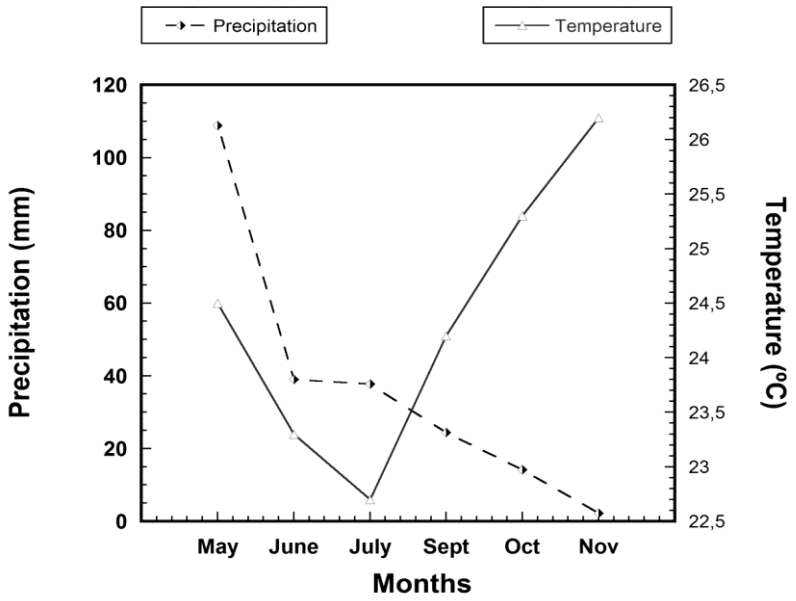

Fig. 1 Mean precipitation (mm) and mean temperature (°C) during the study months in Cabaceiras, Paraíba, Northeast Brazil (INMET 2015)

Data collection

Behavioral observations were performed 10 days per month, from May to November 2014, for a total of 263 hours of direct observation. Data were collected in the most representative months of each season of the year (dry season: May–July; rainy season: September–November) (Medeiros et al. 2012). We monitored five groups of *Callithrix jacchus* with 19 individuals in total: 14 adults, 2 juveniles and 3 infants (Table 1). Behavioral data were collected according to the focal animal observation method (Altmann 1974; Lehner 1996) with 10 minutes sessions of continuous observation for each individual throughout all the period of activity of these animals (5 am to 5 pm) (De la Fuente et al. 2014). Moreover, *ab libitum* observations (Altmann 1974; Lehner 1996) were conducted to record off-session feeding events.

In the present study we reported foraging, gummivory, resting, grooming and locomotion behaviors (please see description available in De la Fuente et al. 2014). "Play" (De la Fuente et al. 2014) and "stationary" behaviors (the individual stay still and performs no activity for less than 1 min) were referred to as "others".

Table 1 Composition of the studied groups of *Callithrix jacchus* in the semiarid Caatinga

Age (month)	G 1		G 2		G 3		G 4		G 5	
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Infant (1-4)	-	1[a]	-	-	-	-	-	2[a]	-	-
Juvenile (5-10)	-	-	-	-	2	-	-	-	-	-
Adult (>11**)**	1	1	1	1	2	3	1	1	1 (1[a])	1

G=group; [a]Individuals not included in the analyses

Whenever possible we recorded and collected the remains of insects captured by the animals. Moreover, all the eaten plant items were recorded. Plant items were collected and subsequently identified at the Botany Lab of the Federal Rural University of Pernambuco, while the insects were identified at the order level at the Entomology Lab of the Federal Rural University of Pernambuco.

Statistical analysis

Data from 15 individuals were used (a total of 215 hours of direct observation), discarding those from an adult female which disappeared during the study and those from infants younger than five months (a total of 48 hours of direct observation). These infants were excluded because their behaviors are not fully developed yet (Schiel et al. 2010).

Time budget was calculated according to the duration of each behavior, including "others", for each season of the year. Since data were not normally distributed the Wilcoxon's test (Lehner 1996) was used to check behavioral differences between each season of the year. Due to the reduced frequency we did not include those behaviors referred to as "others" in the statistical analysis. Wilcoxon's test was also used to check the differences between the number of insects captured in the dry and rainy season. Results at $p \leq 0.05$ (bilateral) were considered significant. All the data were analyzed with the software Instat 3.0 (GraphPad Software, Inc.) and Excel (Microsoft Corporation).

Results

Behavioral time budget

In general, the animals dedicated most of their time to foraging (rainy season: 30.7 %; dry season: 25.6 %) and resting (rainy season: 18.6 %; dry season: 27.8 %). There was a significant increase in the time spent in resting behavior from the rainy season to the dry season (n=15, W=-92.0, p=0.006) (Table 2). All other behavioral patterns did not reveal a significant difference between the two seasons.

Table 2 Comparison of the behavioral time budget of *Callithrix jacchus* in the semiarid Caatinga, between the dry and rainy seasons

Behavior	Rainy season	Dry season	W	*p* value
	Total sample time % (total sample time hours)	Total sample time % (total sample time hours)		
Foraging	30.7 % (29.31 hr)	25.6 % (30.39 hr)	46	0.21
Gummivory	17.7 % (16.90 hr)	15.8 % (18.81 hr)	36	0.33
Resting	18.6 % (17.77 hr)	27.8 % (33.04 hr)	-92	0.006
Locomotion	8.3 % (7.93 hr)	8.8 % (10.48 hr)	16	0.68
Gromming	12.1 % (11.53 hr)	14.6 % (17.34 hr)	-64	0.07
Others[a]	12.5 % (11.91 hr)	7.3 % (8.66 hr)	100	0.002
Total in percentage (Total in hours)[b]	100 % (95.37 hr)	100 % (118,74 hr)	_	_

[a]Behaviors not included in the statistical analysis (stationary and play behavior); [b]total hours of observations of the 15 individuals used for statistical analysis; statistics: Wilcoxon's test (W); values of $p \leq 0.05$ are significant

Consumed food items

In total, we reported 940 feeding events, wherein 850 involved animal items and 90 involved plant items. As for feeding events on animal items, 797 events were directed to the capture and consumption of insects (Table 3) and the remaining 53 to the exploitation of lizards (*n*=32), earthworms (*n*=14), arachnids (*n*=6) and bird eggs (*n*=1). Common marmosets caught a significantly higher amount of insects during the rainy season than during the dry one (*n*=11, W=66.0, *p*=0.001).

Table 3 Insects eaten by *Callithrix jacchus* throughout the study period during the dry and rainy seasons in the semiarid Caatinga

Order	Rainy season	Dry season
	Percentage of captures (absolute value)	Percentage of captures (absolute value)
Orthoptera	44.5 % (254)	35.8 % (80)
Hymenoptera	11.8 % (74)	7.4 % (27)
Coleoptera	7.4 % (39)	5.9 % (14)
Lepidoptera	5.3 % (30)	0.5 % (2)
Hemiptera	2.1 % (13)	2.5 % (8)
Mantodea	2.1 % (13)	1.5 % (4)
Isoptera	1.5 % (11)	0.0 % (0)
Blatodea	1.0 % (6)	2.5 % (4)
Odonata	0.4 % (2)	0.0 % (0)
Diptera	0.2 % (1)	0.0 % (0)
Unidentified	23.8 % (125)	44.1 % (90)

Total of captures	568	229

For what concerns plant items, six species were consumed: three belonging to the family *Cactacea*, two to the family *Leguminosae/Fabaceae* and one to the family *Malvaceae* (Table 4).

Table 4 Plant items eaten by *Callithrix jacchus* in the semiarid Caatinga

Family	Scientific name	Part consumed	Events	Number of individuals that consumed a plant item
Cactaceae	*Pilosocereus pachycladus*	Fruit	3	3
		Cladode	16	8
	Pilosocereus gounellei	Fruit	7	4
		Flower	3	3
	Cereus jamacaru	Fruit	10	9
		Flower	2	1
		Cladode	2	2
Leguminosae/ Fabaceae	*Prosopis juliflora*[a]	Fruit	35	8
	Tamarindus indica[a]	Fruit	4	2
Malvaceae	*Herissantia tiubae*	Flower	8	3

[a]Alien plant

Description of the consume of plant items

Pilosocereus pachycladus – Plant description: cactus up to 10 m tall. It has columnar cladodes presenting areoles with numerous, small and thin spines of 1.8 cm in length and sub-globose red to purple fruit (Menezes et al. 2013). Description of the feeding behavior: cladode - the marmoset reached a tree close to the cactus and stood on a branch close (approximately 10 cm) to the tallest cladode. With its hind limbs grabbing the branch, the individual reached out and held carefully the cactus spines with both hands, bit directly the upper area of the cladode (apparently by choosing the best suitable region to start biting, i.e., damaged areas without, or with few or broken spines), pulling small pieces which were then ingested. This procedure occurred several times (Fig. 2a). Then, one by one all the members of the group performed the same procedure consecutively, alternately eating a portion of the cladode; fruit: the individual reached a branch close to the fruit, grabbed the fruit with both forelimbs and ingested small pieces at a time.

Cereus jamacaru – Plant description: Cactus up to 6 m tall. It has upright cladodes presenting areoles 2-4 cm apart from each other with up to 6 cm long prickly cylindrical spines; it also has ellipsoid red to magenta fruit and harmless white flowers (Rocha and Agra 2002; Menezes et al. 2013). Description of the feeding behavior: cladode - the individual stood with both hind limbs on the cactus, in the upper area of the cladode, among the spines. Afterwards, the animal placed the forelimbs on the cladode biting the spot with no spines and eating it immediately; fruit: the individual stood on the cladode among the spines close to the fruit. In order to eat it, the animal bit the outer portion of the fruit, exposing its pulp and discarding the outer portion; and then, with one of the forelimbs, it took the inner portion of the fruit and put it in its mouth. The procedure is performed repeatedly (Fig. 2b); flower - the individual stood

among the spines of the cladode close to the flower and, holding it with both forelimbs, it removed a piece with its mouth and moved away to eat it.

Pilosocereus gounellei – Plant description: Cactus up to 4 m tall. Its areoles are 1 cm apart from each other and present up to 15 cm long cylindrical and rigid spines with a central and bigger acicular spine; The plant has 17 cm long white tubular flowers, succulent, sub-globose and laterally dehiscent fruit (Rocha and Agra 2002; Menezes et al. 2013). Description of the feeding behavior: fruit - the individual stood on a branch close to the fruit, grabbed the fruit with both forelimbs and ingested small pieces at a time; flower - the marmoset stood on a branch close to the flower and proceeded as described for the consumption of the flower of *Cereus jamacaru.* Afterwards, the other individuals approached the flower and proceeded alternately in the same way (Fig. 2c).

Prosopis juliflora (alien plant) – Plant description: Thorny tree up to 15 m tall. Its fruit does not open spontaneously, has an elongated shape and is divided into compartments each containing a seed (Bukhart 1976). Description of the feeding behavior: fruit - the animal stood on a branch in order to reach the pod vertically hanging therefrom, and it ate the fruit in two ways: (1) the animal ate the pod without pulling it away from the branch; (2) the animal pulled the pod away from the branch and bit it, removing a piece for consumption. Both procedures were conducted several times for the same fruit.

Tamarindus indica (alien plant) – Plant description: Tree native to Africa about 25 m tall. It produces brown indehiscent and woody fruit measuring from 5 to 15 cm in length (Sousa et al. 2010). Description of the feeding behavior: fruit - the individual reached a spot close to the fruit, grabbed the fruit with both forelimbs without pulling it away from the tree, bit it directly and ingested small pieces at a time. Feeding was observed only on unripe fruit.

Herissantia tiubae – Plant description: Perennial plant, with flowers having white petals, yellow anthers and grandular-viscous trichomes (Silva et al. 2013). Description of the feeding behavior: flowers: the individual reached a spot close to the flower and grabbed it by the peduncle with both forelimbs, eating all the petals at once and discarding the calyx.

Fig. 2 Some of the plant items consumed by *Callithrix jacchus* in the study site (a) Cladode of *P. pachycladus* (b) Fruit of *C. jamacaru* (c) Flower of *P. gounellei*

Discussion

The main activity conducted by common marmosets (*Calithrix jacchus*) observed during the day in the Caatinga was foraging. Despite the clear environmental differences, this result was similar to that obtained in two studies developed in the Atlantic Forest (Maier et al. 1982; Alonso and Langguth 1989). We believe that it is a consequence of thermoregulation costs in mammals, which requires a constant food intake (Schmidt-Nielsen 1997; Passamani 1998; Ménard et al. 2013). This behavioral consistency is further supported by the lack of differences in time budget for foraging and locomotion between the dry and rainy seasons in Caatinga.

