

**FILIPA ALEXANDRA DE ABREU PAULOS**

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

RECIFE, 2015

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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.

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(Universidade Federal de Pernambuco)

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Dissertação apresentada e \_\_\_\_\_ em \_\_\_\_/\_\_\_\_/\_\_\_\_

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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**

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## SUMÁRIO

RESUMO .....	xi
ABSTRACT .....	xiii
1. INTRODUÇÃO GERAL.....	14
2. FUNDAMENTAÇÃO TEÓRICA .....	16
2.1 Caatinga .....	16
2.1.1 Fauna.....	16
2.2 Visão em primatas.....	17
2.3 Espécie em estudo: <i>Callithrix jacchus</i> .....	20
REFERÊNCIAS BIBLIOGRÁFICAS .....	22
Artigo 1.....	32
Feeding ecology and behavioral adjustments: flexibility of a small neotropical primate ( <i>Callithrix jacchus</i> ) to survive in a semiarid environment.....	32
Abstract.....	33
Introduction.....	34
Materials and Methods.....	35
<i>Study area</i> .....	35
<i>Data collection</i> .....	36
<i>Statistical analysis</i> .....	37
Results .....	37
<i>Behavioral time budget</i> .....	37
<i>Consumed food items</i> .....	38
<i>Description of the consume of plant items</i> .....	39
Discussion.....	41
References .....	43
Artigo 2.....	47
Comportamento de forrageio por insetos por <i>Callithrix jacchus</i> (PRIMATES, CALLITRICHIDAE) de vida livre: uma abordagem o polimorfismo visual.....	47
Resumo.....	49
Introdução.....	50
Métodos .....	52
<i>Coleta de dados comportamentais</i> .....	53
<i>Coleta de insetos</i> .....	55
<i>Análise estatística</i> .....	55

<b>Resultados</b> .....	56
<b>Discussão</b> .....	59
<b>Agradecimentos</b> .....	62
<b>Referências Bibliográficas</b> .....	62
<b>ANEXO III. NORMAS PARA SUBMISSÃO NA REVISTA <i>MAMMAL RESEARCH</i></b> .....	71
<b>ANEXO III. NORMAS PARA SUBMISSÃO NA REVISTA <i>AMERICAN JOURNAL OF PRIMATOLOGY</i></b> .....	81

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## RESUMO

*Callithrix 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 onívora 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 município 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, nomeadamente 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 Perambuco. 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, occurring 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 common 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 conducted in the Fazenda Marimbondo, located near to Cabaceiras, Paraíba. During 6 months of study, we observed 19 individuals (5 groups), through the focal animal sampling method associated with *ad libitum* 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. Furthermore, 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<sup>2</sup>, 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 28° 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, Bromelaceae, Euphorbaceae (LEAL *et al.*, 2003). Entre 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, reptéis, 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 penicillata*, *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 Platyrrhini (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 mantém 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 (AURICCHIO, 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 callitrichídeos, 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. MICHELS, 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), microespectrofotométricos 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 conseqüentemente, em saguis-comuns. Assim, devido à alta facilidade com que *C. jacchus* se habitua à presença humana, à sua ampla distribuição além da sua atividade diurna, este pequeno primata neotropical foi utilizado como modelo de estudo.

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**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**

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### **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<sup>2</sup> (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)

