MARÍA FERNADA DE LA FUENTE CASTELLÓN

PADRÕES COMPORTAMENTAIS DO SAGUI COMUM (*CALLITHRIX JACCHUS*) EM AMBIENTE DE CAATINGA

RECIFE, 2014

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Dissertação apresentada ao Programa de Pós-Graduação em Ecologia (PPGE) da Universidade Federal Rural de Pernambuco (UFRPE), como exigência para obtenção do titulo de mestre em Ecologia.

Orientadora: Profa. Dra. Nicola Schiel

Co-orientador: Prof. Dr. Antônio da Silva Souto

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Defesa em 20 de fevereiro de 2014

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RECIFE, 2014

DEDICATÓRIA

Dedico esta dissertação à Loli

e a minha família.

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RESUMO

O *Callithrix jacchus* apresenta características morfológicas e comportamentais que permitem que seja uma das espécies mais adaptáveis dentro do seu gênero. Habita diferentes ambientes no Brasil, podendo ser encontrado na Mata Atlântica e na Caatinga. A Caatinga apresenta um clima semiárido e condições extremas que promovem um desafio para a vida no local. Pouco se sabe sobre os aspectos comportamentais e ecológicos de mamíferos que habitam neste bioma. Desta forma, o presente trabalho tem como objetivo caracterizar os padrões comportamentais do *Callithrix jacchus* em ambiente de Caatinga, a fim de entender o sucesso ecológico da espécie. Esperamos que no semiárido, (i) o consumo de exsudato ocorra frequentemente durante as primeiras horas do dia como resposta à escassez de recursos alimentares; (ii) devido às altas temperaturas, o descanso comece mais cedo e dure por mais tempo do que na Mata Atlântica; (iii) a pressão da escassez de recursos leve aos animais a utilizar uma grande área de vida, o que também resultará no aumento da frequência de deslocamento; (iv) juvenis dediquem mais tempo ao forrageio e gomivoria devido a pouca eficiência na captura de presas, e consequentemente dediquem menos tempo ao descanso. O estudo foi realizado na Fazenda Marimbondo, situada na região do Cariri Paraibano. Grupos de sagui comum (2) foram acompanhados durante seis meses a fim de se obter informações acerca de seu tamanho e composição social, área de uso, dieta e padrões comportamentais. A coleta sistemática dos dados comportamentais se realizou através do método animal focal, com sessões de dez minutos contínuos, duas a quatro vezes ao dia para cada indivíduo. O padrão de comportamento geral mostra que os comportamentos mais frequentemente observados foram forrageio e deslocamento. Além disso, o comportamento de gomivoria foi observado durante intervalos maiores, tanto em adultos como em jovens, que aqueles descritos para ambiente de Mata Atlântica. Os animais descansaram por um longo período, durante as horas mais quentes do dia. Contrario ao esperado, os grupos apresentaram áreas de uso com tamanhos dentro do intervalo de variação descrito para a espécie. O padrão comportamental aqui apresentado sugere que o sagui comum encontra-se bem adaptado ao ambiente semiárido. A alta frequência observada em comportamentos relacionados ao forrageio, assim como no comportamento de gomivoria podem estar relacionadas com a escassez de recursos no ambiente semiárido. Por outro lado, o amplo intervalo de tempo que os animais utilizaram para descansar, possivelmente é uma resposta ao estresse térmico durante as horas mais quentes na Caatinga. Estes resultados fornecem as primeiras informações sobre os padrões comportamentais de *Callithrix jacchus* de vida livre em ambiente de Caatinga e reforçam a grande capacidade da espécie de sobreviver em ambientes diferentes.

Palavras-chave: Semiárido, ajustes comportamentais**,** *Callithrix jacchus*

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ABSTRACT

The *Callithrix jacchus* presents morphological and behavioral characteristics that allow it to be one of the most adaptable species within its genus. Occurs in different environments in Brazil and can be found in the Atlantic Forest and Caatinga. The Caatinga is a semi-arid environment with extreme conditions that promote a challenging environment for animals. Little is known about the behavioral and ecological aspects of mammals that inhabit this biome. Thus, this study aims to characterize the behavioral patterns of *Callithrix jacchus* in the semi-arid Caatinga environment, in order to better understand the ecological success of the species. We expected that (i) exudate feeding will occur for an extended time during the first hour of the day in response to scarce food availability; (ii) due to high temperatures resting behavior will start earlier in the day and last longer than reported in Atlantic Forest; (iii) the pressure of food scarcity will lead to the use of a larger home range and, therefore a higher frequency on locomotion; (iv) juveniles will devote more time to foraging and gum eating, they are not as efficient as adults in prey capture, and consequently they will dedicate less time to resting. The study was conducted in the Fazenda Marimbondo, in the state of Paraíba. Groups of free-living common marmosets (2) were observed during six months in order to obtain information about the group size, social composition, home range, diet and behavioral patterns. The behavioral data was collected using the focal animal sampling method. Each session consisted of a 10 min period of continuous observation and two to four sessions were recorded per day for each individual. The overall behavioral pattern showed that the most frequent behaviors were foraging and locomotion. Also, in adults and in juveniles gummivory was observed during a larger time interval than those described for the Atlantic Forest environment. The animals rested for a long period, during the hottest hours of the day. Contrary to what was expected, the groups presented home ranges sizes within the range of variation described for the species. The behavioral patterns found in this study suggest that common marmoset is well adapted to the semi-arid environment. The high frequency observed in foraging behavior, as in gum eating can be related to the resource scarcity in the semi-arid environment. On the other hand, the large time interval that animals used to rest, might be a response to the thermal stress during the hottest hours. These results provide first information on the behavioral patterns of *Callithrix jacchus* living in the Caatinga and reinforce the great ability of the species to survive in very different environments.

Keywords: Semiarid, behavioral adjustments, *Callithrix jacchus*

SUMÁRIO

INTRODUÇÃO GERAL

Os primatas do Novo Mundo se distribuem ao longo da região neotropical, possuindo uma grande variação em suas características anatômicas, ecológicas e comportamentais (EISENBERG e REDFORD, 1999). Tal variação pode ser explicada como sendo um produto da evolução (FLEAGLE, 1999). A seleção natural favorece aqueles indivíduos que conseguem se adaptar melhor a determinado entorno e adotar estratégias de vida que maximizam sua contribuição gênica para futuras gerações (DAVIES et al. 2012).

Segundo Vermeij (1978) "Uma adaptação é uma característica adquirida evolutivamente que permite a um organismo viver e se reproduzir em um ambiente onde ele, de outra maneira não poderia viver". A temperatura ambiental pode vir a ser um fator chave na ecologia comportamental dos animais (HILL, 2006). Os mamíferos são endotérmicos, possuem a capacidade interna de regular a temperatura corporal mantendo-a sempre dentro de limites estreitos, independentemente das variações térmicas do ambiente (CUNNINGHAM e KLEIN, 2007). Assim, o organismo necessita aumentar o gasto energético para manter a temperatura corporal sem variações. O custo da termorregulação pode limitar o tamanho e exploração da área de uso, e os tempos de atividades em ambientes com temperaturas extremas (HILL, 2006). Outro fator que pode vir a ser determinante na ecologia comportamental de uma espécie é a disponibilidade de alimentos (CHAPELL, 1980). Segundo a teoria do forrageamento ótimo a aptidão de um animal depende de sua eficiência ao forragear. Isto é, o custo energético envolvido na procura, captura e manipulação do alimento não deve ser maior que os benefícios energéticos contidos nos itens alimentares (BEGON, 2006). Assim, os animais devem tomar decisões ótimas, tornando-se altamente adaptados na aquisição de recursos, apresentando uma aptidão elevada e maior sucesso na sobrevivência e reprodução (CHAVES E ALVES, 2010).