As for the consumption of stem exudates in the dry and rainy seasons, our findings reported no seasonal differences, supporting a previous study conducted by Amora et al. (2013). This is an interesting phenomenon whose verification is important as this food resource is available throughout the year (Araújo et al. 2007). Accordingly, we expected that common marmosets would exhibit gummivory behavior more frequently during the dry season, in response to the depletion of other food resources in this period (Amorim et al. 2009). The results obtained both in our study and in that conducted by Amora et al. (2013) can be related to the hydric stress which would interfere in exudate composition of tannins, among other compounds (Pizzi and Cameron 1986). Tannins are known to adversely affect palatability and to reduce herbivore predation rate (Monteiro et al. 2005). This phenomenon might well affect marmosets, keeping gum consumption relatively constant even during the more challenging dry season.

For what concerns resting, the effect of the dry season on the behavior of the common marmosets was clear: a significant increase of resting occurred during this season. To this regard, a comparison with the Atlantic Forest is more difficult since the study conducted by Alonso and Langguth

(1989) did not present a seasonal analysis. Nonetheless, our percentage data of the Caatinga for the rainy season are similar to those obtained in the Atlantic Forest by Alonso and Langguth (1989), while for the other climate extreme, the dry season, the results are different. Similarly, grooming, a behavior that often interchangeably accompanies resting behavior (Maier et al. 1982; Alonso and Langguth 1989), approached Alonsos' and Langguths' (1989) findings. Undoubtedly, pronounced changes in common marmosets' time budget for resting are required to face the critical phase of the dry season in the Caatinga. This result complements the study conducted by De la Fuente et al. (2014), which showed that common marmosets in the Caatinga environment reduce their activity during the hottest hours of the day. Thus, the differences in the adjustments for resting occur both within the same day and between the two different seasons of the Caatinga.

The diet of common marmosets in the Caatinga showed to be comprehensive, reflecting the idea of a generalist animal, as documented in the Atlantic Forest (Rylands and Faria 1993; Stevenson and Rylands 1988; Schiel et al. 2010). In fact, these small mammals fed on insects, fruit and flowers, corroborating the findings of Amora et al. (2014) for the Caatinga, as well as spiders, small lizards and bird eggs, also reported by Rylands and Faria (1993) and Schiel et al. (2010) for the Atlantic Forest. However, cladode consumption is described here for the first time, which enhances the adaptability and flexibility of common marmosets living in this environment. The limited consumption of insect during the dry period was probably due to the decrease of this resource in semiarid environments in this season (Vasconcellos et al. 2010). The most important adjustment was undoubtedly the use of cacti, common plants in the area. Their inclusion in the diet of an animal is extremely important, as it provides not only water for thermoregulation but also energy for daily activities (Arnold and Drawe 1979; Mellink and Riojas-López 2002).

Nevertheless, cactus consumption is not easy since these plants are usually protected by many spines which can hurt the animal (Theimer and Bateman 1992; Rangel and Mellink 1993). Overcoming this challenge requires a perception of the problem as well as proper body dexterity to reach the goal without getting hurt. The works carried on in the Atlantic Forest on wild common marmosets documented that these small primates possess both cognitive capacities (Halsey et al. 2006; Gunhold et al. 2014) and motor skills (Souto et al. 2007; Schiel et al. 2010). Our results suggest that these two qualities were important for the success of this species in obtaining a crucial amount of food and water in such a semiarid environment. Of course, common marmoset is not the only animal which successfully exploits these plants; however a few mammals are able to do it so easily. For instance, cattle breeders based in semiarid environments are aware of this issue and know that the livestock usually rejects these plants because of the spines; thus, they have to eliminate the spiny protection before feeding their animals with the cladode (Mizhari et al. 1996). On the other hand, some mammals such as the collared peccary (*Pecari tajacu*) and some rodents (e.g. *Neotoma albigula*) inhabiting semiarid regions also feed on cacti, avoiding the spiniest species (Theimer and Bateman 1992; Rangel and Mellink 1993). This limitation is absent in common marmosets which, in this, resemble another primate, the capuchin monkey (*Sapajus* sp.: Moraes et al. 2014).

Since the Caatinga is a geologically recent environment, Streilein (1982) suggested that behavioral adaptability is the way to explain the presence of mammals in the extensive Brazilian semiarid

region. Common marmosets do not dig holes to escape the heat, nor use tools to gain access to food items, but they do show a number of clear behavioral adjustments to cope with the semiarid conditions. Most importantly, and unlike many other animals, common marmoset gets used to human presence relatively easily, is diurnal and inhabits utterly different habitats. Thus, it represents a good model to better understand how a mammal without unique physiological adaptations to semiarid conditions can survive in such an environment.

Conflict of interest: The authors declare that they have no conflict of interests regarding the publication of this paper.

Ethical approval: All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted. The study was approved by the Ethics Committee for Animals Use (CEUA) of the Federal Rural University of Pernambuco (license number 135/2014).

Informed consent: Informed consent was obtained from all individuals participants included in the study.

References

Ab'Saber AN (1974) O domínio morfoclimático semiárido das caatingas brasileiras. Universidade de São Paulo, Instituto de geografia, São Paulo

Albuquerque UP, Araújo EL, El-Deir ACA et al (2012) Caatinga revisited: ecology and conservation of an important seasonal dry forest. Scientific World J. doi:10.1100/2012/205182

Altmann J (1974) Observational study of behaviour: sampling methods. Behav 49:277-267

Alonso C, Langguth A (1989) Ecologia e comportamento de *Callitrhix jacchus* (Primates: Callitrichidae) numa ilha de floresta atlântica. Rev Nordestina Biol 6(2):105-137

Amora TD, Beltrão-Mendes R, Ferrari SF (2013) Use of alternative plant resources by common marmosets (*Callithrix jacchus*) in the semi-arid Caatinga scrub forests of northeastern Brazil. Am J Primatol 75(4):333–341. doi:10.1002/ajp.22110

Amorim IR, Sampaio EVSB, Araújo LE (2009) Fenologia das espécies lenhosas da caatinga do Seridó, RN. R Árvore 33:491–499

Araújo EL, Castro EC, Albuquerque UP (2007) Dynamic of brazilian Caatinga – a review concerning plants, environment and people. Funct Ecosyst Communities 1(1):15-28

Arnold LA, Drawe DL (1979) Seasonal food habits of white-tailed deer in the south Texas plains. J Range Manage 32:175–176

Barbosa D, Barbosa M, Lima L (2003) Fenologia de espécies lenhosas da Caatinga. In: Leal IR, Tabarelli M, Silva JMC (Eds) Ecologia e conservação da Caatinga, Universidade Federal de Pernambuco (UFPE), Recife, Brazil, pp 657–693

Bezerra BM, Souto A (2008) Structure and usage of the vocal repertoire of *Callithrix jacchus.* Int J Primatol 29:671-701. doi:10.1007/s10764-008-9250-0

Burkhart A (1976) A monograph of the genus *Prosopis* (Leguminosae subfam. Mimosoideae). J Arnold Arbor 57(4):450-525

De la Fuente MFC, Souto A, Boachá M, Schiel N (2014) Behavioral adjustments by a small neotropical primate (*Callithrix jacchus*) in a semiarid Caatinga environment. Scientific World J. doi:10.1155/2014/326524

Diaz GB, Ojeda RA (1999) Kidney structure and allometry of Argentine desert rodents. J Arid Environ 41:453–461

Hasley LG, Bezerra BM, Souto AS (2006) Can wild common marmosets (*Callithrix jacchus*) solve the parallel problem strings task? Anim Cogn 9:229-233. doi:10.1007/s10071-006-0016-9

INMET (2015) Instituto Nacional de Meteorologia. Ministério da Agricultura, Pecuária e Abastecimento/MAPA. http//www.inmet.gov.br. Accessed 20 April 2015

Gunhold T, Massen JJM, Schiel N, Souto A, Bugnyar T (2014) Memory, transmission and persistence of alternative foraging techniques in wild common marmosets. Anim Behav 91:79-91. doi:10.1016/j.anbehav.2014.02.023

Lehner PN (1996) Handbook of ethological methods. Cambridge University Press, Cambridge, UK, 2nd edition

Maier W, Alonso C, Langguth A (1982) Field observations on *Callithrix jacchus jacchus*. L. Z. Saugetierkunde 47: 334-346

Marshall AJ, Wrangham RW (2007) Evolutionary consequences of fallback foods. Int J Primatol 28:1219–1235. doi:10.1007/s10764-007-9218-5

Medeiros RM, Brito JIB, Borges CK (2012) Análise hidroclimático do município de Cabaceiras, PB. Rev Bras de Geogr Fis 5(5):1174-1190

Mellink E, Riojas-López ME (2002) Consumption of *Platyopuntias* by wild vertebrates. In: Nobel, PS (Ed) Cacti biology and uses, University of California Press, Berkeley and Los Angeles, California, pp 109-123

Menárd N, Motsch P, Delahaye A, Saintvanne A, Flohic GL, Dupé S, Vallet D, Qarro M, Pierre J (2013) Effect of habitat quality on the ecological behaviour of a temperate-living primate: time-budget adjustments. Primates 54(3):217-228. doi:10.1007/s10329-013-0350-x

Menezes MOT, Taylor NP, Loiola MIB (2013) Flora do Ceará, Brasil: Cactaceae. Rodriguésia 64(4):757-774

Mizrahi Y, Nerd A, Nobel PS (1996) Cacti as crops. In: Janick J (Ed) Horticultural reviews, Volume 18, John Wiley & Sons, Inc, Oxford, UK. doi:10.1002/9780470650608.ch6

Monteiro JM, Neto EM, Amorim ELC, Strattmann RR, Araújo EL, Albuquerque UP (2005) Teor de taninos em três espécies medicinais arbóreas simpátricas da Caatinga. R Árvore, 29(6):999-1005

Moraes BLC, Souto A, Schiel, N (2014) Adaptability in stone use by capuchin monkeys (*Sapajus libidinosus*). Am J Primatol 76:967-977. doi:10.1002/ajp.22286

Moura AC, Lee P (2004) Capuchin stone tool use in Caatinga dry forest. Science 306:1909. doi:10.1126/science.1102558

Nascimento SS, Alves JJA (2008) Ecoclimatology of the Cariri Paraibano. Rev Geogr Acad 2(3):28-41

Nash LT (1986) Dietary, behavioral, and morphological aspects of gummivory in primates. Am J Phys Anthropol 29:113–137. doi:10.1002/ajpa.1330290505

Passamani M (1998) Activity budget of geoffroy's marmoset (*Callithrix geoffroyi*) in an Atlantic forest in southeastern Brazil. Am J Primatol 46:333-340. doi:10.1002/(SICI)1098-2345(1998)46:4<333::AID-AJP5>3.0.CO;2-7

Pesendorfer MB, Gunhold T, Schiel N, Souto A, Huber L, Range F (2009) The maintenance of traditions in marmosets: individual habit, not social conformity? A field experiment. PLoS ONE 4(2):e4472. doi:10.1371/journal.pone.0004472

Pizzi A, Cameron, FA (1986) Flavonoid tannins: structural wood components for drought-resistance mechanisms of plants. Wood Sci Technol 20 (2):119-124

Prado D (2003) As caatingas da América do Sul. In: Leal IR, Tabarelli M, Silva JMC (Eds) Ecologia e conservação da Caatinga, Editora Universitária, Universidade Federal de Pernambuco, Recife, Brazil, pp 3–74

Rangel MG, Mellink E (1993) Historia natural de la rata magueyera en el Altiplano Mexicano. In: Medellín RA, Ceballos G (Eds) Avances en el estudio de los mamíferos de México, Asociación Mexicana de Mastozoología, México City, pp 173–183

Rocha PLB (1995) *Proechimys yonenagae*, a new species of spiny rat (Rodentia: Echimyidae) from fossil sand dunes in the Brazilian Caatinga. Mamm 59(4):537– 549

Rocha EA, Agra MF (2002) Flora do Pico do Jabre, Paraíba, Brasil: Cactaceae Juss. Acta Bot Bras 16(1):15-21. doi:10.1590/S0102-33062002000100004

Rylands AB, Faria DS (1993) Habitats, feeding ecology, and home range size in the genus *Callithrix*. In: Rylands AB (Ed) Marmosets and tamarins: systematics, behaviour, and ecology, Oxford: Oxford University Press, pp 262-272

Schiel N, Souto A, Huber L, and Bezerra BM (2010) Hunting strategies in wild common marmosets are prey and age dependent. Am J Primatol 72(12):1039–1046. doi:10.1002/ajp.20860