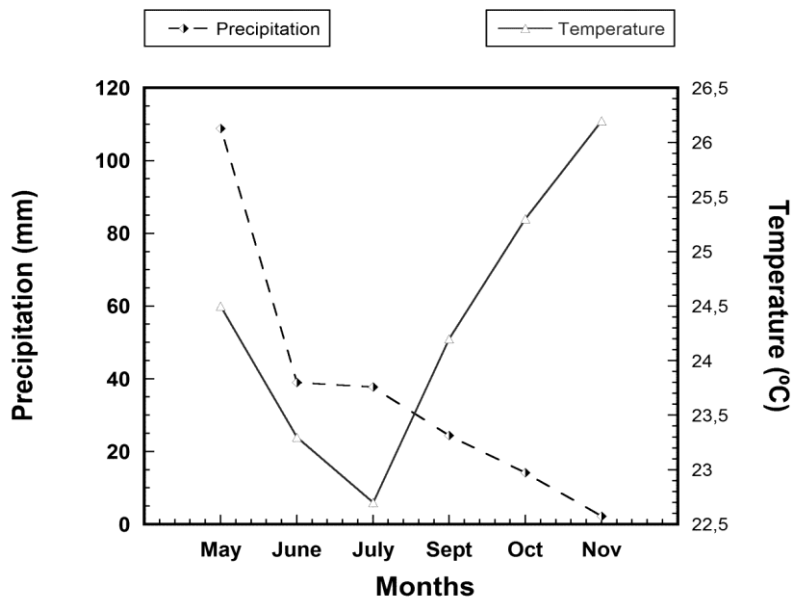
Nevertheless, despite these advantages, scarce is the information about how these small mammals cope with the difficult conditions of the Caatinga. In fact, although the only two studies on the common marmoset in a semiarid environment are certainly important, they have some limitations. The research 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 (7°31'42" S – 36°17'50" 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 <sup>a</sup>	-	-	-	-	-	2 <sup>a</sup>	-	-
Juvenile (5-10)	-	-	-	-	2	-	-	-	-	-
Adult (>11)	1	1	1	1	2	3	1	1	1 (1 <sup>a</sup> )	1

G=group; <sup>a</sup>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
Grooming	12.1 % (11.53 hr)	14.6 % (17.34 hr)	-64	0.07
Others <sup>a</sup>	12.5 % (11.91 hr)	7.3 % (8.66 hr)	100	0.002
Total in percentage (Total in hours) <sup>b</sup>	100 % (95.37 hr)	100 % (118,74 hr)	–	–

<sup>a</sup>Behaviors not included in the statistical analysis (stationary and play behavior); <sup>b</sup>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
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For what concerns plant items, six species were consumed: three belonging to the family *Cactaceae*, 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	<i>Pilosocereus pachycladus</i>	Fruit	3	3
		Cladode	16	8
	<i>Pilosocereus gounellei</i>	Fruit	7	4
		Flower	3	3
	<i>Cereus jamacaru</i>	Fruit	10	9
		Flower	2	1
Cladode		2	2	
Leguminosae/ Fabaceae	<i>Prosopis juliflora</i> <sup>a</sup>	Fruit	35	8
	<i>Tamarindus indica</i> <sup>a</sup>	Fruit	4	2
Malvaceae	<i>Herissantia tiubae</i>	Flower	8	3

<sup>a</sup>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.