Dessa forma, adaptações anatômicas, fisiológicas, ecológicas e comportamentais possibilitam aos seres vivos a capacidade de se ajustarem e sobreviverem no habitat em que se encontram inseridos (HICKMAN et al. 2004). Por exemplo, na Caatinga, algumas espécies de anuros apresentam variação no padrão reprodutivo quando habitam diferentes altitudes (ARZABE, 1999). Espécies de lagartos que habitam dunas e áreas de restinga apresentam variações morfológicas especificas para cada habitat (FREIRE, 1996). No grupo das aves, Medeiros e Alves (2010) sugerem que machos e fêmeas de certas espécies que vivem em habitats temperados e tropicais, apresentam variação no investimento reprodutivo e cuidado parental. Em mamíferos, alguns roedores desérticos são eficientes em concentrar urina para reduzir a perda de água, especializações na morfologia e função renal evidenciam a adaptação ao ambiente árido (DIAZ e OJEDA, 1999). Por outro lado, alguns mamíferos apresentam

respostas comportamentais para sobreviver no ambiente semiárido, como por exemplo, o roedor endêmico *Trinomys yonenage* que cava buracos nas dunas para se esconder do sol nos períodos mais quentes do dia (DA ROCHA, 1995). Nos primatas do Novo Mundo, os macacos pregos (*Sapagus libidinosus)* na Caatinga, fazem uso de ferramentas e possuem uma maior flexibilidade alimentar, atribuída à limitação de recursos do semi-árido (MOURA e LEE, 2004). Modesto e Bergallo (2008) mostraram que apresentando variações no comportamento, *Callithrix jacchus* e *Callithrix penicillata* possuem capacidade de adaptação em diferentes ambientes.

Devido à grande variação nas características morfológicas, ecológicas e comportamentais, os primatas neotropicais formam um grupo muito diverso (EISENBERG e REDFORD, 1999). O sagui comum (*Callithrix jacchus)*, um pequeno primata Neotropical pertencente à família Callitrichidae, destaca-se pela grande capacidade de sobrevivência à diferentes tipos de ambientes (MODESTO e BERGALLO, 2008). Dessa forma, habita tanto a Mata Atlântica como a Caatinga (RYLANDS e FARIA, 1993), também são encontrados em áreas distantes de sua distribuição original, devido a introduções causadas pelo homem (AFFONSO et al. 2004).

Acredita-se que o sucesso ecológico da distribuição geográfica e adaptação a estes diversos tipos de ambientes do *Callithrix jacchus* se deve à suas características morfofisiológicas e estratégias comportamentais (FERRARI, 1993). Dessa forma, são animais de dieta generalista e oportunista, seus dentes são anatomicamente adaptados para a gomivoria lhes viabilizando o exsudato como um recurso alimentar e possuem uma alta taxa de reprodução e cuidado aloparental (STEVENSON e RYLANDS, 1988; RYLANDS e FARIA, 1993).

Existem diversos estudos, realizados em vida livre, que tratam de aspectos ecológicos e/ou comportamentais de *Callithrix jacchus* no bioma Mata Atlântica (STEVENSON e RYLANDS, 1988; ALONSO e LANGGUTH, 1989; DIGBY e BARRETO, 1993; DIGBY, 1995; CUNHA et al. 2006; SCHIEL e HUBER, 2006; SOUTO et al. 2007; BEZERRA e SOUTO, 2008; BEZERRA et al. 2009; SCHIEL et al. 2010). Alguns estudos publicados sobre o gênero *Callithrix* (*Callithrix penicillata*) na área do Cerrado são encontrados (FARIA, 1984; FONSECA e LACHER, 1984; VILELA e FARIA, 2004). Na Caatinga, Moura (2007) observou que os grupos de *Callithrix jacchus* são menores e ocorrem em menor densidade quando comparados com outros tipos de biomas. Ao contrario, Freitas et al. em 2011, referem-se ao sagui comum na Caatinga como relativamente abundante. Por outro lado, Amora et al. (2013) relatou sobre o uso de recursos vegetais alternativos na dieta de dois

indivíduos no semiárido. Porém, publicações que tratam do comportamento do *Callithrix jacchus* em ambiente de Caatinga ainda são ausentes.

O sagui comum pode funcionar como um modelo para explicar o comportamento de alguns animais em ambientes adversos, por ser um grupo diferenciado e que possui plasticidade. De maneira a obter um melhor entendimento sobre a flexibilidade e sucesso ecológico da espécie, o presente estudo busca investigar aspectos da adaptação comportamental de *Callithrix jacchus* em ambiente semiárido, avaliando e descrevendo o padrão comportamental de grupos sagui comum de vida livre na Caatinga.

FUNDAMENTAÇÃO TEÓRICA

A Caatinga é o único bioma restrito ao território brasileiro, inclui os estados do Piauí, Ceará, Rio Grande do Norte, a maior parte da Paraíba e Pernambuco, Alagoas, Sergipe, Bahia e algumas áreas no Estado de Minas Gerais, no vale do Jequitinhonha (LEAL et al. 2005). Representa aproximadamente 10% do solo brasileiro, e é limitada por biomas tropicais, ao leste pela Mata Atlântica, a oeste pela Floresta Amazônica, e ao sul pelo Cerrado (SANTOS et al. 2011).

O clima da Caatinga apresenta características extremas nos parâmetros meteorológicos (PRADO, 2003). Alta radiação solar, elevada temperatura média anual, baixa nebulosidade, baixas taxas de umidade relativa, evapotranspiração potencial elevada e principalmente precipitações baixas (300 a 800 mm) e irregulares (PRADO, 2003). As precipitações são limitadas a um período muito curto do ano (três meses consecutivos), resultando em secas severas periódicas, que caracterizam a região (PRADO, 2003; LEAL et al. 2005). A vegetação é um mosaico de florestas secas e vegetação arbustiva, apresentando árvores e arbustos baixos, geralmente decíduos, com espinhos, microfilia e algumas características xerofílicas. Também são encontradas diferentes cactáceas e bromeliáceas, presentes no solo pedregoso (PRADO, 2003). Pouco se sabe sobre a biodiversidade e ecologia de este ecossistema. Um estudo realizado por Santos et al. em 2011, mostra que a Caatinga apresenta os menores esforços de pesquisa e geração de conhecimento de todos os biomas brasileiros, limitando os avanços nesta área. Um recente levantamento, realizado por Alburquerque et al. (2012) mostrou o registro de 156 espécies de mamíferos para a região de Caatinga, incluindo o *Callithrix jacchus* dentro dos primatas encontrados.