Schmidt-Nielsen K (1997) Animal physiology: adaptation and environment. Cambridge University Press, UK, 5th edition

Silva PPF, Oliveira PAB, Baracho GS, Agra MF (2013) O gênero *Herissantia* Medik. (Malvoide, Malvaceae) no nordeste do Brasil. 64º Congresso Nacional de Botânica, Belo Horizonte

Sousa DMM, Bruno RLA, Dornelas CSM, Alves EU, Andrade AP, Nascimento LC (2010) Caracterização morfológica de frutos e sementes e desenvolvimento pós-seminal de *Tamarinus indica* L.- Leguminosae: Caesalpinioideae. R. Árvore 34(6):1009/1015

Souto A, Bezerra BM, Schiel N, Huber L (2007) Saltatory search in free-living *Callithrix jacchus*: environmental and ages influences. Int J Primatol 28:881-89. doi:10.1007/s10764-007-9165-1

Stevenson MF, Rylands AB (1988) The marmosets, genus *Callithrix*. In: Mittermeier RA, Rylands AB, Coimbra-Filho AF, Da Fonseca GAB (Eds) Ecology and behavior of neotropical primates, Washington DC: World Wildlife Foundation, 2:131-222

Theimer TC, Bateman GC (1992) Patterns of prickly-pear herbivory by collared peccaries. J Wildl Manag 56:234–240. doi:10.2307/3808817

Vasconcellos A, Andreazze R, Almeida AM, Araujo AMA, Oliveira ES, Oliveira U (2010) Seasonality of insects in the semi-arid Caatinga of northeastern Brazil. Rev Bras Entomol 54(3):471-476. doi:10.1590/S0085-56262010000300019

Artigo 2

Comportamento de forrageio por insetos por *Callithrix jacchus* (PRIMATES, CALLITRICHIDAE) de vida livre: uma abordagem o polimorfismo visual

Artigo a ser submetido à American Journal of Primatology – fator de impacto: 2.43

(Normas para publicação Anexo II)

Comportamento de forrageio por insetos por *Callithrix jacchus* (PRIMATES, CALLITRICHIDAE) de vida livre: um viés ao polimorfismo visual

Filipa Abreu[1], Antonio Souto[2], Daniel M. A. Pessoa[3], Nicola Schiel[1*]

[1] Departamento de Biologia, Universidade Federal Rural de Pernambuco, Recife, Brasil.

[2] Departamento de Zoologia, Universidade Federal de Pernambuco, Recife, Brasil.

[3] Departamento de Fisiologia, Universidade Federal do Rio Grande do Norte, Natal, Brasil.

Short title: Captura de insetos por saguis comuns

*Autor de correspondência:

Nicola Schiel

Universidade Federal Rural de Pernambuco,

Rua Dom Manuel Medeiros, s/n

Dois Irmãos, Recife

CEP: 52171-900

E-mail: nschiel@yahoo.com.br

Telefone: (81) 99499-7271

Resumo

O polimorfismo visual está presente em primatas do Novo Mundo, em que machos e fêmeas homozigóticas possuem dicromatismo e fêmeas heterozigóticas têm visão tricromática. Enquanto dicromatas são mais eficazes na detecção e captura de insetos de coloração críptica, a principal vantagem dos indíviduos tricromatas é a detecção de itens de coloração conspícua. Estudos nesta área têm sido realizados principalmente em cativeiro, e até a data apenas dois estudos focaram nesta temática em ambiente natural mas apenas no gênero *Cebus* e *Saguinus*. Assim, este estudo objetivou uma comparação do comportamento de forrageio por insetos de 15 saguis-comuns (*Callithrix jacchus*) em ambiente natural, de forma a relacionar o efeito dos fenótipos nestas capturas. Os indivíduos foram observados utilizando o método de animal focal associado ao método *ad libitum*, e sempre que havia eventos de predação por parte destes eram registradas as colorações dos insetos capturados assim como o seu local de captura. Os resultados mostram que a lactação exerce um papel importante nas capturas, uma vez que esta demanda um grande gasto energético e consequentemente, uma alta necessidade nutricional. Por outro lado, não foram observadas diferenças entre fêmeas e machos na captura de insetos crípticos, sugerindo que não só o polimorfismo afeta as capturas, mas também as diferenças sexuais, como por exemplo, prioridade no acesso ao alimento por parte de fêmeas. Mostramos também neste estudo que o tamanho associado á coloração do inseto possui um efeito na captura de insetos por machos (dicromatas), mostrando que nesta população machos possuem "tricromatismo de campo grande". Por fim, acreditamos que nesta população haja uma vantagem para fêmeas (que possuem majoritariamente tricromatismo), e que esta seja mantida por dominância heterozigótica.

Palavras-chave: visão de cores; lactantes; primata neotropical; tricromatismo; vantagem heterozigótica

Introdução

Primatas do Novo Mundo (Platyrrhini) são conhecidos pelo seu peculiar polimorfismo visual [Mollon et al., 1984]. Os machos sempre são dicromatas (homozigóticos), enquanto que as fêmeas podem ser dicromatas (homozigóticas) ou tricromatas (heterozigóticas) [Jacobs, 1983; Jacobs & Neitz, 1987]. De acordo com Jacobs & Deegan II [2005], 40% das fêmeas apresentam dicromatismo, enquanto 60% tricromatismo. No entanto, duas exceções são conhecidas: *Aotus* spp. (macacos-da-noite) que são monocromáticos, e *Allouata* spp. (bugios) que são tricromáticos [Jacobs et al., 1996a,b].

A presença do polimorfismo nos Platyrrhini há 14 milhões de anos sugere uma adaptação evolutiva desta característica [Surridge & Mundy, 2002]. Existem duas hipóteses levantadas para a permanência deste polimorfismo: (i) Hipóteseda dominância heterozigótica, que refere que fêmeas heterozigóticas teriam um "fitness" mais elevado que os restantes indivíduos e (ii) hipótese da seleção dependente de frequência negativa, que por sua vez refere que os dois fenótipos são mantidos pois a seleção favorece o fenótipo com menor frequência na população, que neste caso seria o tricromatismo [Boissinot et al., 1998; Mollon et al., 1984].

Mais recentemente, pesquisadores têm tentado entender as vantagens e desvantagens de cada fenótipo, através de estudos relacionados com a busca por alimentos. Em geral, os resultados apontam que indivíduos tricromatas têm mais facilidade em distinguir objetos de cor conspícua [e.g. Bompas et al., 2013; Caine &

Mundy, 2000; Dominy & Lucas, 2001; Osorio & Vorobyev, 1996; Perini et al., 2009; Regan et al., 2001; Smith et al., 2003].

Por outro lado, indivíduos dicromatas são mais eficazes no forrageio em áreas de pouca luminosidade [Caine et al., 2010; Freitag & Pessoa, 2012; Perini et al., 2009], possuem uma melhor visão espacial e detectam com mais facilidade organismos crípticos e camuflados [e.g. Melin et al., 2007; Morgan et al., 1992; Saito et al., 2005; Smith et al., 2012]. Melin et al. [2007] e Smith et al. [2012] que trabalharam com as espécies *Cebus capucinus* e *Saguinus* spp., respectivamente, verificaram que dicromatas seriam mais eficientes na captura de insetos com coloração críptica ou que fiquem camuflados em relação ao substrato. Enquanto Dominy et al. [2003] não observaram vantagem de fêmeas (dicromatas e tricromatas) sobre machos (exclusivamente dicromatas) no forrageio por alimento, Smith et al. [2012] mostraram que tricromatas capturam, em geral, mais insetos do que dicromatas, indicando uma vantagem de tricromatas no forrageio por insetos. Smith et al. [2012] afirmam ainda que o polimorfismo não se apresenta vantajoso quando o tamanho do inseto a ser capturado varia. Ainda, no estudo de Melin et al. [2007], os autores mostraram que tricromatas capturam em maior número insetos conspícuos de superfície do que dicromatas.

Estudos que visem o efeito do polimorfismo no comportamento de forrageio do gênero *Callithrix* na natureza ainda são inexistentes. Até o presente momento, pesquisas de laboratório focaram em estudos genéticos [e.g. Hunt et al., 1993; Shyue et al., 1998 Surridge & Mundy, 2002], microespectofotométricos [e.g. Kawamura et al., 2001; Tovée et al., 1992; Travis et al., 1988; Williams et al., 1992] e comportamentais [e.g. Caine & Mundy, 2000; Caine et al., 2003, 2010; Freitag & Pessoa, 2012; Moreira et al., 2015; Pessoa et al., 2005a,b]. No presente estudo, investigamos a hipótese da vantagem

de fêmeas de *Callithrix jacchus* na detecção de insetos na natureza. Saguis são pequenos primatas neotropicais da família Callithrichidae e, normalmente, possuem em seu grupo apenas uma fêmea reprodutora [Auricchio, 1995; Yamamoto, 1991]. Apesar da ausência de dimorfismo sexual, estudos apontam para uma maior vantagem de fêmeas no forrageio por alimento [e.g. Box et al., 1999]. A alimentação destes primatas é essencialmente composta por frutos, insetos e goma [Rylands & de Faria, 1993; Souto et al., 2007]. Entre os insetos mais consumidos encontram-se grilos, gafanhotos, cigarras, formigas e cupins [Schiel et al., 2010; Souto et al., 2007]. Estes possuem elaboradas estratégias para evitar a predação [Edmunds, 1974; Poulton, 1980]. Quando não utilizam a estratégia de se esconderem entre frestas, a maioria encontra-se de forma críptica sob o substrato, ou apresentam cores conspícuas [Edmunds, 1974; Poulton, 1980].

Deste modo, este estudo aborda uma comparação do comportamento de forrageio por insetos entre fêmeas e machos de saguis. Ao se observar a taxa de captura de insetos por sexo, espera-se que fêmeas capturem significativamente mais insetos do que os machos, assim como capturem significativamente mais insetos de cor conspícua do que os machos. Relativamente à captura de insetos crípticos, espera-se que haja uma maior captura destes insetos por parte dos machos.

Métodos

Área de estudo e composição dos grupos

O estudo foi conduzido na Fazenda Marimbondo, uma área privada com cerca de 400 ha (7º31’42”S – 36º17’50”W), situada próxima ao município de Cabaceiras, no estado da Paraíba, Nordeste do Brasil (Fig. 1). Esta região está inserida no Cariri

Paraibano, apresentando vegetação típica de Caatinga e condições climáticas únicas [para mais detalhes ver De La Fuente et al., 2014].

Foram observados cinco grupos (G1 – G5) da espécie *Callithrix jacchus*, em um total de 19 indivíduos (Tabela I). Os indivíduos foram identificados de acordo com marcas naturais ou cicatrizes, sexo e idade [De La Fuente et al., 2014; Schiel et al., 2008; Schiel et al., 2010].

Fig. 1. Área de estudo na fazenda Marimbondo em ambiente semiárido, Paraíba, Brasil (Fonte: Javiera De la Fuente).

Tabela I – Composição dos grupos de estudo em ambiente semiárido

Idade (meses)	G 1		G 2		G 3		G 4		G 5	
	♀	♂	♀	♂	♀	♂	♀	♂	♀	♂
Infante (1-4)	-	1*	-	-	-	-	-	2*	-	-
Juvenil (5 – 10)	-	-	-	-	2	-	-	-	-	-
Adulto (> 11)	1	1	1	1	2	3	1	1	1 (1*)	1

G=grupo. *Indivíduos que desapareceram durante o estudo. Estes não foram incluídos nas análises.

Coleta de dados comportamentais

Após quatro meses de habituação dos animais e do observador, deu-se início às observações sistemáticas que foram realizadas por F. Abreu. Os dados sistemáticos

foram coletados de maio a julho e de setembro a novembro de 2014 (meses mais representativos da estação chuvosa e seca, respectivamente) [Medeiros et al., 2012]. A coleta ocorreu durante 10 dias por mês, totalizando 263 horas de observação direta.

O método de amostragem utilizado foi animal focal, com sessões de 10 minutos contínuos [Altmann, 1974]. Utilizou-se o método *ad libitum* [Altmann, 1974] ao se observar algum indivíduo consumindo uma presa. Sempre que um animal ficava "fora de visão" por mais de 60 segundos, a sessão era descartada [Schiel & Huber, 2006]. A coleta de dados comportamentais foi realizada com auxílio de um gravador digital (Olympus VN-702PC).