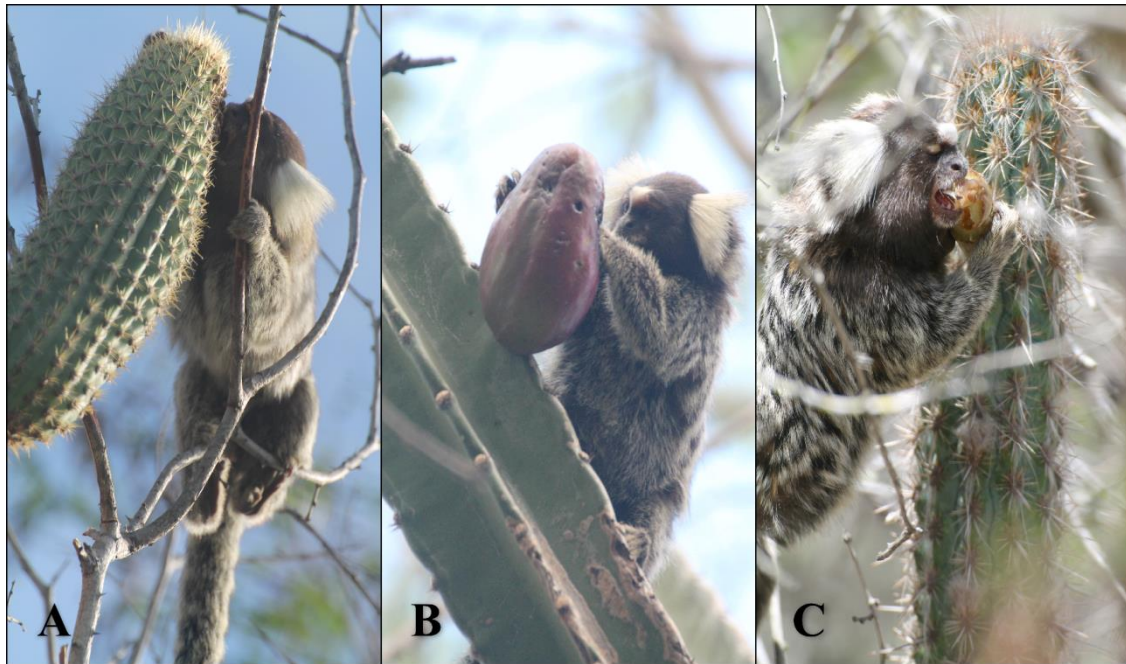
*Pilosocereus gounellei* – Plant description: Cactus up to 4 m tall. Its areoles are 1 cm apart from each other and present up to 15 cm long cylindrical and rigid spines with a central and bigger acicular spine; The plant has 17 cm long white tubular flowers, succulent, sub-globose and laterally dehiscent 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 glandular-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. jamararu* (c) Flower of *P. gounellei*

## Discussion

The main activity conducted by common marmosets (*Callithrix 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.

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**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)

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

3

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10

11 Short title: Captura de insetos por saguis comuns

12

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## 25 **Resumo**

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

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

50

## 51 **Introdução**

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

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

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

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

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

89 Estudos que visem o efeito do polimorfismo no comportamento de forrageio do  
90 gênero *Callithrix* na natureza ainda são inexistentes. Até o presente momento, pesquisas  
91 de laboratório focaram em estudos genéticos [e.g. Hunt et al., 1993; Shyue et al., 1998  
92 Surrige & Mundy, 2002], microespectrofotométricos [e.g. Kawamura et al., 2001;  
93 Tovée et al., 1992; Travis et al., 1988; Williams et al., 1992] e comportamentais [e.g.  
94 Caine & Mundy, 2000; Caine et al., 2003, 2010; Freitag & Pessoa, 2012; Moreira et al.,  
95 2015; Pessoa et al., 2005a,b]. No presente estudo, investigamos a hipótese da vantagem

96 de fêmeas de *Callithrix jacchus* na detecção de insetos na natureza. Saguis são pequenos  
97 primatas neotropicais da família Callithrichidae e, normalmente, possuem em seu grupo  
98 apenas uma fêmea reprodutora [Auricchio, 1995; Yamamoto, 1991]. Apesar da  
99 ausência de dimorfismo sexual, estudos apontam para uma maior vantagem de fêmeas  
100 no forrageio por alimento [e.g. Box et al., 1999]. A alimentação destes primatas é  
101 essencialmente composta por frutos, insetos e goma [Rylands & de Faria, 1993; Souto  
102 et al., 2007]. Entre os insetos mais consumidos encontram-se grilos, gafanhotos,  
103 cigarras, formigas e cupins [Schiel et al., 2010; Souto et al., 2007]. Estes possuem  
104 elaboradas estratégias para evitar a predação [Edmunds, 1974; Poulton, 1980]. Quando  
105 não utilizam a estratégia de se esconderem entre frestas, a maioria encontra-se de forma  
106 críptica sob o substrato, ou apresentam cores conspícuas [Edmunds, 1974; Poulton,  
107 1980].