O sagui comum (*Callithrix jacchus*), também conhecido como sagui de tufos brancos é um primata de pequeno porte pertencente ao gênero *Callithrix* e família Callitrichidae (RYLANDS et al. 2008). Sua pelagem é estriada, de coloração preta, cinza ou avermelhada, apresenta uma coroa preta, mancha branca na testa e tufos brancos auriculares, que crescem

na frente das orelhas (STEVENSON e RYLANDS, 1988). Não possui dimorfismo sexual evidente (AURICCHIO, 1995). Os filhotes nascem com 22 a 38 gramas e o adulto chega a medir aproximadamente 25 centímetros, desde o pescoço ate a base da cauda, com um peso que varia entre 300 e 450 gramas. A cauda, não preênsil, é maior do que o corpo, medindo próximo de 28 centímetros na fase adulta, e tem a função de garantir o equilíbrio do animal (STEVENSON e RYLANDS, 1988; AURICCHIO, 1995).

Este primata neotropical, endêmico do Nordeste do Brasil, é uma das espécies mais adaptáveis do seu gênero, podendo ocupar uma ampla variedade de biomas, desde florestas semi-decíduas com estação chuvosa definida, até ambientes áridos com chuvas irregulares e vegetação xerófita (STEVENSON e RYLANDS, 1988). Habita diferentes ambientes, tanto no extremo norte da Mata Atlântica, como na mata ciliar altamente seca da Caatinga, e também no Cerrado, no centro do Brasil (RYLANDS e FARIA, 1993). Na Mata Atlântica, é altamente adaptado à vida saltatória arbórea, com locomoção vertical pelos troncos (AURICCHIO, 1995; SOUTO et al. 2007). Apresenta preferência por florestas secundárias, ambientes alterados pela ação antrópica ou em processo de regeneração natural, e hábitats de borda, pois estes ambientes oferecem melhores possibilidades para suas necessidades alimentares (RYLANDS e FARIA, 1993; KINZEY, 1997).

Estes primatas foram introduzidos em varias regiões fora da sua área natural, principalmente no Sudeste, e devido a sua grande capacidade de adaptação foram capazes de se desenvolver, competir e deslocar outras espécies de primatas nativos (AFFONSO et al., 2004; DE MORAIS et al., 2008). Devido a estas introduções, atualmente podem ser encontrados na Bahia, Espírito Santo, Paraná, Rio de Janeiro, Santa Catarina, São Paulo e Sergipe (STEVENSON e RYLANDS, 1988; RYLANDS et al. 2008).

Em se tratando de sua ecologia, sabe-se que se trata de uma espécie onívora, alimentando-se, dessa forma, de frutas, sementes, insetos, aracnídeos, pequenos lagartos, sapos e filhotes/ovos de aves (STEVENSON e RYLANDS, 1988; KINZEY, 1997; SOUTO et al. 2007). Uma importante parcela na alimentação desta espécie é a goma de algumas espécies arbóreas, a qual é obtida roendo ativamente os troncos e galhos das árvores produtoras de goma com os dentes para estimular o fluxo do exsudato (STEVENSON e RYLANDS, 1988). O sagui comum apresenta uma dentição diferenciada, seus dentes incisivos inferiores são longos e estreitos, formando uma estrutura parecida com um cinzel, adaptados para esta função (NASH, 1986; STEVENSON e RYLANDS, 1988; FERRARI, 1993). Por outro lado, estudos (RYLANDS, 1984; FERRARI e MARTINS, 1992) indicam que o sagui comum possui um ceco aumentado, onde ocorre o armazenamento da goma, facilitando a fermentação microbiana e digestão da mesma (GARBER e KINZEY, 1992; NASH, 1986). Tal recurso

lhes serve como importante fonte de carboidratos, cálcio e alguma proteína (AURICCHIO, 1995).

Possuem unhas em forma de garras em todos os dedos, exceto o hálux (GARBER, 1992). Estas unhas modificadas são utilizadas nas posturas durante a alimentação, permitem que os indivíduos possam ficar em posição vertical nas árvores, ajudando no consumo de goma (NASH, 1986; GARBER, 1992) e também facilitam a captura de insetos em frestas (AURICCHIO, 1995).

As proporções do consumo de goma na dieta estão relacionadas com o tamanho da área de uso (STEVENSON e RYLANDS, 1988). A goma está disponível durante o ano inteiro e pode chegar a constituir mais de 50% da alimentação vegetal na estação seca (AURICCHIO, 1995), desta forma, somente algumas árvores são necessárias para suprir as necessidades do grupo (RYLANDS e FARIA, 1993). Isto permite que a espécie utilize uma área comparativamente menor do que outros primatas do gênero que são mais frutívoros e que, devido à maior dispersão das árvores frugívoras, precisam se deslocar mais e utilizar maiores áreas (STEVENSON e RYLANDS, 1988, KINZEY, 1997). A área de uso de um grupo de *Callithrix jacchus* pode ser de 0,5 a 5 ha em ambiente de Mata Atlântica (AURICCHIO, 1995; RABOY et al. 2008). A área de uso tende a ser maior nas estações de chuva, quando existe disponibilidade de um número maior de diferentes itens alimentares (STEVENSON e RYLANDS, 1988). Mudanças sazonais na abundância de recursos tem uma forte influência na ecologia comportamental dos calitriquídeos. Porém, aqueles *Callithrix* que se alimentam de exsudatos durante a estação seca, como o *Callithrix jacchus*, não apresentam variações significativas no tamanho da área de uso, períodos de atividades ou estabilidade do grupo durante o ano em Mata Atlântica (FERRARI e LOPES FERRARI, 1989).

Callithrix jacchus são animais sociais que vivem em grupos de 3 a 15 indivíduos, formados por animais adultos (reprodutores e não reprodutores), subadultos, juvenis e infantes (STEVENSON e RYLANDS, 1988), podendo ser aparentados ou não aparentados. Estes grupos são chamados famílias nucleares ou estendidas (FERRARI e LOPES FERRARI, 1989). Sua composição permanece estável, exceto quando eventualmente ocorre a imigração ou emigração de algum adulto para outro grupo (KINZEY, 1997), e com o nascimento de prole. Ocasionalmente alguns indivíduos podem se separar do grupo e forragear sozinhos por algum tempo, numa distância que varia de 30 até 100m. Eles sempre mantêm contato com o grupo através de vocalizações (STEVENSON e RYLANDS, 1988).

Os saguis podem interagir através de sinais táteis, como a catação, que estabelece a relação social, reduz a tensão e previne a agressão (LAZARO-PEREA et al. 2004). Também utilizam padrões visuais, olfativos e acústicos, como a piloereção, marcação e vocalizações

respectivamente, importantes nas interações sociais, comunicação, reprodução e sobrevivência (STEVENSON e RYLANDS, 1988; BEZERRA e SOUTO, 2008).

O sistema reprodutivo do sagui comum é típico dos calitriquídeos, normalmente ocorre o acasalamento monogâmico, onde a fêmea dominante se reproduz com o macho dominante, e filhotes gêmeos são usualmente gerados, duas vezes por ano (AURICCHIO, 1995). A fêmea reprodutora suprime a fertilidade das outras fêmeas de idade reprodutiva fisiológica e comportamentalmente, assim como o macho reprodutor suprime a atividade reprodutiva dos machos subordinados do grupo (STEVENSON e RYLANDS, 1988). No entanto, reprodução com mais machos pode ocorrer, em uma chamada poliandria "fraternal", vista como uma extensão do padrão monogâmico, onde a fêmea dominante também pode acasalar com o irmão gêmeo do macho reprodutor (FERRARI e LOPES FERRARI, 1989), assim como a poliginia, onde o macho dominante pode se acasalar com mais fêmeas (REFERENCIA).