Cada grupo foi seguido durante o seu principal período de atividade (5:00 até 17:00) [De La Fuente et al., 2014]. Ao início de cada sessão, escolhia-se ao acaso qual indivíduo seria observado. A coleta dos dados comportamentais para cada indivíduo foi igualmente distribuída ao longo do dia. Obtiveram-se, aproximadamente, 80 sessões por indivíduo, totalizando 1.581 sessões. Nas observações foram anotados: (i) eventos de predação realizados pelos saguis de acordo com o sexo; (ii) coloração e taxonomia do inseto; e (iii) substrato e cor do substrato em que o inseto foi capturado. A identificação dos insetos foi feita a nível de ordem, sendo classificados em crípticos (insetos que se encontravam camuflados em relação ao substrato no momento da captura) ou conspícuos (insetos de coloração chamativa ou visíveis sob o substrato) de acordo com Melin et al., [2007]. Além da coloração, dividimos os insetos em categorias de acordo com o seu tamanho: insetos crípticos pequenos (insetos $\leq$ 2 cm); insetos crípticos grandes (insetos > 2 cm); insetos conspícuos pequenos (insetos $\leq$ 2 cm); insetos conspícuos grandes (insetos > 2 cm) [modificado de Schiel et al. (2010)]. O estudo foi não invasivo e está de acordo com as leis brasileiras, tendo sido aprovado pelo Comité

de Ética para Uso de Animais da Universidade Federal Rural de Pernambuco (CEUA nº 135/2014).

Coleta de insetos

A coleta de insetos visou a identificação e a medição do tamanho da ordem de presas que observamos os animais consumirem. Para a coleta foram usados três tipos de armadilhas: rede entomológica (insetos voadores), guarda-chuva entomológico (insetos que se situam em galhos ou folhas de árvores), e armadilha de queda (insetos terrestres) [Paulson, 2005]. As coletas foram feitas em julho e novembro de 2014 e o esforço amostral foi de 12 horas por dia, totalizando 120 horas.

Análise estatística

Para a análise estatística foram utilizados 15 indivíduos. Retiramos das análises todos os animais que desapareceram durante o período de observações (N = 1) e aqueles com idade inferior a 5 meses (N = 3). A exclusão dos indivíduos mais jovens visou evitar um efeito da inexperiência dos mesmos na captura de insetos [De La Fuente et al., 2014; Schiel et al., 2010]. Para verificarmos se a lactação tem algum efeito na eficiência de captura, foram realizadas análises (i) com as fêmeas lactantes (N = 8) e (ii) sem as fêmeas lactantes (N = 6). Verificou-se também se haveria algum efeito retirando outras duas fêmeas não lactantes das análises estatísticas.

Para a análise estatística utilizamos a média do número total de presas capturadas divididas pelo número total de sessões para cada indivíduo. Devido à não normalidade dos dados assim como a heterogeneidade das variâncias, utilizamos o teste não paramétrico *U* de Mann-Whitney [Siegel, 1956]. Este teste foi utilizado para

verificarmos qual dos sexos (fêmeas ou machos): (i) capturou mais insetos; (ii) capturou mais insetos conspícuos ou crípticos; (iii) capturou mais insetos de acordo com suas categorias.

Para todas as análises considerou-se P≤0.05 como significativo. Todos os dados foram analisados com o GraphPad Instat3 (GraphPad Software, Inc.) e Excel (Microsoft Corporation).

Resultados

No total, registraramos 797 eventos direcionados à captura de insetos. Foram identificados 582 insetos a nível de ordem, havendo capturas de insetos de 10 ordens distintas

Quando comparamos as fêmeas e machos, incluindo nesta análise todas as fêmeas observadas, foram observadas diferenças significativas tanto na captura de insetos totais ($U = 47$; $P \leq 0.05$) como na de insetos de coloração conspícua ($U = 47.5$, $P \leq 0.05$), sendo as fêmeas mais eficazes nestas duas categorias. Por sua vez, na captura de insetos crípticos não observamos diferenças entre sexos ($U = 42$, $P = 0.12$) (Fig. 2).

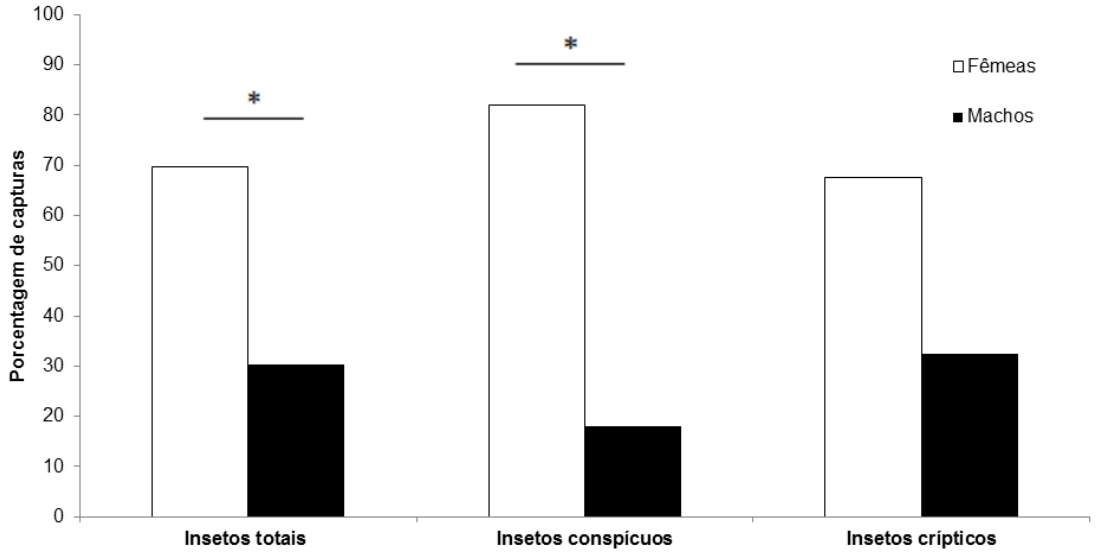

Fig. 2. Comparação da porcentagem de insetos capturados entre fêmeas (N = 8) e machos (N = 7) de *Callithrix jacchus*. *$P \leq 0.05$.

Em relação às análises de categorias de insetos, apenas observamos diferenças significativas na captura de insetos conspícuos pequenos (U = 49, $P \leq 0.01$), com uma maior captura destes insetos por parte de fêmeas. Nas capturas de insetos crípticos pequenos (U = 41, P = 0.15), insetos crípticos grandes (U = 41, P = 0.15) e insetos conspícuos grandes (U = 30, P = 0.81) não foram observadas diferenças significativas entre sexos (Fig. 3).

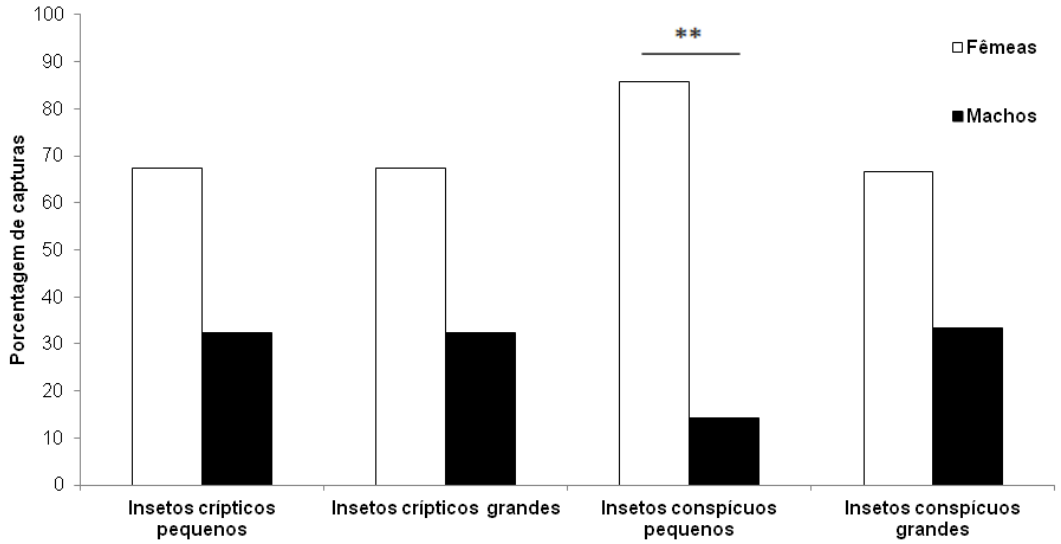

Fig. 3. Comparação da porcentagem de capturas nas diferentes categorias de tamanho e coloração de insetos entre fêmeas (*N* = 8) e machos (*N* = 7) de *Callithrix jacchus*. **$P \leq$ 0.01.

Com a retirada das fêmeas que estavam lactantes durante o período de estudo (N = 2), nenhuma diferença significativa entre sexos foi observada nas capturas totais (U = 33, *P* = 0.10), capturas de insetos de coloração conspícua (U = 33.5, *P* = 0.08) e de insetos de coloração críptica (U = 31, *P* = 0.18) (Fig. 4).

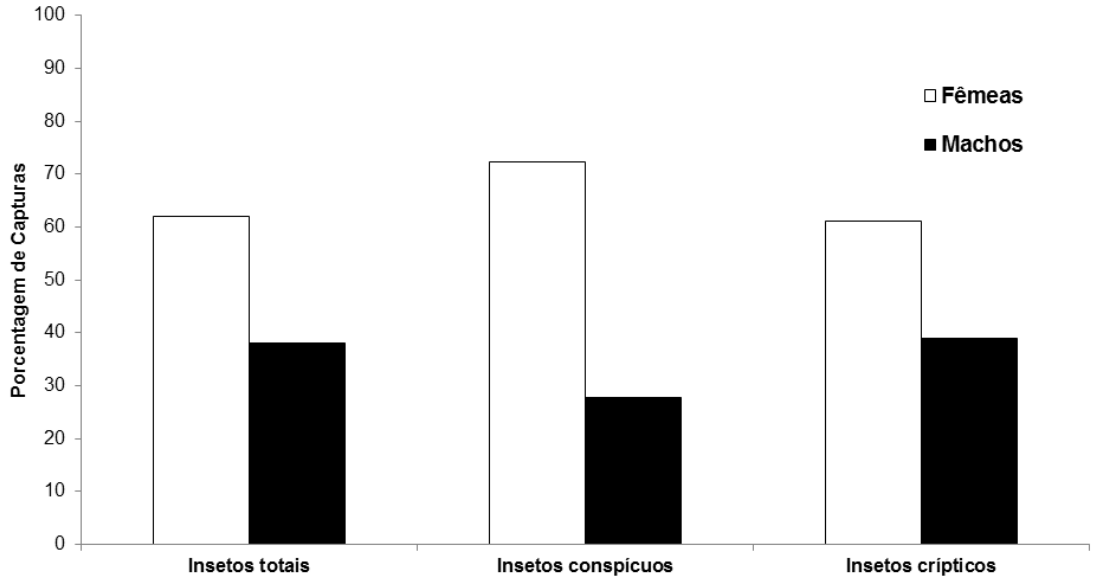

Fig. 4. Comparação da porcentagem de insetos capturados entre fêmeas (*N* = 6) e machos (*N* = 7) de *Callithrix jacchus*, sem a presença de fêmeas lactantes.

Na análise por categorias de insetos (excluindo as fêmeas lactantes) apenas foi observada diferença significativa na captura de insetos conspícuos pequenos (U = 33.5; $P \leq 0.05$), com fêmeas capturando um maior número de insetos desta categoria do que machos. Nas demais análises não foram encontradas diferenças significativas entre sexos (insetos crípticos pequenos: U = 30, $P = 0.23$; insetos crípticos grandes: U = 31, $P = 0.18$; insetos conspícuos grandes: U = 23, $P = 0.83$) (Fig. 5).