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

114

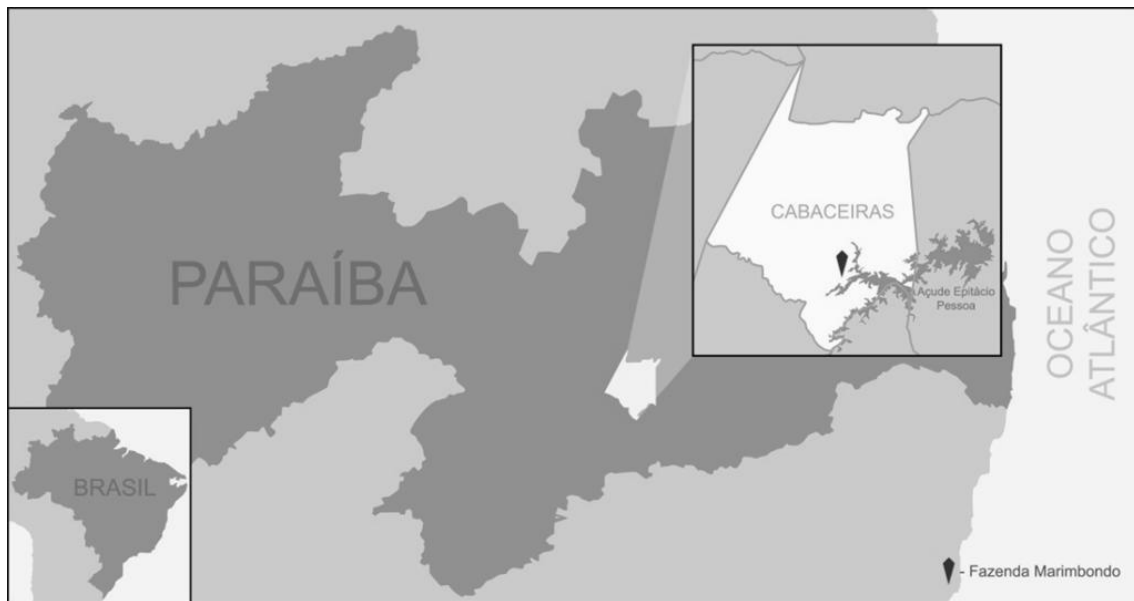
## 115 **Métodos**

### 116 *Área de estudo e composição dos grupos*

117 O estudo foi conduzido na Fazenda Marimbondo, uma área privada com cerca de  
118 400 ha (7°31'42"S – 36°17'50"W), situada próxima ao município de Cabaceiras, no  
119 estado da Paraíba, Nordeste do Brasil (Fig. 1). Esta região está inserida no Cariri

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

122 Foram observados cinco grupos (G1 – G5) da espécie *Callithrix jacchus*, em um  
 123 total de 19 indivíduos (Tabela I). Os indivíduos foram identificados de acordo com  
 124 marcas naturais ou cicatrizes, sexo e idade [De La Fuente et al., 2014; Schiel et al.,  
 125 2008; Schiel et al., 2010].



126 Fig. 1. Área de estudo na fazenda Marimbondo em ambiente semiárido, Paraíba, Brasil  
 127 (Fonte: Javiera De la Fuente).  
 128