A criação dos infantes é realizada tanto pela mãe quanto pelo pai, nas primeiras semanas a mãe se encarrega de transportar os filhotes, e à medida que eles vão crescendo essa tarefa passa a ser do pai. Uma vez que a fêmea possui um estro logo após o parto, o pai ajuda a carregar os filhotes enquanto a fêmea já está apta para a gestação de outros dois filhotes (FERRARI e LOPES FERRARI, 1989). Também ocorre a participação e cooperação dos integrantes do grupo no cuidado aos filhotes desde os primeiros dias de vida, no transporte dos filhotes na provisão de alimento (FAULKES et al. 2009). Geralmente os adultos não reprodutores são da mesma prole ou irmãos do par reprodutor. Desta forma, estão mais dispostos a prover cuidados aos filhotes e tentem a competir menos pelo status de reprodutor, que adultos não relacionados (FERRARI e LOPES FERRARI, 1989).

A gestação é de 140 a 150 dias, os partos ocorrem de noite em cativeiro, entre as 19 e 23 horas (STEVENSON e RYLANDS, 1988; TARDIF et al. 2003), não havendo registros de partos em vida livre. Os filhotes nascem sem as características adultas. Os tufos auriculares aparecem na sexta semana de idade e a coroa preta entre os quatro a cinco meses. A coloração adulta aparece quando a próxima ninhada é produzida, tempo em que os infantes alcançam outro estagio de desenvolvimento (STEVENSON e RYLANDS, 1988).

Observações do padrão de atividades realizadas por Maier et al. (1982) mostram que os grupos de *Callithrix jacchus* de vida livre mantém um ciclo de atividades diárias de aproximadamente 12 horas. Deixam sua arvore de dormida entre 10 a 30 minutos após o amanhecer e se dirigem diretamente até a árvore de gomivoría principal, onde passam de 40 minutos a uma hora se alimentando da goma (PONTES e SOARES, 2005). Após este momento, os animais passam o resto do dia se deslocando, forrageando e interagindo com

outros indivíduos do grupo. Exceto no horário mais quente do dia (perto de meio-dia), quando os grupos retornam a árvore principal para um período de descanso. O retorno ao sitio de dormida ocorre cerca de 30 minutos antes de anoitecer. Os grupos tentem a dormir perto da área onde se alimentaram por ultimo durante o dia. (STEVENSON e RYLANDS, 1988; ALONSO e LANGGUTH, 1989).

Segundo Raboy et al. (2008) parece haver um relação entre o tempo que as espécies de *Callithrix* gastam se trasladando, com o tempo que gastam realizando outras atividades. Alguns callitriquíneos, por exemplo, gastam mais tempo se deslocando do que se alimentando, já para *Callithrix jacchus* o tempo despendido em se deslocar é menor do que o tempo que passam forrageando, descansando e realizando comportamentos sociais. Embora, o "daily path length" (comprimento do caminho percorrido por dia) para *Callithrix jacchus* na literatura varia de 150 a 1300 metros, esta variação pode ser explicada pelos diferentes ambientes que a espécie habita e pela variação natural na qualidade e distribuição de recursos (KINZEY, 1997; RABOY et al. 2008).

As características mencionadas como o uso da goma na alimentação, o sistema de reprodução (dois filhotes duas vezes por ano e o cuidado aloparental), além de adaptações morfo-fisiológicas como a dentição especializada e unhas em forma de garras contribuíram para o sucesso ecológico da espécie (NASH, 1986, STEVENSON e RYLANDS, 1988, AURICCHIO, 1995). Isto permitiu que o *Callithrix jacchus* se adaptasse a diferentes ambientes, colaborando para a sua radiação (FERRARI, 1993; KINZEY, 1997).

OBJETIVO GERAL

Avaliar e descrever o padrão comportamental de grupos de vida livre de *Callithrix jacchus* no ambiente de Caatinga, para melhor elucidar o sucesso ecológico da espécie.

HIPÓTESES

(1) Em contraste com a Mata Atlântica, onde os animais passam a primeira hora do seu dia consumindo exsudato intensamente, na Caatinga a gomivoria ocorrera por um tempo prolongado durante as primeiras horas do dia, como uma estratégia de "alimento reserva" (Fallback food) em resposta a escassez de recursos disponíveis.

(2) Devido às altas temperaturas, o comportamento de descanso começará mais cedo durante o dia e durara mais tempo do que o relatado para saguis na Mata Atlântica.

(3) A pressão de escassez de recursos levara aos saguis na Caatinga a explorar um tamanho maior de área de uso e, portanto a dedicar mais tempo ao deslocamento do que na Mata Atlântica.

(4) Nos saguis a idade é importante na captura de presas, os animais mais jovens precisam de mais tempo para capturar presas de forma eficiente, portanto esperamos que os jovens dediquem mais tempo ao forrageio e gomivoria do que os adultos e consequentemente dediquem menos tempo ao descanso.

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CAPÍTULO I

Wild common marmosets' (*Callithrix jacchus*) behavioral adaptability in the semi-arid Caatinga environment

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Wild common marmosets' (*Callithrix jacchus*) behavioral adaptability in the semi-arid Caatinga environment

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Short title: Behavior of *Callithrix jacchus* in the Caatinga

In this study we provide the first information on the behavioral patterns of free-living common marmosets (*Callithrix jacchus*) inhabiting a semi-arid Caatinga environment in northeastern Brazil. Due to the high temperatures, low precipitation and the resource scarcity of the Caatinga, we expected that the common marmosets would adjust their behavioral activity by extending their gum eating time during the first hours of the day, extending the resting behavior time during the hottest hours of the day, devoting more of their activity budget to locomotion, and use a larger home range. During a six months period we collected 246 hours of behavioral data on two groups (10 individuals) of *Callithrix jacchus*. The most frequent behaviors were foraging, locomotion and resting. Adult common marmosets in Caatinga devoted twice as much time to resting as that reported for these primates in the cooler and wetter Atlantic Forest. Changes in behavioral patterns appear to represent a response to the thermal stress during the hottest hours of the day. In addition, common marmosets in the Caatinga devoted more of their feeding time during the first hours of the day to gum eating. This high dependence of plant exudates may be related to the scarcity of other readily available resources. Furthermore, juveniles spent more time consuming gums than adults (16% vs. 10.8%), which may be associated with their inexperience in prey capture. Both study groups exploited home ranges of 2.21ha and 3.26ha, which is within the variation range described for common marmosets inhabiting the Atlantic Forest. Our findings confirm that common marmosets adjust their ecological and behavioral patterns in order to deal with the high temperatures and resource scarcity that characterized a Caatinga environment, and highlights their ability to survive across a wide range of different environments.

Keywords: Semi-arid, Caatinga, behavioral adjustments, *Callithrix jacchus*

INTRODUCTION

Common marmosets (*Callithrix jacchus*) are distributed across northeastern Brazil, and exploit a range of forest types including the humid Atlantic Forest and the semi-arid Caatinga scrublands [Rylands & de Faria, 1993]. The Atlantic Forest is a moist tropical forest receiving more than 2000mm of rain a year and contains high biological diversity [Thomas, 2008]. The Caatinga, in contrast, is a mosaic of scrubs and patches of seasonally dry forest with high temperatures, receiving less than 500mm of rain per year [Albuquerque et al., 2012; Leal et al. 2005; Prado, 2003]. Temperature during the months of November to April can exceed 36°C, with the highest daily temperature occurring between 11-15hr [INMET, 2012/2013; referring to the meteorological station of Cabaceiras (Paraíba, Brazil)].