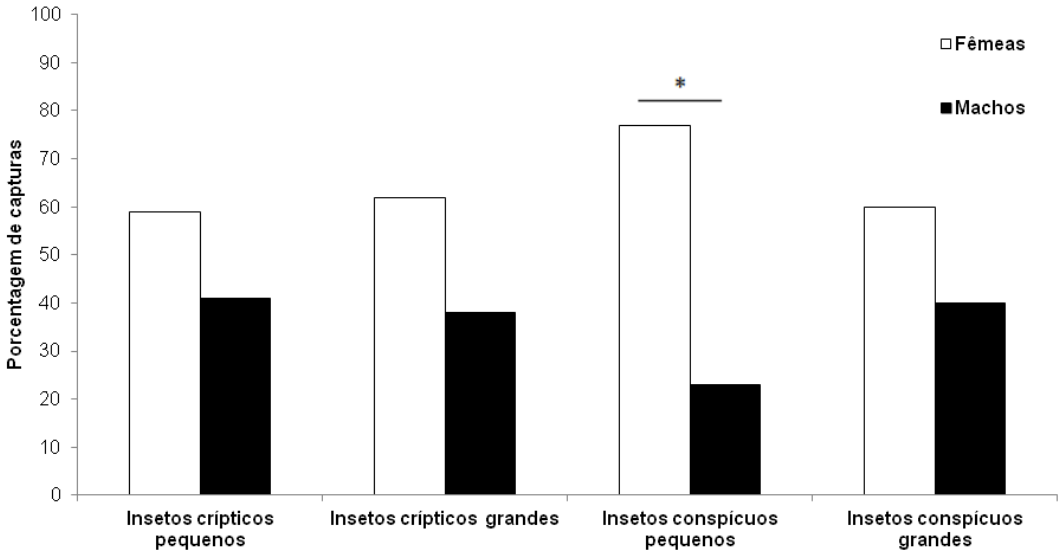

Fig. 5. Comparação da porcentagem de capturas nas diferentes categorias de tamanho e coloração de insetos entre fêmeas ($N = 6$) e machos ($N = 7$) de *Callithrix jacchus*, sem a presença de fêmeas lactantes. *$P \leq 0.05$.

Discussão

Os resultados obtidos corroboram algumas das nossas hipóteses iniciais, indicando que fêmeas capturam um maior número de insetos em geral, assim como insetos de coloração conspícua. Nossos dados também revelaram que, além do efeito do polimorfismo, parece também existir um efeito da lactação no sucesso de capturas por parte das fêmeas. Sabendo-se que fêmeas deste gênero têm uma maior probabilidade de possuírem o tricromatismo (66%) ao invés do dicromatismo (34%) [Rowe & Jacobs, 2004; Surridge et al., 2005], poderia se esperar uma vantagem para as fêmeas aqui

estudadas nas capturas de insetos totais [Smith et al. 2012], assim como de insetos de coloração conspícua [Melin et al., 2007; Smith et al., 2012], tanto na presença como na ausência de fêmeas lactantes. Contudo, apenas foi verificada uma vantagem de fêmeas sobre machos nas capturas referidas acima quando as fêmeas lactantes estavam inclusas nas análises. Isto sugere que a lactação parece exercer um efeito nestas capturas, possivelmente porque há uma maior demanda energética por parte das fêmeas [Gittleman & Thompson, 1988, Nievergelt & Martin, 1999; Araújo et al., 2000; Tardif et al., 2001, 2004]. Assim, as fêmeas podem compensar essa necessidade nutricional através do aumento do consumo de insetos que são ricos em proteínas [Garber, 1987]. Considerando-se que estas fêmeas possam ser tricromatas, estudos anteriores afirmam que além da vantagem na discriminação de itens conspícuos, o tricromatismo é também vantajoso na procura de alimento nutritivo [e.g. Lucas et al., 1998, 2003; Dominy & Lucas, 2001, 2004; Riba-Hernandez et al., 2005], o que apoiaria os resultados aqui apresentados.

Com relação às capturas de insetos de coloração críptica não foram observadas diferenças significativas entre os dois sexos. Este resultado não era previsto, uma vez que a captura de insetos com este tipo de coloração é referida como uma das vantagens dos indivíduos com visão dicromata (principalmente os machos) [Morgan et al., 1992; Saito et al., 2005; Melin et al., 2007; Smith et al., 2012]. Porém, alguns estudos indicam que fêmeas têm prioridade no acesso ao alimento [Tardif & Richter, 1981; Lopes et al., 1997], assim como obtêm mais alimento do que os machos [e.g. Michels, 1988; Yamamoto et al., 2004], indicando que o sexo possa ter ocasionado um efeito neste resultado.

Relativamente aos resultados nas diferentes categorias de tamanho e coloração, observamos um possível efeito da visão na categoria de insetos conspícuos pequenos. O fato de fêmeas capturarem um maior número de insetos nesta categoria do que machos corrobora resultados de estudos anteriores, mostrando uma vez mais que fêmeas têm uma facilidade maior para capturar insetos de colorações mais chamativas [Melin et al., 2007; Smith et al., 2012] e de menor tamanho que os machos.

Observamos, ainda, uma relação interessante entre o tamanho do inseto capturado e o polimorfismo visual. A vantagem das fêmeas desaparece quando se trata de insetos conspícuos grandes sugerindo que, após certo comprimento (>2 cm) a desvantagem dos machos (dicromatas) em capturar itens alimentares de colorações conspícuas é superada. Este fato já foi discutido e observado em primatas humanos dicromatas [e.g. Breton & Tansley, 1985], sendo conhecido como "tricromacia de campo grande" em que dicromatas conseguem discriminar objetos que seriam apenas detectados por indivíduos com tricromacia. Esta discriminação é facilitada quando os objetos são de maior tamanho, no entanto, nem todos os dicromatas a possuem [Sharpe et al., 1999]. Por exemplo, Smith et al. [2012] não encontraram efeito do tamanho nas capturas de insetos por *Saguinus* spp. O mesmo resultado foi observado num estudo experimental realizado por Gomes et al. [2005], em que os autores observaram que a espécie *Cebus apella* não melhorava sua discriminação de objetos de cores conspícuas com a alteração do tamanho destes, sugerindo que os sujeitos do seu estudo não apresentavam "interação de campo grande".

Em conclusão, nossos dados sugerem que o polimorfismo visual nesta população seja mantido por vantagem heterozigótica, uma vez que as fêmeas apresentaram uma maior captura de insetos totais e de insetos conspícuos. Ressaltamos que esta vantagem

pode ser atribuída ao polimorfismo visual, no entanto, a lactação é uma varíavel importante e que deve ser considerada. Da mesma forma, destacamos a importância do tamanho do inseto capturado, já que machos passaram a ter sucesso em suas capturas por insetos conspícuos quando os mesmos apresetavam um tamanho acima de 2 cm.

Agradecimentos

Os autores agradecem ao Dr. Geraldo Baracuhy por nos facultar a Fazenda Marimbondo para conduzirmos a nossa pesquisa. O presente estudo foi financiado por uma bolsa de mestrado Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) atribuída a Filipa Abreu.

Referências Bibliográficas

Altmann J, 1974. Observational study of behavior: sampling methods. Behaviour 49: 227-265.

Araújo M, Arruda MF, Alencar AI, et al. 2000. Body weight of wild and captive common marmosets (*Callithrix jacchus*). International Journal of Primatology 21 (2): 317-324.

Auricchio P. 1995. Primatas do Brasil. São Paulo, Editora Terra Brasilis, 168p.

Boissinot S, Tan Y, Shyue S, et al. 1998. Origins and antiquity of x-linked triallelic color vision systems in New World monkeys. Proceedings of the National Academy of Science USA 95: 13749-13754.

Bompas A, Kendall G, Sumner P. 2013. Spotting fruit versus picking fruit as the selective advantage of human color vision. i-Perception 4: 84-94.

Box H, Yamamoto ME, Lopes FA. 1999. Gender differences in marmosets and tamarins: responses to food tasks. International Journal of Comparative Psychology 12(2): 59-70.

Breton ME, Tansley BW. 1985. Improved color test results with large-field viewing in dichromats. Archives Ophthalmology 103: 1490–1495.

Bunce JA. 2015. Incorporating ecology and social system into formal hypothesis to guide field studies of color vision in primates. American Journal of Primatology 77: 516-526.

Caine NG & Mundy NI. 2000. Demonstration of a foraging advantage for trichromatic marmosets (*Callithrix geoffroyi*) dependent on food color. Proceedings of a Royal Society of London B 267: 439-444.

Caine NG, Surridge AL, Mundy NI. 2003. Dichromatic and trichromatic *Callithrix geoffroyi* differ in relative foraging ability for red-green color-camouflaged and non-camouflaged food. International Journal of Primatology 24 (6): 1163-1175.

Caine NG, Osorio D, Mundy NI. 2010. A foraging advantage for dichromatic marmosets (*Callithrix geoffroyi*) at low light intensity. Biology Letters 6: 36-38.

De la Fuente MFC, Souto A, Sampaio B, Schiel N. 2014. Behavioral adjustments by a small Neotropical primate (*Callithrix jacchus*) in a semiarid Caatinga environment. The Scientific World Journal. doi:10.1155/2014/326524.

Dominy NJ, Garber PA, Bicca-marques JC, Azevedo-lopes MA. 2003. Do female tamarins use visual cues to detect fruit rewards more successfully than do males? Animal Behaviour 66: 829-837.

Dominy NJ, Lucas PW. 2001. Ecological importance of trichromatic vision to primates. Nature 410: 363-366.

Dominy NJ, Lucas PW. 2004. Significance of color, calories, and climate to the visual ecology of catarrhines. American Journal of Primatology 66: 189-207.

Edmunds, M. 1974. Defense in animals: a survey of antipredator defenses. Harlow, Longman Group Limited, 357pp.

Freitag FB, Pessoa DMA. 2012. Effect of luminosity on color discrimination of dichromatic marmosets (*Callithrix jacchus*). Journal of Optical Society of America 29 (2): 216-222.

Garber PA. 1987. Foraging living strategies among living primates. Annual Review of Anthropology 16: 339-364.

Gittleman JL, Thompson SD. 1988. Energy allocation in mammalian reproduction. American Zoologist 28: 863–875.

Gomes UR, Pessoa DMA, Suganuma E, Tomaz C, Pessoa VF. 2005. Influence of stimuli size on color discrimonation in capuchin monkeys. American Journal of Primatology 67: 437-446.

Hunt DV, Williams AJ, Bowmaker JK, Mollon, JD. 1993. Structure and evolution of the polymorphic photopigment gene of the marmoset. Vision Research 33 (2): 147-154.

Jacobs, GH. 1983. Colour vision in animals. Endeavour 7 (3): 137-140.

Jacobs GH, Neitz J. 1987. Inheritance of color vision in a New World monkey (*Saimiri sciureus*). Proceedings of the National Academy of Science, 84: 2545-2549.

Jacobs GH, Neitz M, Deegan F, Neitz J. 1996A. Trichromatic colour vision in new world monkey. Nature 382: 156-158.

Jacobs GH, Neitz M, Neitz J. 1996B. Mutations in S-cone pigment genes and the absence of colour vision in two species of nocturnal primates. Proceedings of the Royal Society of London B 263: 705-710.

Jacobs GH, Deegan II JF. 2005. Polymorphic New World monkeys with more than three M/L cone types. Journal of Optical Society of America A 22(10): 2072-2080.

Kawamura S, Hirai M, Takenaka O, Radlwimmer FB, Yokoyama S. 2001. Genomic and spectral analyses of long to middle wavelength-sensitive visual pigments of common marmoset (*Callithrix jacchus*). Gene 269: 45-51.

Lopes FA, Yamamoto ME, Medeiros IS, Delgado KVC. 1997. A influência do estado reprodutivo da fêmea na competição por alimento no sagüí comum (*Callithrix jacchus*). Anais de Etologia 15:35-46.

Lucas PW, Darvell BW, Lee PKD, Yuen TDB, Choong MF. 1998. Colour cues of leaf food selection by long-tailed macaques (*Macaca fascicularis*) with a new suggestion for the evolution of trichromatic vision. Folia Primatológica 69: 139-154.

Lucas PW, Dominy NJ, Riba-Hernádez P, et al. 2003. Evolution and function of routine trichromatic vision in primates. Evolution 57(11): 2636-2643.

Medeiros RM, Brito JIB, Borges CK. 2012. Análise hidroclimático do município de Cabaceiras, PB. Revista Brasileirade Geografia Fisíca 5(5):1174-1190.

Melin AD, Fedigan LM, Hiramatsu C, Sendall CL, Kawamura S. 2007. Effects of colour vision phenotype on insect capture by a free-ranging population of white-faced capuchins, *Cebus capuchins*. Animal Behaviour 73: 205-214.