129  
 130

**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

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

132

133 *Coleta de dados comportamentais*

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

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

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

145 Cada grupo foi seguido durante o seu principal período de atividade (5:00 até  
146 17:00) [De La Fuente et al., 2014]. Ao início de cada sessão, escolhia-se ao acaso qual  
147 indivíduo seria observado. A coleta dos dados comportamentais para cada indivíduo foi  
148 igualmente distribuída ao longo do dia. Obtiveram-se, aproximadamente, 80 sessões por  
149 indivíduo, totalizando 1.581 sessões. Nas observações foram anotados: (i) eventos de  
150 predação realizados pelos saguis de acordo com o sexo; (ii) coloração e taxonomia do  
151 inseto; e (iii) substrato e cor do substrato em que o inseto foi capturado. A identificação  
152 dos insetos foi feita a nível de ordem, sendo classificados em crípticos (insetos que se  
153 encontravam camuflados em relação ao substrato no momento da captura) ou  
154 conspícuos (insetos de coloração chamativa ou visíveis sob o substrato) de acordo com  
155 Melin et al., [2007]. Além da coloração, dividimos os insetos em categorias de acordo  
156 com o seu tamanho: insetos crípticos pequenos (insetos  $\leq 2$  cm); insetos crípticos  
157 grandes (insetos  $> 2$  cm); insetos conspícuos pequenos (insetos  $\leq 2$  cm); insetos  
158 conspícuos grandes (insetos  $> 2$  cm) [modificado de Schiel et al. (2010)]. O estudo foi  
159 não invasivo e está de acordo com as leis brasileiras, tendo sido aprovado pelo Comitê

160 de Ética para Uso de Animais da Universidade Federal Rural de Pernambuco (CEUA nº  
161 135/2014).

162

### 163 *Coleta de insetos*

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

170

### 171 *Análise estatística*

172 Para a análise estatística foram utilizados 15 indivíduos. Retiramos das análises  
173 todos os animais que desapareceram durante o período de observações ( $N = 1$ ) e aqueles  
174 com idade inferior a 5 meses ( $N = 3$ ). A exclusão dos indivíduos mais jovens visou  
175 evitar um efeito da inexperiência dos mesmos na captura de insetos [De La Fuente et al.,  
176 2014; Schiel et al., 2010]. Para verificarmos se a lactação tem algum efeito na eficiência  
177 de captura, foram realizadas análises (i) com as fêmeas lactantes ( $N = 8$ ) e (ii) sem as  
178 fêmeas lactantes ( $N = 6$ ). Verificou-se também se haveria algum efeito retirando outras  
179 duas fêmeas não lactantes das análises estatísticas.

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

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

187 Para todas as análises considerou-se  $P \leq 0.05$  como significativo. Todos os dados  
188 foram analisados com o GraphPad InStat3 (GraphPad Software, Inc.) e Excel (Microsoft  
189 Corporation).