Although primates such as *Leontopithecus* and *Brachyteles* are present in the Atlantic Forest [Kleiman, et al., 1988; Nishimura et al., 1988], only *Sapajus, Callicebus* and *Callithrix* are reported to inhabit Caatinga forest [Freitas et al., 2011; Moura, 2007; Stevenson & Rylands, 1988]. It is argued that the ecological success of common marmosets, across a wide geographical distribution and the range of different environments, is due to a set of morphological adaptations and behavioral strategies [Ferrari, 1993]. Thus, the dentition of *Callithrix* differs from other callitrichines and New World primates by having specialized elongated lower incisors with a chisel-like structure that facilitate tree gouging [Ferrari, 1993; Garber & Kinzey, 1992; Rylands & de Faria, 1993]. Studies by Rylands [1984] and Ferrari and Martins [1992] indicate that the common marmosets hindgut is characterized by an enlarge ceacum and colon which provides an increased area for fermentation and makes it anatomically suitable for the exploitation of foods high in structural carbohydrates such as plant gums [Garber & Kinzey, 1992; Nash, 1986]. In addition to that characteristics, common marmosets have an omnivorous diet (e.g. animal prey, fruits, flowers and plant exudates) [Rylands & de Faria, 1993; Souto et al., 2007], a high rate of reproduction (e.g. a single common marmoset female can produce 4 offspring per year), and alloparental care, provided

principally by older males group members that perform most of the carrying of the offspring [Rylands & de Faria, 1993; Stevenson & Rylands, 1988].

Virtually all ecological and behavioral studies of wild groups of *Callithrix jacchus* have been conducted in the Atlantic Forest [e.g. Alonso & Langguth, 1989; Bezerra et al. 2009; Bezerra & Souto, 2008; Cunha et al. 2006; Digby, 1995; Digby & Barreto, 1993; Schiel et al. 2010; Schiel & Huber, 2006; Souto et al. 2007; Stevenson & Rylands, 1988]. Only three studies that refers to *C. jacchus* living in the Caatinga [Amora et al., 2013; Freitas et al., 2011; Moura, 2007], resulting in a gap on our knowledge of the behavioral strategies used by common marmosets to exploit arid habitats. Specifically, Moura [2007] reported that in Caatinga, *C. jacchus* occurs in lower densities (not informed) and smaller group sizes (average of 2.9 ± SD 1.67 individuals/group) than at areas of Atlantic Forest (8.7 individuals/group). In contrast Freitas et al. [2011] refers to *C. jacchus* in the Caatinga as relatively abundant (169.7 and 116.7 individuals/km^2). In the study by Amora et al. [2013] on the feeding ecology of *C. jacchus* in Caatinga, the authors report diet items that differed from the feeding pattern registered for this species in other forest, for example: parts of cactus species (flowers and fruits), the nectar of a terrestrial bromeliad (*Encholirium spectaile*), the leaves from seven different tree species and the use of Capparaceae, Celastraceae and Vitaceae.

The semi-arid conditions of the Caatinga impose significant challenges in terms of heat stress, thermoregulation, available water, and limited resource availability to mammals [Albuquerque et al., 2012; Diaz & Ojeda, 1999], especially during the dry season. The dry season can have high annual variation and long periods of drought, and some areas can present up to 7 to 11 months of low water availability [Medeiros et al. 2012; Prado, 2003]. In this environment due to high temperature, thermal stress is likely to be a significant constraint on the behavioral ecology of primates [Hill, 2006; Stelzner, 1988; Takemoto, 2004] resulting in an increase in resting, especially during the midday hours, and difficulties in locating

resources such as insects and ripe fruits [Chaves et al., 2011; Hill, 2006; Kosheleff & Anderson, 2009]. Also, the reduced availability of resources in Caatinga environments is likely to result in an increase in home range area as individuals are required to travel for longer distances in the search for food [Passamani & Rylands, 2000].

Given the conditions and challenges of Caatinga [e.g. Moura & Lee, 2004], we expect that common marmosets will exhibit a set of ecological and behavioral adjustments that include: (1) in contrast to the Atlantic Forest where animals intensively spend the first hour of their day consuming exudates [Alonso & Langguth, 1989], in Caatinga exudate feeding will occur for an extended time during the first hours of the day. This will take place as a fallback food strategy in response to the harsh conditions of relatively scarce food availability, especially edible fruits [Marshall & Wrangham, 2007]. Furthermore, (2) due to the high temperatures, resting behavior will start earlier in the day and last longer than reported for common marmosets in the Atlantic Forest [Korstjens et al., 2010]. In addition, (3) food scarcity [Amorin et al., 2009; Van Schaik et al., 1993] will result in Caatinga marmosets exploiting a larger home range [Passamani & Rylands, 2000], and devote more of their activity budget to locomotion than in Atlantic Forest. Finally, (4) as age in common marmosets can play an important role in the outcome of behaviors, where younger animals needs more time for efficiently capture prey items [e.g. Schiel et al., 2010], we expect that juveniles devote more of their time to foraging and gum eating than adults and consequently dedicate less time to resting behavior. Therefore in order to better understand the ecological success of the common marmosets across a range of environmental conditions, the goals of this research are to evaluate and describe the behavioral patterns of free-living groups of common marmosets in the semi-arid Caatinga environment.

METHODS

Study site

125 The study was conducted at the Fazenda Marimbondo, near the Municipality of
126 Cabaceiras (384m of altitude) in the state of Paraíba, Northeast of Brazil ($7^{o}31'42'S$ and
127 $36^{o}17'50'W$) (Fig.1). It covers an area of 400ha in the micro region of Eastern Cariri which
128 has a total area of 424.213ha. The study site is near the water reservoir Epitácio Pessoa,
129 inaugurated in 1957, which extends for several municipalities and supplies a large number of
130 cities. The reservoir receives the waters of Paraíba and Taperoá rivers.