383 Michels AN. 1988. Sex differences in food acquisition and aggression in captive
384 commom marmosets (*Callithrix jacchus*). Primates 39(4): 549-556.
385 Mollon JD, Bowmaker JK, Jacobs GH. 1984. Variations of colour vision in a new world
386 primate can be explained by polymorphism of retinal photopigments. Proceedings
387 of the Royal Society of London B 222: 373-399.
388 Moreira LAO, Oliveira DGR, Sousa MBC, Pessoa DMA. 2015. Parturition signaling by
389 visual cues in female marmosets (*Callithrix jacchus*). PLos ONE e0129319. doi:
390 10.1371/journal.pone.0129319.
391 Morgan MJ, Adam A, Mollon JD. 1992. Dichrimats detect colour-camouflaged objects
392 that are not detected by trichromats. Proceedings of the Royal Society of London
393 B 248: 291-295.
394 Nievergelt CM, Martin RD. 1999. Energy intake during reproduction in captive
395 common marmosets (*Callithrix jacchus*). Physiology & Behavior 65 (4/5):849-
396 854.
397 Osorio D, Vorobyev M. 1996. Colour vision as an adaptation to frugivory in primates.
398 Proceedings of the Royal Society of London 263: 593-599.
399 Paulson GS. 2005. Handbook to the construction and use of insect collection and
400 rearing devices: A guide for teachers with suggested classroom applications.
401 Springer Science & Business Media, 121pp.
402 Perini ES, Pessoa VF, Pessoa DMA. 2009. Detection of fruit by cerrado's marmoset
403 (*Callithrix penicillata*): modeling color signals for different background scenarios
404 and ambient light intensities. Journal of Experimental Zoology 311A: 289-302.
405 Pessoa DMA, Tomaz C, Pessoa VF. 2005a. Color vision in marmosets and tamarins:
406 Behavioral evidence. American Journal of Primatology 67: 487-495.

Pessoa DMA, Cunha JF, Tomaz C, Pessoa VF. 2005b. Colour discrimination in the Black-tufted-ear marmoset (*Callithrix penicillata*): Ecological implications. Folia Primatológica 76: 125-134.

Poulton EB, 1980. The colours of animals: Their meaning and use, especially considered in the case of insects. The internacional scientific series, New York: D. Appleton and company.

Regan BC, Jullliot C, Simmen B, Viénot F, Charles-Dominique P, Mollon JD. 2001. Fruits, foliage and the evolution of primate colour vision. Philosophical Transactions of the Royal Society B 356: 229-283.

Riba-Hernández P, Stoner KE, Osório D. 2005. Effect of polymorphic colour vision for fruit detection in the spider monkey Ateles geoffroyi, and its implications for the maintenance of polymorphic colour vision in platyrrhine monkeys. The Journal of Experimental Biology 207: 2465-2470.

Rowes MP, Jacobs GH. 2004. Cone pigment polymorphism in new world monkeys: are all pigments created equal? Visual Neuroscience 21: 217-222. doi: 10.10170S095252380404310X.

Rylands AB, de Faria DS. 1993. Habitats, feeding ecology, and home range size in the genus Callithrix. In: Rylands, AB, editor. Marmosets and tamarins: systematic, behaviour and ecolgy. New York: Oxford University Press, p.262-272.

Saito A, Mikami A, Kawamura S, et al. 2005. Advantage of dichromats over trichromats in discrimination of color-camouflaged stimuli in nonhuman primates. American Journal of Primatology 67: 425-436.

Schiel N, Huber L. 2006. Social influences on the development of foraging behavior in free-living common marmosets (*Callithrix jacchus*). American Journal of Primatology 68: 1-11.

Schiel N, Souto A, Bezerra BM, Huber L. 2008. A stress-free method of identifying common marmosets (*Callithrix jacchus*) in the wild. A Primatologia no Brasil, Aracajú, Sociedade Brasileira de Primatologia, Biologia Geral e Experimental – UFS 9: 147-153.

Schiel N, Souto A, Huber L, Bezerra B. 2010. Hunting strategies in wild common marmosets are prey and age dependent. American Journal of Primatology 71: 1-8.

Shyue S, Boissinot S, Schneider H, et al. 1998. Molecular genetics of spectral tuning in new world monkey color vision. Journal of Molecular Evolution, 46: 697-702.

Siegel S. 1956. Non parametric statistics for the behavioral sciences. McGraw-Hill, New York.

Smith AC, Buchanan-smith HM, Surridge AK, Osorio D, Mundy NI. 2003. The effect of color vision status on the detection and selection of fruits by tamarins (*Saguinus spp.*). Journal of Experimental Biology 206: 3159-3165.

Smith AC, Surridge AK, Prescott MJ, et al. 2012. Effect of colour vision status on insect prey capture efficiency of captive and wild tamarins (*Saguinus* spp.). Animal Behaviour 83: 479-486.

Souto A, Bezerra BM, Schiel N, Huber L. 2007. Saltatory search in free-living *Callithrix jacchus*: Environmental and age influences. International Journal of Primatology 28: 881-893.

Surridge AK, Mundy NI. 2002. Trans-specific evolution of opsin alleles and the maintenance of trichromatic colour vision in Callitrichine primates. Molecular Ecology 11: 2157-2169.

Surridge AK, Suárez SS, Buchanan-Smith HM, Smith AC, Mundy NI. 2005. Color vision pigment frequencies in wild tamarins (*Saguinus* spp.). American Journal of Primatology 67: 463-470.

Tardif SD, Richter CB. 1981. Competition for a desired food in family groups of then common marmoset (*Callithrix jacchus*) and the cotton top tamarin (*Saguinus oedipus*). Laboratory of Animal Science Professional 31: 52-55.

Tardif SD, Power M, Oftedal OT, Power RA, Layne DG. 2001. Lactation, maternal behavior and infant growth in common marmoset monkeys (*Callithrix jacchus*): effects of maternal size and litter size. Behavioral Ecology Sociobiology 51: 17-25.

Tardif SD, Power M, Layne D, Smucny D, Ziegler T. 2004. Energy restriction initiated at different gestational ages has varying effects on maternal weight gain and pregnancy outcome in common marmosets monkeys (*Callithrix jacchus*). British Journal of Nutrition 92: 841-849.

Tovée MJ, Bowmaker JK, Mollon JD. 1992. The relationship between cone pigments and behavioural sensitivity in a new world monkey (*Callithrix jacchus jacchus*). Vision Research 32 (5): 867-878.

Travis DS, Bowmaker JK, Mollon JD. 1998. Polymorphism of visual pigments in a callitrichid monkey. Vision Research 28 (4): 481-490.

473 Williams AJ, Hunt DM, Bowmaker JK, Mollon J. 1992. The polymorphic
474 photopigments of the marmoset: spectral tuning and genetic basis. The EMBO
475 Journal 11 (6): 2039-2045.
476 Yamamoto ME. 1991. Comportamento social do gênero *Callithrix* em cativeiro. A
477 primatologia no Brasil 3: 63-81.
478 Yamamoto ME, Domeniconi C, Box H. 2004. Sex differences in commom marmosets
479 (*Callithrix jacchus*) in response to an unfamiliar food task. Primates 45: 249-254.

ANEXO III. NORMAS PARA SUBMISSÃO NA REVISTA *MAMMAL RESEARCH*

Instructions for Authors

Manuscript Submission
Submission of a manuscript implies: that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all coauthors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out. The publisher will not be held legally responsible should there be any claims for compensation.

Permissions
Authors wishing to include figures, tables, or text passages that have already been published elsewhere are required to obtain permission from the copyright owner(s) for both the print and online format and to include evidence that such permission has been granted when submitting their papers. Any material received without such evidence will be assumed to originate from the authors.

Online Submission
Please follow the hyperlink "Submit online" on the right and upload all of your manuscript files following the instructions given on the screen.

Costs of Color Illustrations
Online publication of color illustrations is always free of charge. For color in the print version, authors will be expected to make a contribution towards the extra costs of EUR 950 / US$ 1150 (+ local tax) per article, irrespective of the number of figures in it.

LANGUAGE
Manuscripts that are accepted for publication will be checked by our copyeditors for spelling and formal style. This may not be sufficient if English is not your native language and substantial editing would be required. In that case, you may want to ask a native speaker to help you or arrange for your manuscript to be checked by a professional language editor prior to submission. A clear and concise language will help editors and reviewers concentrate on the scientific content of your paper and thus smooth the peer review process. The following editing service provides language editing for scientific articles in medicine, biomedical and life sciences, chemistry, physics, engineering, business/economics, and humanities. Please contact the editing service directly to make arrangements for editing and payment. Use of an editing service is neither a requirement nor a guarantee of acceptance for publication.

TITLE PAGE

Title Page
The title page should include:
The name(s) of the author(s)
A concise and informative title

The affiliation(s) and address(es) of the author(s)
The email address, telephone and fax numbers of the corresponding author

Abstract
Please provide an abstract of 150 to 250 words. The abstract should not contain any undefined abbreviations or unspecified references.

Keywords
Please provide 4 to 6 keywords which can be used for indexing purposes.

TEXT

Text Formatting
Manuscripts should be submitted in Word.
Use a normal, plain font (e.g., 10point Times Roman) for text.
Use italics for emphasis.
Use the automatic page numbering function to number the pages.
Do not use field functions.
Use tab stops or other commands for indents, not the space bar.
Use the table function, not spreadsheets, to make tables.
Use the equation editor or MathType for equations.
Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).
Manuscripts with mathematical content can also be submitted in LaTeX.
LaTeX macro package (zip, 182 kB).

Headings
Please use no more than three levels of displayed headings.

Abbreviations
Abbreviations should be defined at first mention and used consistently thereafter.

Footnotes
Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables. Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lowercase letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols. Always use footnotes instead of endnotes.

Acknowledgments
Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full.

REFERENCES

Citation
Cite references in the text by name and year in parentheses. Some examples:

Negotiation research spans many disciplines (Thompson 1990).
This result was later contradicted by Becker and Seligman (1996).
This effect has been widely studied (Abbott 1991; Barakat et al. 1995; Kelso and Smith 1998; Medvec et al. 1999).

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.

EndNote style (zip, 2 kB)

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

Journal article

Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, Nottin S, Bosquet L (2009) Effect of high intensity intermittent training on heart rate variability in prepubescent children. Eur J Appl Physiol 105:731738. doi: 10.1007/s0042100809558

Ideally, the names of all authors should be provided, but the usage of "et al" in long author lists will also be accepted:

Smith J, Jones M Jr, Houghton L et al (1999) Future of health insurance. N Engl J Med 965:325–329

Article by DOI

Slifka MK, Whitton JL (2000) Clinical implications of dysregulated cytokine production. J Mol Med. doi:10.1007/s001090000086

Book

South J, Blass B (2001) The future of modern genomics. Blackwell, London

Book chapter

Brown B, Aaron M (2001) The politics of nature. In: Smith J (ed) The rise of modern genomics, 3rd edn. Wiley, New York, pp 230257

Online document

Cartwright J (2007) Big stars have weather too. IOP Publishing PhysicsWeb. http://physicsweb.org/articles/news/11/6/16/1. Accessed 26 June 2007

Dissertation

Trent JW (1975) Experimental acute renal failure. Dissertation, University of California

Always use the standard abbreviation of a journal's name according to the ISSN List of Title Word Abbreviations, see

ISSN.org LTWA

If you are unsure, please use the full journal title. For authors using EndNote, Springer provides an output style that supports the formatting of intext citations and reference list.

TABLES

All tables are to be numbered using Arabic numerals. Tables should always be cited in text in consecutive numerical order. For each table, please supply a table caption (title) explaining the components of the table. 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 lowercase letters (or asterisks for significance values and other statistical data) and included beneath the table body.

ARTWORK AND ILLUSTRATIONS GUIDELINES

Electronic Figure Submission
Supply all figures electronically. Indicate what graphics program was used to create the artwork. For vector graphics, the preferred format is EPS; for halftones, please use TIFF format. MSOffice 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
Color art is free of charge for online publication. If black and white will be shown in the print version, make sure 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 finalsized artwork, usually about 2–3 mm (8–12 pt). Variance of type size within an illustration should be minimal, e.g., do not use 8pt type on an axis and 20pt type for the axis label. Avoid effects such as shading, outline letters, etc. Do not include titles or captions within your illustrations.

Figure Numbering
All figures are to be numbered using Arabic numerals. Figures should always be cited in text in consecutive numerical order. Figure parts should be denoted by lowercase letters (a, b, c, etc.). If an appendix appears in your article and it contains one or more figures, continue the consecutive numbering of the main text. Do not number the appendix figures, "A1, A2, A3, etc." Figures in online appendices (Electronic Supplementary Material) should, however, be numbered separately.

Figure Captions

Each figure should have a concise caption describing accurately what the figure depicts. Include the captions in the text file of the manuscript, not in the figure file. Figure captions begin with the term Fig. in bold type, followed by the figure number, also in bold type. No punctuation is to be included after the number, nor is any punctuation to be placed 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.

Figure Placement and Size
Figures should be submitted separately from the text, if possible. When preparing your figures, size figures to fit in 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. For books and booksized journals, the figures should be 80 mm or 122 mm wide and not higher than 198 mm.