190

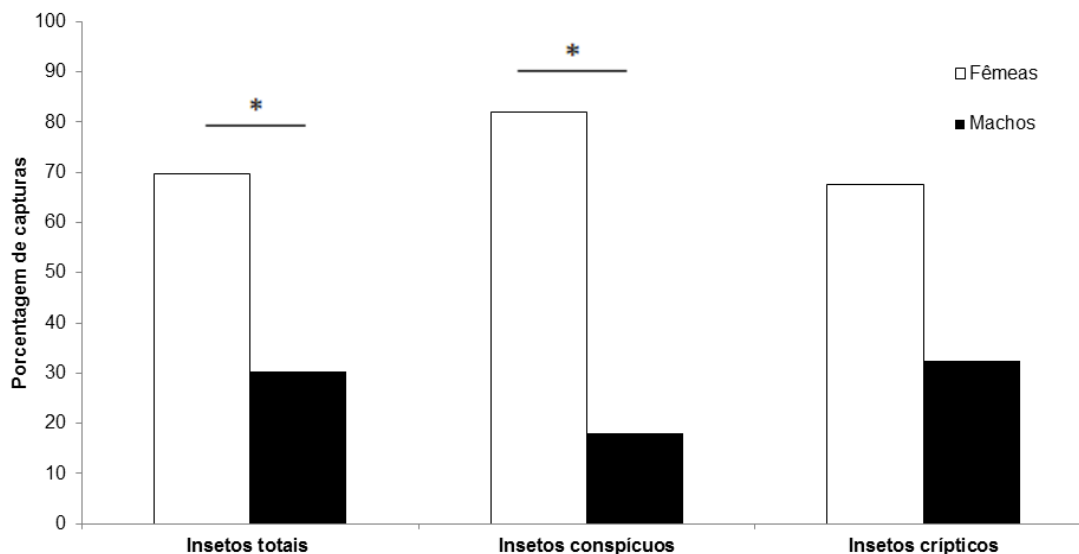
## 191 **Resultados**

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

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

200

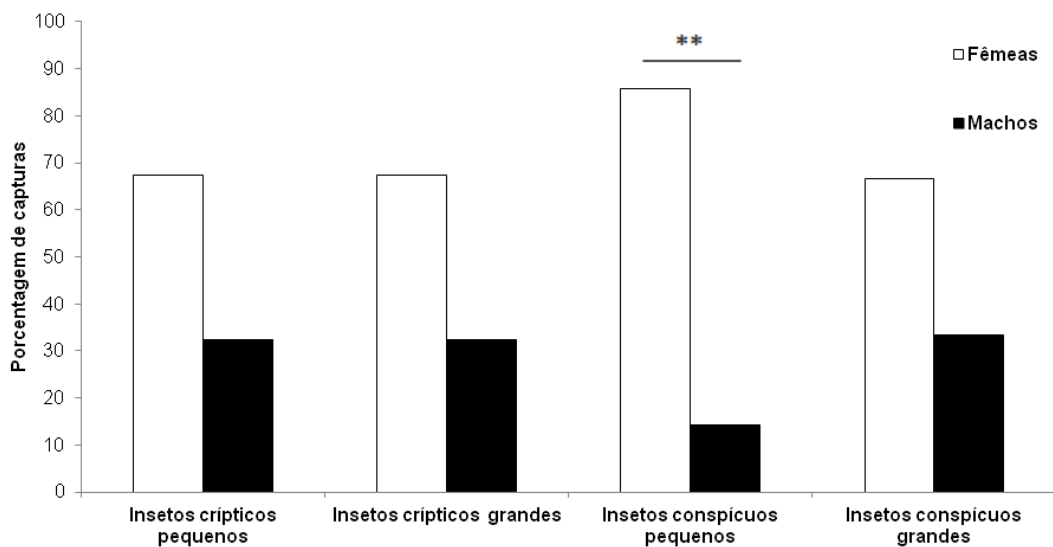




201 Fig. 2. Comparação da porcentagem de insetos capturados entre fêmeas ( $N = 8$ ) e  
 202 machos ( $N = 7$ ) de *Callithrix jacchus*.  $*P \leq 0.05$ .  
 203