131 According to Köppen climate classification, the study area is considered BSh type (hot
132 semi-arid) [Peel et al., 2007]. The mean annual temperature is 24°C, with temperatures that
133 can reach up to 36.7°C and a mean annual relative humidity of 63.8% [Medeiros et al., 2012].
134 Rainfall is irregular and sparse. The mean annual rainfall over 86 years (1926 to 2011) is
135 336.6mm [Medeiros et al., 2012], representing one of the driest areas of Brazil. Even though
136 the rainy season occurs generally between February and June, during the study period
137 precipitations levels were very low, averaging 10.7mm/month. The vegetation is arboreal
138 shrub type, typical of this semi-arid region and is dominated by a small number of scattered
139 tree species [e.g. *Amburana cearensis* (Fabaceae); *Spondias tuberosa* (Anacardiaceae);
140 *Aspidosperma pyrifolium* (Apocynaceae)] and shrubs [*Caesalpinia* spp. (Fabaceae); *Mimosa*
141 spp. (Fabaceae); *Jatropha* spp. (Euphorbiaceae); *Acacia* spp. (Fabaceae)] [Prado, 2003]. It is
142 predominantly low vegetation (mean canopy height 3.55 ± SD 0.54m) with low tree/shrub
143 density (4.46 individuals/ha; mean DBH (Diameter at breast height) = 10.75 ± SD 2.97cm;
144 Mean distance between trees = 105 ± SD 23.86cm) as a result of limited rainfall and generally
145 shallow and rocky soils, with low water retention capacity [Sampaio et al., 1981]. Some
146 potential predators of *Callithrix jacchus* that can be found in the Caatinga environment are:
147 canidae (*Cerdocyon thous*), some felidae like *Puma concolor, Herpailurus yaguarondi,*
148 *Leopardus pardalis, L. wiedii* and *L. tigrinus* [Oliveira et al., 2003; Oliveira et al., 2004];
149 birds of the families Accipitridae, Falconidae, Cathartidae, Tytonidae and Strigidae [Silva et

al., 2003]; and snakes of the families Boidae, Colubridae, Elapidae and Viperidae [Rodrigues, 2003].

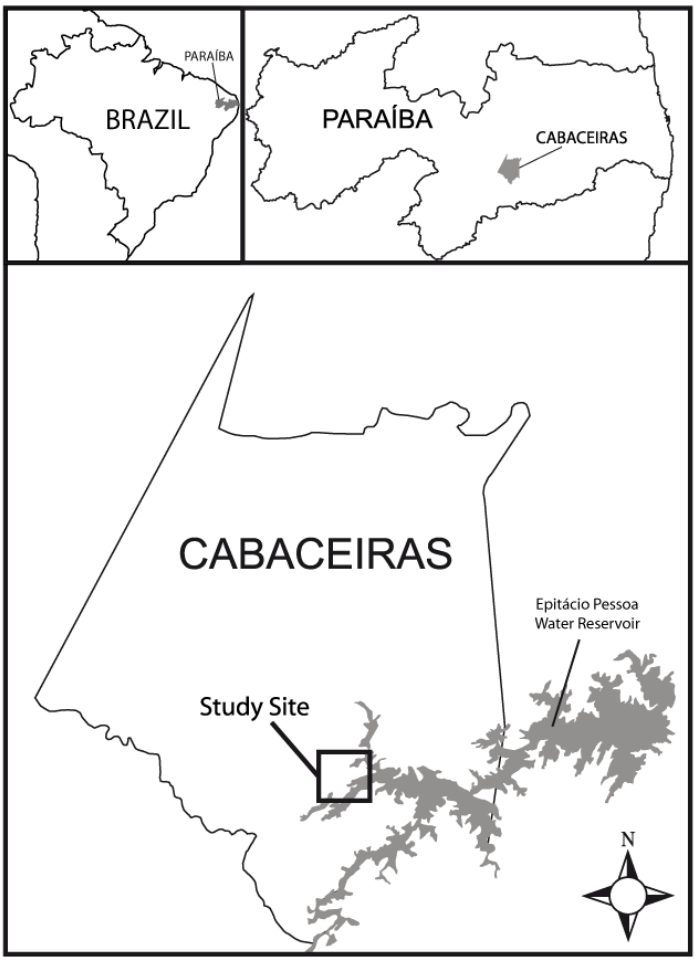


Fig 1. Study site situated in an area of semi-arid Caatinga in the state of Paraíba, Northeast of Brazil.

Subjects

For the present study we observed two wild groups of *Callithrix jacchus* with a total of 16 individuals at the beginning of the study (Table I). Age classes were adapted from Schiel & Huber [2006]: we include old infants in the age group of juveniles, and sub-adults together with the adult age group. The composition of both groups changed over the course of the study: in group A the dominant female and another adult female disappeared (January/2013), and a new female entered the group and became the primary breeder. In August/2013, one of

the missing females was seeing in another group nearby. In group B, four out of eight individuals disappeared (December/2012) overnight. They were probably predated by a couple of owls living near the site, as the animals were not seen again. In both groups, the animals were individually identified applying the method described by Schiel et al. [2008], using natural marks, sex, age and social status within the group.

Table I. Composition of the common marmosets groups in our study sites

Age class	Group A		Group B	
	♀	♂	♀	♂
Infant (1 – 12 weeks)	-	-	1*	1*
Juvenile (4–10 months)	-	3	1	1*
Adult (>11 months)	4(2*)	1	2(1*)	2

*Number of individuals that disappeared during the observation period. These individuals were not included in the statistical analyses.

Procedure

After three months of habituation, systematic observations were carried out by De la Fuente, M.F.C. from November 2012 to April 2013, 10 days per month, for a total of 246h of direct observation (146hrs on Group A and 100hrs on Group B) and 720 hours of fieldwork. Quantitative behavioral data were collected using focal animal sampling method [Altmann, 1974; Lehner, 1996]. Each session consisted of a 10min period of continuous observation during which we recorded the group's activity budget (Table II). During the session, when an animal was out of sight for more than 60s, the session was stopped and discarded. Sessions were carried out between 5am and 5pm, and were distributed evenly during all hours of the day. For each individual two to four sessions per day were recorded. Individuals were observed for equal amounts of time (150 sessions per individual) except for the adult female that entered group A in January (126 sessions), counting a total of 1476 sessions. The observed behavioral data were recorded by using a voice recorder (Sony ICD-PX312; Sony Corporation, Tokyo) and later transcribed into Excel (Microsoft Corporation, Redmond, WA)

189 spreadsheets. We used a GPS (eTrex20®; Garmin International, Inc. Kansas) to mark the
190 areas where the animals were visualized during the study period to estimate the group home
191 range.

192 The study adhered to the American Society of Primatologists principles for the ethical
193 treatment of primates and the laws of Brazilian governing wild animal research.

194

195 **Table II. Description of the recorded behavioral patterns**
196

Behavior	Description
Resting	Individual lying down on its belly or seated with its tail around the body or between the legs, the eyes may be open or closed [Stevenson & Poole, 1976] and stays in this posture for more than 60 seconds [Schiel & Huber, 2006].
Grooming	One individual parts the fur of another with its hands and removes particles like dirt and parasites using its mouth and/or hands [Stevenson & Rylands, 1988].
Autogrooming	Individual remove particles from its own skin and fur using its mouth and/or hands [adapted from Stevenson & Rylands, 1988].
Locomotion	Set of actions where the animal is moving from one place to another a distance greater than 3m at once [Schiel & Huber, 2006], includes walking, running, climbing and jumping [Stevenson & Poole, 1976].
Foraging	Group of actions in which the individual seeks and consume food items (plant or animal). For our study, we did not consider in this category the exploration for exudates [Alonso & Langguth, 1989].
Gummivory	Set of acts where the individual gnaws the tree bark with its teeth and either licks or eats the exudates flow. It usually includes scent-marking the area with the circumgenital region at the end of the procedure [Stevenson & Poole, 1976].
Play	Interaction between two or more group members involving a series of playful actions [Stevenson & Poole, 1976] including hide-and-seek, wrestling, body-bite, chase.