Permissions
If you include figures that have already been published elsewhere, you must obtain permission from the copyright owner(s) for both the print and online format. Please be aware that some publishers do not grant electronic rights for free and that Springer will not be able to refund any costs that may have occurred to receive these permissions. In such cases, material from other sources should be used.

Accessibility
In order 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 could then use a texttospeech software or a texttoBraille hardware) Patterns are used instead of or in addition to colors for conveying information (colorblind users would then be able to distinguish the visual elements). Any figure lettering has a contrast ratio of at least 4.5:1.

ELECTRONIC SUPPLEMENTARY MATERIAL
Springer accepts electronic multimedia files (animations, movies, audio, etc.) and other supplementary files to be published online along with an article or a book chapter. This feature can add dimension to the author's article, as certain information cannot be printed or is more convenient in electronic form.

Submission
Supply all supplementary material in standard file formats. Please include in each file the following information: article title, journal name, author names; affiliation and email address of the corresponding author. To accommodate user downloads, please keep in mind that largersized files may require very long download times and that some users may experience other problems during downloading.

Audio, Video, and Animations
Resolution: 16:9 or 4:3
Maximum file size: 25 GB
Minimum video duration: 1 sec
Supported file formats: avi, wmv, mp4, mov, m2p, mp2, mpg, mpeg, flv, mxf, mts, m4v, 3gp

Text and Presentations
Submit your material in PDF format; .doc or .ppt files are not suitable for longterm viability. A collection of figures may also be combined in a PDF file.

Spreadsheets
Spreadsheets should be converted to PDF if no interaction with the data is intended. If the readers should be encouraged to make their own calculations, spreadsheets should be submitted as .xls files (MS Excel).

Specialized Formats
Specialized format such as .pdb (chemical), .wrl (VRML), .nb (Mathematica notebook), and .tex can also be supplied.

Collecting Multiple Files
It is possible to collect multiple files in a .zip or .gz file.

Numbering
If supplying any supplementary material, the text must make specific mention of the material as a citation, similar to that of figures and tables. Refer to the supplementary files as “Online Resource”, e.g., "... as shown in the animation (Online Resource 3)", “... additional data are given in Online Resource 4”. Name the files consecutively, e.g. “ESM_3.mpg”, “ESM_4.pdf”.

Captions
For each supplementary material, please supply a concise caption describing the content of the file.

Processing of supplementary files
Electronic supplementary material will be published as received from the author without any conversion, editing, or reformatting.

Accessibility
In order to give people of all abilities and disabilities access to the content of your supplementary files, please make sure that the manuscript contains a descriptive caption for each supplementary material. Video files do not contain anything that flashes more than three times per second (so that users prone to seizures caused by such effects are not put at risk).

SCIENTIFIC STYLE
Genus and species names should be in italics.

ETHICAL RESPONSIBILITIES OF AUTHORS
This journal is committed to upholding the integrity of the scientific record. As a member of the Committee on Publication Ethics (COPE) the journal will follow the COPE guidelines on how to deal with potential acts of misconduct. Authors should refrain from misrepresenting research results which could damage the trust in the journal, the professionalism of scientific authorship, and ultimately the entire scientific endeavour. Maintaining integrity of the research and its presentation can be achieved by following the rules of good scientific practice, which include: The manuscript has not

been submitted to more than one journal for simultaneous consideration. The manuscript has not been published previously (partly or in full), unless the new work concerns an expansion of previous work (please provide transparency on the reuse of material to avoid the hint of textrecycling ("selfplagiarism")). A single study is not split up into several parts to increase the quantity of submissions and submitted to various journals or to one journal over time (e.g. "salamipublishing"). No data have been fabricated or manipulated (including images) to support your conclusions. No data, text, or theories by others are presented as if they were the author's own ("plagiarism"). Proper acknowledgements to other works must be given (this includes material that is closely copied (near verbatim), summarized and/or paraphrased), quotation marks are used for verbatim copying of material, and permissions are secured for material that is copyrighted. Important note: the journal may use software to screen for plagiarism. Consent to submit has been received explicitly from all coauthors, as well as from the responsible authorities tacitly or explicitly at the institute/organization where the work has been carried out, before the work is submitted. Authors whose names appear on the submission have contributed sufficiently to the scientific work and therefore share collective responsibility and accountability for the results. In addition: Changes of authorship or in the order of authors are not accepted after acceptance of a manuscript. Requesting to add or delete authors at revision stage, proof stage, or after publication is a serious matter and may be considered when justifiably warranted. Justification for changes in authorship must be compelling and may be considered only after receipt of written approval from all authors and a convincing, detailed explanation about the role/deletion of the new/deleted author. In case of changes at revision stage, a letter must accompany the revised manuscript. In case of changes after acceptance or publication, the request and documentation must be sent via the Publisher to the EditorinChief. In all cases, further documentation may be required to support your request. The decision on accepting the change rests with the EditorinChief of the journal and may be turned down. Therefore authors are strongly advised to ensure the correct author group, corresponding author, and order of authors at submission. Upon request authors should be prepared to send relevant documentation or data in order to verify the validity of the results. This could be in the form of raw data, samples, records, etc. If there is a suspicion of misconduct, the journal will carry out an investigation following the COPE guidelines. If, after investigation, the allegation seems to raise valid concerns, the accused author will be contacted and given an opportunity to address the issue. If misconduct has been established beyond reasonable doubt, this may result in the EditorinChief's implementation of the following measures, including, but not limited to:
If the article is still under consideration, it may be rejected and returned to the author.
If the article has already been published online, depending on the nature and severity of the infraction, either an erratum will be placed with the article or in severe cases complete retraction of the article will occur. The reason must be given in the published erratum or retraction note. The author's institution may be informed.

COMPLIANCE WITH ETHICAL STANDARDS

To ensure objectivity and transparency in research and to ensure that accepted principles of ethical and professional conduct have been followed, authors should include information regarding sources of funding, potential conflicts of interest (financial or nonfinancial), informed consent if the research involved human participants, and a statement on welfare of animals if the research involved animals. Authors should include the following statements (if applicable) in a separate section entitled

“Compliance with Ethical Standards” on the title page when submitting a paper:
Disclosure of potential conflicts of interest
Research involving Human Participants and/or Animals
Informed consent
Please note that standards could vary slightly per journal dependent on their peer review policies (i.e. double blind peer review) as well as per journal subject discipline. Before submitting your article check the Instructions for Authors carefully. The corresponding author should be prepared to collect documentation of compliance with ethical standards and send if requested during peer review or after publication. The Editors reserve the right to reject manuscripts that do not comply with the abovementioned guidelines. The author will be held responsible for false statements or failure to fulfill the abovementioned guidelines.

DISCLOSURE OF POTENTIAL CONFLICTS OF INTEREST

Authors must disclose all relationships or interests that could have direct or potential influence or impart bias on the work. Although an author may not feel there is any conflict, disclosure of relationships and interests provides a more complete and transparent process, leading to an accurate and objective assessment of the work. Awareness of a real or perceived conflicts of interest is a perspective to which the readers are entitled. This is not meant to imply that a financial relationship with an organization that sponsored the research or compensation received for consultancy work is inappropriate. Examples of potential conflicts of interests that are directly or indirectly related to the research may include but are not limited to the following:
Research grants from funding agencies (please give the research funder and the grant number)
Honoraria for speaking at symposia
Financial support for attending symposia
Financial support for educational programs
Employment or consultation
Support from a project sponsor
Position on advisory board or board of directors or other type of management relationships
Multiple affiliations
Financial relationships, for example equity ownership or investment interest
Intellectual property rights (e.g. patents, copyrights and royalties from such rights)
Holdings of spouse and/or children that may have financial interest in the work
In addition, interests that go beyond financial interests and compensation (nonfinancial interests) that may be important to readers should be disclosed. These may include but are not limited to personal relationships or competing interests directly or indirectly tied to this research, or professional interests or personal beliefs that may influence your research. The corresponding author collects the conflict of interest disclosure forms from all authors. In author collaborations where formal agreements for representation allow it, it is sufficient for the corresponding author to sign the disclosure form on behalf of all authors. Examples of forms can be found here:
The corresponding author will include a summary statement in the text of the manuscript in a separate section before the reference list, that reflects what is recorded in the potential conflict of interest disclosure form(s). See below examples of disclosures:
Funding: This study was funded by X (grant number X).

Conflict of Interest: Author A has received research grants from Company A. Author B has received a speaker honorarium from Company X and owns stock in Company Y. Author C is a member of committee Z.
If no conflict exists, the authors should state:
Conflict of Interest: The authors declare that they have no conflict of interest.

RESEARCH INVOLVING HUMAN PARTICIPANTS AND/OR ANIMALS

1) Statement of human rights
When reporting studies that involve human participants, authors should include a statement that the studies have been approved by the appropriate institutional and/or national research ethics committee and have been performed in accordance with the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. If doubt exists whether the research was conducted in accordance with the 1964 Helsinki.
Declaration or comparable standards, the authors must explain the reasons for their approach, and demonstrate that the independent ethics committee or institutional review board explicitly approved the doubtful aspects of the study. The following statements should be included in the text before the References section:
Ethical approval: "All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards."
For retrospective studies, please add the following sentence: "For this type of study formal consent is not required."

2) Statement on the welfare of animals
The welfare of animals used for research must be respected. When reporting experiments on animals, authors should indicate whether the international, national, and/or institutional guidelines for the care and use of animals have been followed, and that the studies have been approved by a research ethics committee at the institution or practice at which the studies were conducted (where such a committee exists). For studies with animals, the following statement should be included in the text before the References section:
Ethical approval: "All applicable international, national, and/or institutional guidelines for the
care and use of animals were followed."
If applicable (where such a committee exists): "All procedures performed in studies involving animals were in accordance with the ethical standards of the institution or practice at which the studies were conducted." If articles do not contain studies with human participants or animals by any of the authors, please select one of the following statements:
"This article does not contain any studies with human participants performed by any of the authors." "This article does not contain any studies with animals performed by any of the authors." "This article does not contain any studies with human participants or animals performed by any of the authors."

INFORMED CONSENT

All individuals have individual rights that are not to be infringed. Individual participants in studies have, for example, the right to decide what happens to the (identifiable) personal data gathered, to what they have said during a study or an interview, as well as to any photograph that was taken. Hence it is important that all participants gave their informed consent in writing prior to inclusion in the study. Identifying details (names, dates of birth, identity numbers and other information) of the participants that were studied should not be published in written descriptions, photographs, and genetic profiles unless the information is essential for scientific purposes and the participant (or parent or guardian if the participant is incapable) gave written informed consent for publication. Complete anonymity is difficult to achieve in some cases, and informed consent should be obtained if there is any doubt. For example, masking the eye region in photographs of participants is inadequate protection of anonymity. If identifying characteristics are altered to protect anonymity, such as in genetic profiles, authors should provide assurance that alterations do not distort scientific meaning. The following statement should be included:
Informed consent: "Informed consent was obtained from all individual participants included in the study." If identifying information about participants is available in the article, the following statement should be included: "Additional informed consent was obtained from all individual participants for whom identifying information is included in this article."

DOES SPRINGER PROVIDE ENGLISH LANGUAGE SUPPORT?
Manuscripts that are accepted for publication will be checked by our copyeditors for spelling and formal style. This may not be sufficient if English is not your native language and substantial editing would be required. In that case, you may want to have your manuscript edited by a native speaker prior to submission. A clear and concise language will help editors and reviewers concentrate on the scientific content of your paper and thus smooth the peer review process. The following editing service provides language editing for scientific articles in all areas Springer publishes in:
Edanz English editing for scientists
Use of an editing service is neither a requirement nor a guarantee of acceptance for publication. Please contact the editing service directly to make arrangements for editing and payment. Edanz English editing for scientists

ANEXO III. NORMAS PARA SUBMISSÃO NA REVISTA *AMERICAN JOURNAL OF PRIMATOLOGY*

Manuscripts must be submitted in English (American style), and must be double-spaced with no less than 12 cpi font and 3-cm margins throughout. Lines should be numbered consecutively from the title through the references. Number all pages in sequence beginning with the title page, placing the first author's surname and the page number in the upper right hand corner of each page. **A Research Article should not exceed 35 pages total, and a Review Article should not exceed 45 pages in total. Page limits for Commentaries and New Approaches are flexible, but they should fall in the range of 10-15 pages. Page limits include the title page, abstract, text, acknowledgements, references, tables, figure legends, and figures.**

Cover Letter. All manuscripts must be accompanied by a formal statement that explicitly confirms the following:

- Acceptance of the provisos in the next paragraph of these Instructions (see "Provisos" below).
- The Methods section must also include a statement that:
  - the research complied with protocols approved by the appropriate Institutional Animal Care Committee (provide the name of the committee; see iacuc.org);
  - the research adhered to the legal requirements of the country in which the research was conducted; and
  - the research adhered to the American Society of Primatologists (ASP) Principles for the Ethical Treatment of Non Human Primates (seehttps://www.asp.org/society/resolutions/EthicalTreatmentOfNonHumanPrimates.cfm.
- All research protocols reported in this manuscript were reviewed and approved by an appropriate institution and/or governmental agency that regulates research with animals.
- All research reported. in this manuscript complied with the protocols approved by the appropriate institutional Animal Care and Use Committee (see www.iacuc.org). Researchers outside the U.S. must confirm that their research receieved clearance from, and complied with, the protocols approved by the equivalent institutional animal care committees of their country.
- All research reported in this manuscript adhered to the legal requirements of the country in which the work took place.