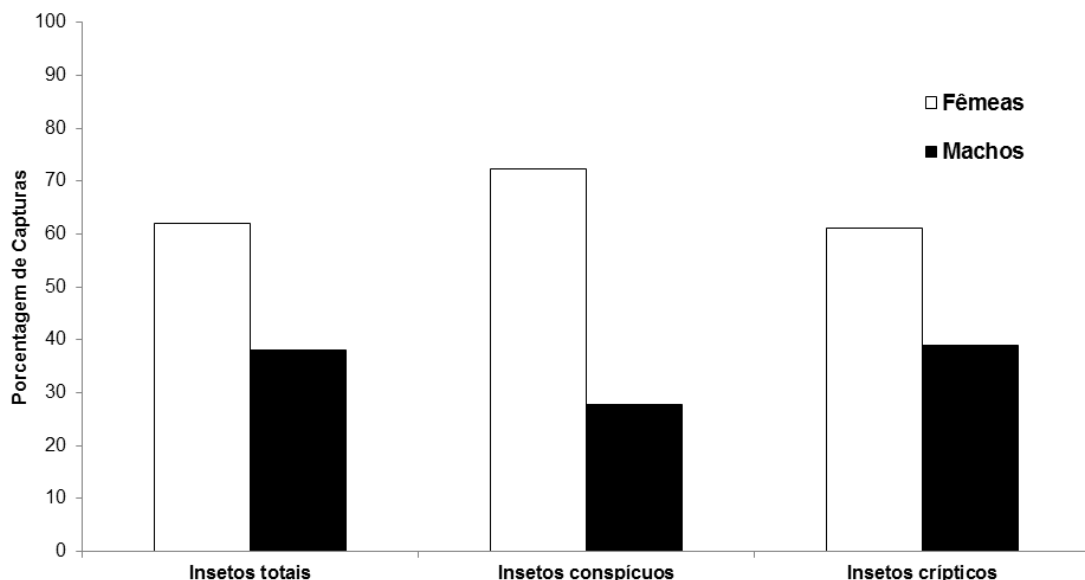
204 Em relação às análises de categorias de insetos, apenas observamos diferenças  
 205 significativas na captura de insetos conspícuos pequenos ( $U = 49$ ,  $P \leq 0.01$ ), com uma  
 206 maior captura destes insetos por parte de fêmeas. Nas capturas de insetos crípticos  
 207 pequenos ( $U = 41$ ,  $P = 0.15$ ), insetos crípticos grandes ( $U = 41$ ,  $P = 0.15$ ) e insetos  
 208 conspícuos grandes ( $U = 30$ ,  $P = 0.81$ ) não foram observadas diferenças significativas  
 209 entre sexos (Fig. 3).  
 210

211



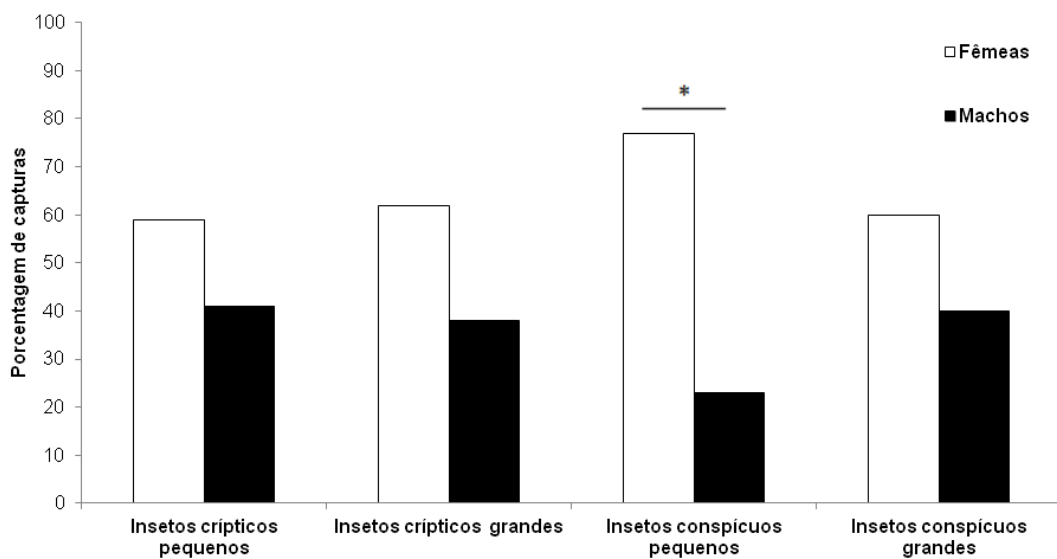
212  
 213 Fig. 3. Comparação da porcentagem de capturas nas diferentes categorias de tamanho e  
 214 coloração de insetos entre fêmeas ( $N = 8$ ) e machos ( $N = 7$ ) de *Callithrix jacchus*.  $**P \leq$   
 215 0.01.