197

Statistical Analysis

For statistical analysis we used only the animals that had not disappeared during the observation period. Data were analyzed using the statistical program GraphPad InStat3 (GraphPad Software, Inc.) and Excel (Microsoft Corporation). For statistical analysis, we calculated the mean values (by dividing the sum of the frequencies of each behavior on every session, between the total number of sessions), standard deviation, and percentages of behaviors. To determine whether the behaviors were significantly different between each other we used Kruskal-Wallis test. Dunn's post hoc was applied to determine which pairs were significantly different. In order to see if the behaviors changed between time intervals we used the Friedman test and Dunn's post hoc test to determine which pairs were significantly different. Due to the small sample size we excluded from statistical analysis: grooming, autogrooming and play behavior. Also, Spearman's correlation was used to verify evidence for changes in behavior during the day in response to changes in temperature. For all analyses the statistical significance was set at $P \leq 0.05$ (2-tailed tests).

RESULTS

Behavioral Data

Assuming that each behavioral pattern should occur in equal frequency, we found significant differences in the percentage of time wild common marmosets ($N = 10$) devoted to different behaviors (Kruskal-Wallis: $H = 58.77$, $df = 6$, $P < 0.0001$). The most frequent behaviors were foraging (30.7%), followed by locomotion (28%) and rest (16%) (Fig. 2).

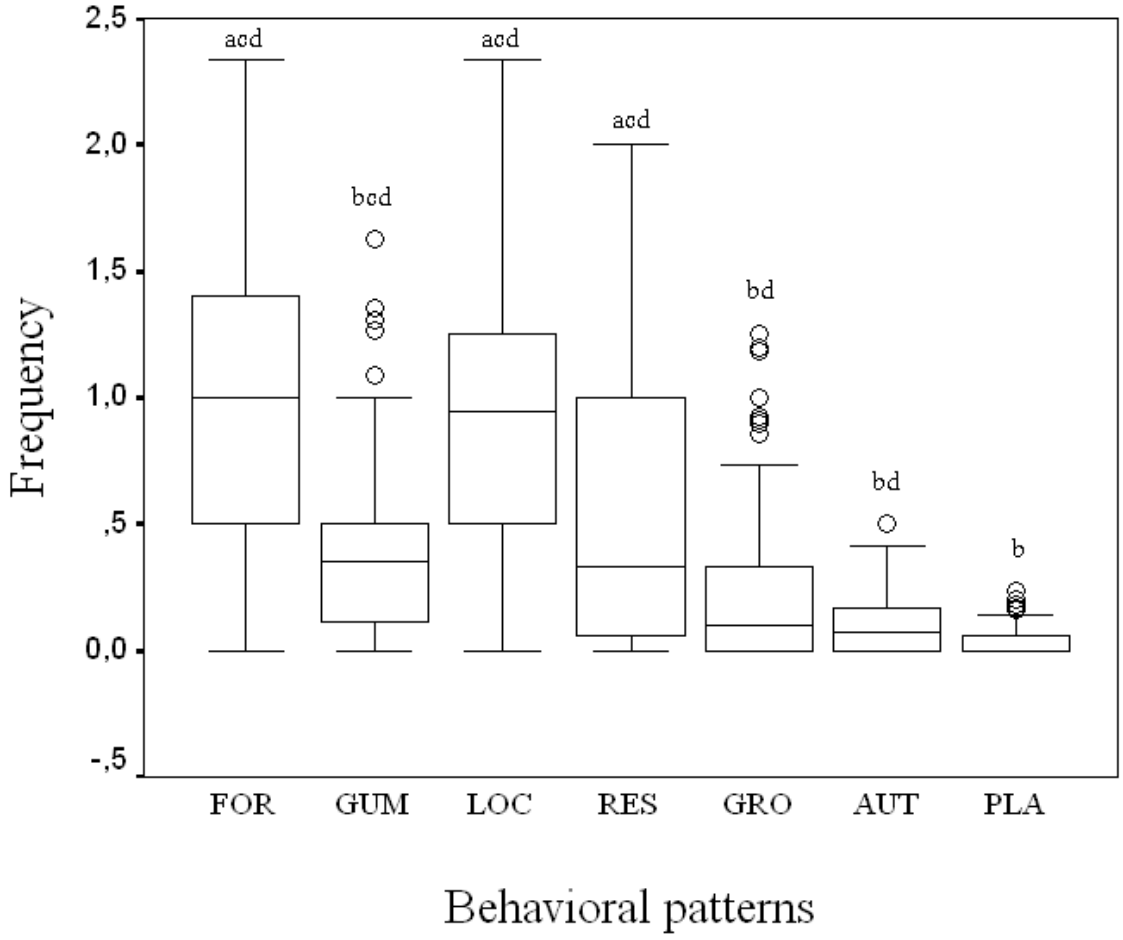
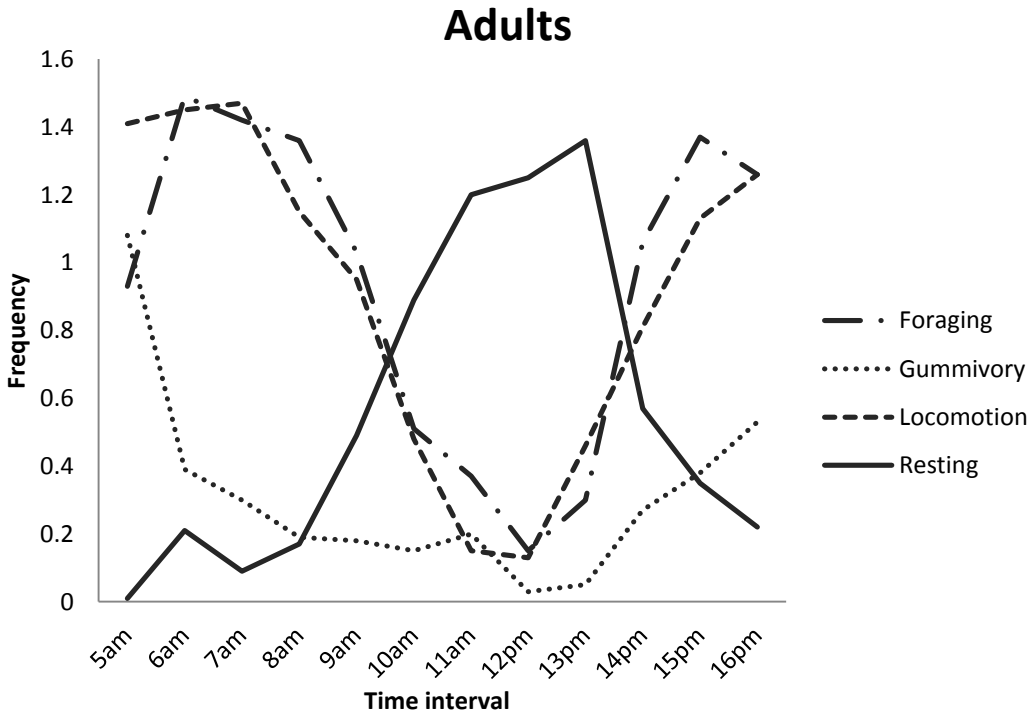