Provisos. All manuscripts submitted to the ***American Journal of Primatology*** (AJP) must be submitted solely to this journal, and may not have been published in any substantial form in any other publication, professional or lay. Submission is taken to mean that each of the co-authors acknowledge their participation in conducting the research leading to this manuscript and that all agree to its submission to be considered for publication by AJP. The Editorial Office cannot be responsible for returning any materials submitted for review. The publisher reserves copyright, and no published material may be reproduced or published elsewhere without the written permission of the publisher and the author. The journal will not be responsible for the loss of manuscripts at any time. All statements in, or omissions from, published manuscripts are the responsibility of the authors who will assist the editors by reviewing proofs

before publication. Reprints may be ordered from https://caesar.sheridan.com/reprints/redir.php?pub=10089&acro=AJP No page charges will be levied against authors or their institutions for publication in the journal.

Conflict of Interest. AJP requires that all authors disclose any potential sources of conflict of interest. Any interest or relationship, financial or otherwise, that might be perceived as influencing an author's objectivity is considered a potential source of conflict of interest. These must be disclosed when directly relevant or indirectly related to the work that the authors describe in their manuscript. Potential sources of conflict of interest include but are not limited to patent or stock ownership, membership of a company board of directors, membership of an advisory board or committee for a company, and consultancy for or receipt of speaker's fees from a company. The existence of a conflict of interest does not preclude publication in this journal.

If the authors have no conflict of interest to declare, they must also state this at submission. It is the responsibility of the corresponding author to review this policy with all authors and to collectively list in the cover letter (if applicable) to the Editor-in-Chief, in the manuscript (in the footnotes, Conflict of Interest or Acknowledgments section), and in the online submission system ALL pertinent commercial and other relationships.

Manuscript Preparation. Manuscripts should be divided into the major divisions given below in the order indicated. (Review Articles, New Approaches, and Commentaries may deviate from this style of organization, but must include an Abstract, Introduction, Discussion, and Acknowledgments.) Please see below for additional guidelines regarding New Approaches.

Title page. The first page of the manuscript should include the complete title of the paper; the names of authors and their affiliations; a short title (not more than 40 characters including spaces); and name, postal address, E-mail address, and phone number of person to whom editorial correspondence, page proofs, and reprint requests should be sent.

Abstract. The abstract must be a factual condensation of the entire work, including a statement of its purpose, a succinct statement of research design, a clear description of the most important results, and a concise presentation of the conclusions. Abstracts should not exceed 300 words. Three to six key words for use in indexing should be listed immediately below the abstract.

Text. The body of Research Articles must be organized into the following sections: Abstract, Introduction, Methods, Results, Discussion and Acknowledgments. The Methods section must include the dates and location of the study. The Methods section must also include a statement that the research complied with protocols approved by the appropriate institutional animal care committee (provide the name of the committee) and adhered to the legal requirements of the country in which the research was conducted. The Results section must include the essential values from all statistical tests cited to support statements regarding findings, in addition to summarizing key data using tables and figures where possible. Acknowledgments should include: funding sources; names of those who contributed but are not authors, further statements of recognition appropriate to the study; and brief confirmation of compliance with animal care regulations and applicable national laws. If photos or identifiable data on human subjects are in any manuscript, they must be accompanied by a notarized copy of the consent form. Footnotes are not to be used except for tables and figures. Nonstandard abbreviations should be kept to a minimum and defined in the text. Measurements should be given in metric units and abbreviated according to the American Institute for

Biological Sciences' Style Manual for Biological Journals. Review Articles and Commentaries may deviate from this style of organization, but must include an Abstract, Introduction, Discussion, and Acknowledgements.

References. In the text, references should be cited chronologically by publication date, then alphabetically by author, with the author's surname and year of publication in square brackets. The reference list should be arranged alphabetically by first author's surname. List all authors if there are five or fewer; when there are six or more authors, list the first three followed by et al. Journal titles should NOT be abbreviated. Examples follow.

Journal Articles:

King VM, Armstrong DM, Apps R, Trott JR. 1998. Numerical aspects of pontine, lateral reticular, and inferior olivary projections to two paravermal cortical zones of the cat cerebellum. Journal of Comparative Neurology 390:537-551.

Boubli JP, de Lima MG. 2009. Modeling the geographical distribution and fundamental niches of*Cacajao* spp. and *Chiropotes israelita* in Northwestern Amazonia via a maximum entropy algorithm. International Journal of Primatology 30:217–228.

Chapman CA, Chapman LJ, Naughton-Treves L, Lawes MJ, McDowell LR. 2004. Predicting folivorous primate abundance: validation of a nutritional model. American Journal of Primatology 62:55–69.

Books and Monographs:

Voet D, Voet JG. 1990. Biochemistry. New York: John Wiley & Sons. 1223 p.

Dissertations:

Lastname FN. Year. Title of dissertation (Doctoral dissertation). Retrieved from Name of database. (Accession or Order Number).

Ritzmann RE. 1974. The snapping mechanism of Alpheid shrimp [dissertation]. Charlottesville (VA): University of Virginia. 59 p. Available from: University Microfilms, Ann Arbor, MI; AAD74–23.

Book Chapters:

Gilmor ML, Rouse ST, Heilman CJ, Nash NR, Levey AI. 1998. Receptor fusion proteins and analysis. In: Ariano MA, editor. Receptor localization. New York: Wiley-Liss. p 75-90.

Conklin-Brittain NL, Knott CD, Wrangham RW. 2006. Energy intake by wild chimpanzees and orang-utans: methodological considerations and a preliminary comparison. In: Hohmann G, Robbins MM, Boesch C, editors. Feeding ecology in apes and other primates: Ecological, physical and behavioral aspects. Cambridge: Cambridge University Press. p 445–471.

Format for Presenting Statistical Information. Overall is it recommended that authors provide the details of their statistical analyses in the Methods, Tables, and Figures as appropriate. Linear statistics: means and standard deviation/standard errors should be written 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). Circular statistics: mean and angular dispersion should be written in the format X± AD unit (i.e., phase relationship between head linear and angular displacement=104 ± AD 14 deg). Ranges should be written as range: 15-29; sample sizes should be written as N=731; numbers less than 1 should be written as 0.54 not as .54. P values that are deemed significant can be presented as less than a threshold value (i.e., $P < 0.05$, $P < 0.01$, $P < 0.001$). Nonsignificant test outcomes should be reported using an exact probability value whenever possible. The P value (P) and sample size (N) should be capitalized, and degrees of freedom, if required, should be written in lower case (e.g. df=4). For example: $X2 = 1.84$, df=8, $P = 0.91$ Unless a test statistic unambiguously refers to a particular statistical test (i.e., X2 is understood to refer to a Chi-squared test), results should include the name of the statistical test which should be 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 that issue has been addressed for the manuscript as a whole before any statistical results are given). These entries should be separated by commas. Wilcoxon signed-ranks test: $Z=3.82$, $P<0.001$, N=20 ANOVA: $F=2.26$, df=1, $P=0.17$

Tables. Tables should be titled and numbered in accordance with the order of their appearance; each table should be placed on a separate page. All tables must be cited in the text with approximate placement clearly defined. Table titles should be concise descriptions of the data in the table. Table footnotes should provide more detail relating to the interpretation of data presented in the table (i.e., notes on sample sizes, tests performed, etc.). Samples are shown below:

Table title: Leadership of Group Movements by Males and Females within Each Group
Table footnote: Chi-square results for adult female- versus adult male-led group progressions overall (A), when feeding occurred within 5 min of group movement (B), and when feeding did not occur within 5 min of group movement (C). N refers to the number of progressions led by each sex. Females in each group, except C3, led group movements significantly more than males overall and in all contexts.

Table title: Food Species and Plant Parts in the Diet of *Rhinopithecus brelichi* at Yangaoping, Guizhou During the Study Period Table footnote: Season: Sp, spring (February, March, April); Su, summer (May, June, July); A, autumn (August, September, October); W, winter (November, December, January); Y, four seasons. E, evergreen; D, deciduous

Figure Legends. A descriptive legend must be provided for each figure and must define all abbreviations used therein.

Figures/Illustrations. Figures must be submitted in TIFF or EPS format. Do not embed figures in your text document. To ensure the highest reproduction quality, figures should be submitted according to the following minimum resolutions:

- 1200 dpi (dots per inch) for black and white line art (simple bargraphs, charts, etc.)
- 300 dpi for halftones (black and white photographs)
- 600 dpi for combination halftones (photographs that also contain line art such as labeling or thin lines)

This specification means that a figure which you wish to be printed at a size, for example, of 2 x 2 inches will be 2,400 dots wide (black and white line art), or 600 dots wide (halftone). Vector-based figures (e.g., figures created in Adobe Illustrator) should be submitted in EPS format. Figure sizes should be no more than 5 inches in width and

6 inches in height. Please contact AJP Production at ajpprod@wiley.com for further information.
In addition to the above guidelines, color figures must be submitted in the RGB colorspace. All color figures will be reproduced at no charge.

Journal Cover Artwork. Along with their manuscript, authors are welcome to submit an original photograph or other artwork that illustrates their research for possible use on the cover of the issue in which the article appears. This artwork is submitted with the understanding that it has not been published elsewhere, that the author has copyright, and that the author grants Wiley permission to publish the photo as a cover image, should it be chosen. Candidate images for journal covers may be submitted electronically as TIF files.
AJP is pleased to announce the introduction of a new category for publication: "**New Approaches**". This category provides the opportunity for researchers to share new methods, techniques, and protocols in order to facilitate more rapid scientific advances in the field of Primatology. The emphasis is on approaches that are either newly developed or modifications and improvements of established approaches in Primatology and other scientific fields. Manuscripts in this category should be organized around the following four sections: (1)**Introduction:** set the stage for justifying why a new approach is required; (2) **Description:**describe the new approach; (3) **Example:** apply the new approach to a particular experiment or problem; and (4) **Comparison and Critique:** discuss the advantages and disadvantages of the new approach when compared to other available approaches. These sections should be followed by **Acknowledgments** and **References**, the final sections used in other categories of AJP manuscripts.
Copyright/Licensing Agreements. If your paper is accepted, the author identified as the formal corresponding author for the paper will receive an email prompting them to login into Author Services; where via the Wiley Author Licensing Service (WALS) they will be able to complete the license agreement on behalf of all authors on the paper.
For authors signing the copyright transfer agreement:
If the OnlineOpen option is not selected the corresponding author will be presented with the copyright transfer agreement (CTA) to sign. The terms and conditions of the CTA can be previewed in the samples associated with the Copyright FAQs below:
CTA Terms and Conditions http://authorservices.wiley.com/bauthor/faqs_copyright.asp

For authors choosing OnlineOpen:
If the OnlineOpen option is selected the corresponding author will have a choice of the following Creative Commons License Open Access Agreements (OAA):
Creative Commons Attribution License OAA
Creative Commons Attribution Non-Commercial License OAA
Creative Commons Attribution Non-Commercial -NoDerivs License OAA
To preview the terms and conditions of these open access agreements please visit the Copyright FAQs hosted on Wiley Author Services http://authorservices.wiley.com/bauthor/faqs_copyright.aspand visit http://www.wileyopenaccess.com/details/content/12f25db4c87/Copyright--License.html
If you select the OnlineOpen option and your research is funded by The Wellcome Trust and members of the Research Councils UK (RCUK) you will be given the opportunity to publish your article under a CC-BY license supporting you in complying with

Wellcome Trust and Research Councils UK requirements. For more information on this policy and the Journal's compliant self-archiving policy please visit: http://www.wiley.com/go/funderstatement.