216  
 217 Com a retirada das fêmeas que estavam lactantes durante o período de estudo ( $N =$   
 218 2), nenhuma diferença significativa entre sexos foi observada nas capturas totais ( $U =$   
 219 33,  $P = 0.10$ ), capturas de insetos de coloração conspícua ( $U = 33.5$ ,  $P = 0.08$ ) e de  
 220 insetos de coloração críptica ( $U = 31$ ,  $P = 0.18$ ) (Fig. 4).



221  
 222 Fig. 4. Comparação da porcentagem de insetos capturados entre fêmeas ( $N = 6$ ) e  
 223 machos ( $N = 7$ ) de *Callithrix jacchus*, sem a presença de fêmeas lactantes.  
 224

225 Na análise por categorias de insetos (excluindo as fêmeas lactantes) apenas foi  
 226 observada diferença significativa na captura de insetos conspícuos pequenos ( $U = 33.5$ ;  
 227  $P \leq 0.05$ ), com fêmeas capturando um maior número de insetos desta categoria do que  
 228 machos. Nas demais análises não foram encontradas diferenças significativas entre  
 229 sexos (insetos crípticos pequenos:  $U = 30$ ,  $P = 0.23$ ; insetos crípticos grandes:  $U = 31$ ,  $P$   
 230  $= 0.18$ ; insetos conspícuos grandes:  $U = 23$ ,  $P = 0.83$ ) (Fig. 5).



231 Fig. 5. Comparação da porcentagem de capturas nas diferentes categorias de tamanho e  
 232 coloração de insetos entre fêmeas ( $N = 6$ ) e machos ( $N = 7$ ) de *Callithrix jacchus*, sem a  
 233 presença de fêmeas lactantes. \* $P \leq 0.05$ .  
 234  
 235

## 236 **Discussão**

237 Os resultados obtidos corroboram algumas das nossas hipóteses iniciais,  
 238 indicando que fêmeas capturam um maior número de insetos em geral, assim como  
 239 insetos de coloração conspícua. Nossos dados também revelaram que, além do efeito do  
 240 polimorfismo, parece também existir um efeito da lactação no sucesso de capturas por  
 241 parte das fêmeas. Sabendo-se que fêmeas deste gênero têm uma maior probabilidade de  
 242 possuírem o tricromatismo (66%) ao invés do dicromatismo (34%) [Rowe & Jacobs,  
 243 2004; Surridge et al., 2005], poderia se esperar uma vantagem para as fêmeas aqui

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

258 Com relação às capturas de insetos de coloração críptica não foram observadas  
259 diferenças significativas entre os dois sexos. Este resultado não era previsto, uma vez  
260 que a captura de insetos com este tipo de coloração é referida como uma das vantagens  
261 dos indivíduos com visão dicromata (principalmente os machos) [Morgan et al., 1992;  
262 Saito et al., 2005; Melin et al., 2007; Smith et al., 2012]. Porém, alguns estudos indicam  
263 que fêmeas têm prioridade no acesso ao alimento [Tardif & Richter, 1981; Lopes et al.,  
264 1997], assim como obtêm mais alimento do que os machos [e.g. Michels, 1988;  
265 Yamamoto et al., 2004], indicando que o sexo possa ter ocasionado um efeito neste  
266 resultado.

267 Relativamente aos resultados nas diferentes categorias de tamanho e coloração,  
268 observamos um possível efeito da visão na categoria de insetos conspícuos pequenos. O  
269 fato de fêmeas capturarem um maior número de insetos nesta categoria do que machos  
270 corrobora resultados de estudos anteriores, mostrando uma vez mais que fêmeas têm  
271 uma facilidade maior para capturar insetos de colorações mais chamativas [Melin et al.,  
272 2007; Smith et al., 2012] e de menor tamanho que os machos.

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

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

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

295

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301

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## **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.

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Use the automatic page numbering function to number the pages.

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Use the equation editor or MathType for equations.

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LaTeX macro package (zip, 182 kB).

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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.

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### **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).

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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* 341:325–329

#### 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  
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**Journal**

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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.

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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

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