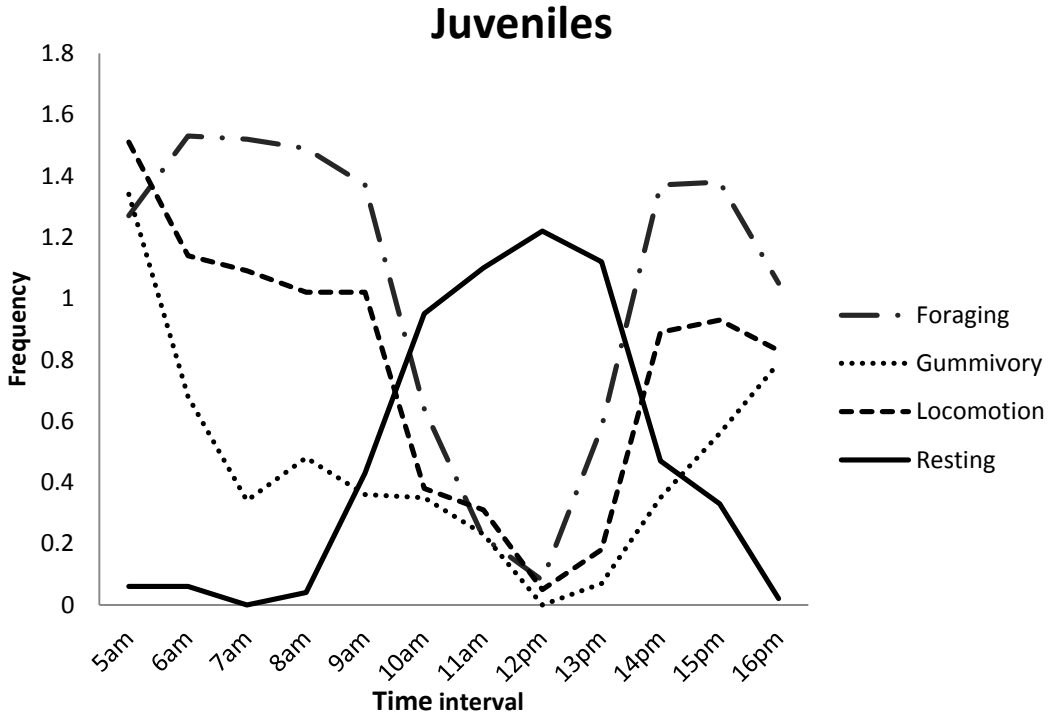
Fig 2. Overall behavioral patterns performed by wild common marmosets (N = 10) during the study period. Different letters indicates statistically significant differences ($P \leq 0.05$) between the behavioral patterns. Statistics: Kruskal-Wallis test followed by post-hoc Dunn's test. For: foraging; Gum: gummivory; Loc: locomotion; Res: resting; Gro: grooming; Aut: autogrooming; Pla: playing.

In adults (N = 6), we observed highly significant differences when comparing behavioral patterns among the time intervals (Friedman: Foraging: Fr = 47.89, df = 11, P < 0.0001; Gummivory: Fr = 44.80, df = 11, P < 0.0001; Locomotion: Fr = 52.06, df = 11, P < 0.0001; Resting: Fr = 55.12, df = 11, P < 0.0001). Gummivory and locomotion were found to decrease significantly after 10am (from 30% to 5% and 40.5% to 16%, respectively), while foraging exhibited a significant decrease after 11am (from 38% to 13%). Resting behavior increased significantly beginning at 10am (from 0.3% to 30%), maintained a high frequency (between 30 and 49% of all records) until 2pm, and then decreased significantly (from 44% to 18.5%). Coinciding with a significant increase in activity after 2pm in foraging (from 9.7% to

34%) and gummivory (1.6% to 9%). Locomotion increased significantly at 1pm (from 5% to 15%). Foraging, gummivory and locomotion became the most frequent behaviors through the end of the activity cycle (5pm) (Fig. 3).

Juveniles (N = 4) also were found to alter their behavioral patterns among time intervals (Friedman: Foraging: Fr = 30.65, df = 11, P = 0.0012; Gummivory: Fr = 34.39, df = 11, P = 0.0003; Locomotion: Fr = 32.85, df = 11, P = 0.0006; Resting: Fr = 37.64, df = 11, P < 0.0001). Locomotion decreased significantly after 11am (from 33% to 16%), while gummivory decreased significantly after 12pm (from 29% to 0%). Juveniles increased time devoted to resting beginning at 12pm (from 0% to 66%). Gummivory and locomotion increased significantly among juveniles beginning at 2pm (from 3% to 11% and 7% to 27%, respectively). Although the Friedman test found a significant difference concerning the foraging behavior among time intervals, Dunn's post-hoc test did not revealed between which pairs the differences occurred. Nonetheless, we observed that foraging decreased at 12pm (from 42% to 4%) and increased again at 2pm (from 9.7% to 34%) (Fig. 3).





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253 **Fig 3.** Behavioral activity among time intervals of adults (*N* = 6) and juveniles (*N* = 4)
254 common marmosets in the Caatinga.

255

256 In order to examine the effect of temperature on the common marmoset activity
257 budget, we correlate the observed behavioral patterns with the mean temperature of each hour
258 of the day. Resting behavior increased significantly in adults and juveniles as the temperature
259 increase (Spearman's Correlation Coefficient: Adults: *N* = 12, *rs* = 0.79, *T* = 4.08, *P* = 0.0022;
260 Juveniles: *N* = 12, *rs* = 0.63, *T* = 2.55, *P* = 0.0291). Locomotion behavior decreased as
261 temperature increased (Spearman's Correlation Coefficient: Adults: *N* = 12, *rs* = -0.71, *T* = -
262 3.22, *P* = 0.0092; Juveniles: *N* = 12, *rs* = -0.77, *T* = -3.87, *P* = 0.0031). No significant
263 correlation between gummivory and temperatures was found (Spearman's Correlation
264 Coefficient: Adults: *N* = 12, *rs* = -0.44, *T* = -1.55, *P* > 0.05; Juveniles: *N* = 12, *rs* = -0.52, *T* =
265 -1.95, *P* > 0.05); and no significant correlation between foraging and temperatures could be
266 observed (Spearman's Correlation Coefficient: Adults: *N* = 12, *rs* = -0.42, *T* = -1.52, *P* > 0.05;
267 Juveniles: *N* = 12, *rs* = -0.49, *T* = -1.76, *P* > 0.05).

268

Feeding ecology

Wild common marmosets captured and consumed animal prey such as ants, termites, butterflies, moths, cockroaches, caterpillars, worms, spiders and lizards. These prey items accounted for 88.26% of overall foraging events. The home range of group A was adjacent to some fruits for this group accounted for 18.7% of foraging events. The fruits consumed included: Soursop: *Annona muricata* (Annonaceae), Apple guava: *Psidium guajava* (Myrtaceae), and Bitter melon: *Momordica charantia* (Cucurbitaceae). Group B had no fruit in their home range. The marmosets of both groups exploited two sources of exudates: Baraúna: *Schinopsis brasiliensis* (Anacardiaceae) and Mesquite: *Prosopis juliflora* (Leguminosae). Both exudates species were common across the group's home range.

Home range

The average home range area of the two study groups was 2.73ha (Group A - 2.21ha / Group B - 3.26ha) (Fig. 4). We recorded intergroup encounters between Group A and at least two other wild groups of common marmosets. The home range used by group B was located 540m from the home range of Group A. It was higher in elevation (449,82m vs. 383,74m) and given its distance from the water reservoir (570m), appeared to represent a drier habitat. There were no other wild groups of common marmosets seen near the home range of Group B over the study period.

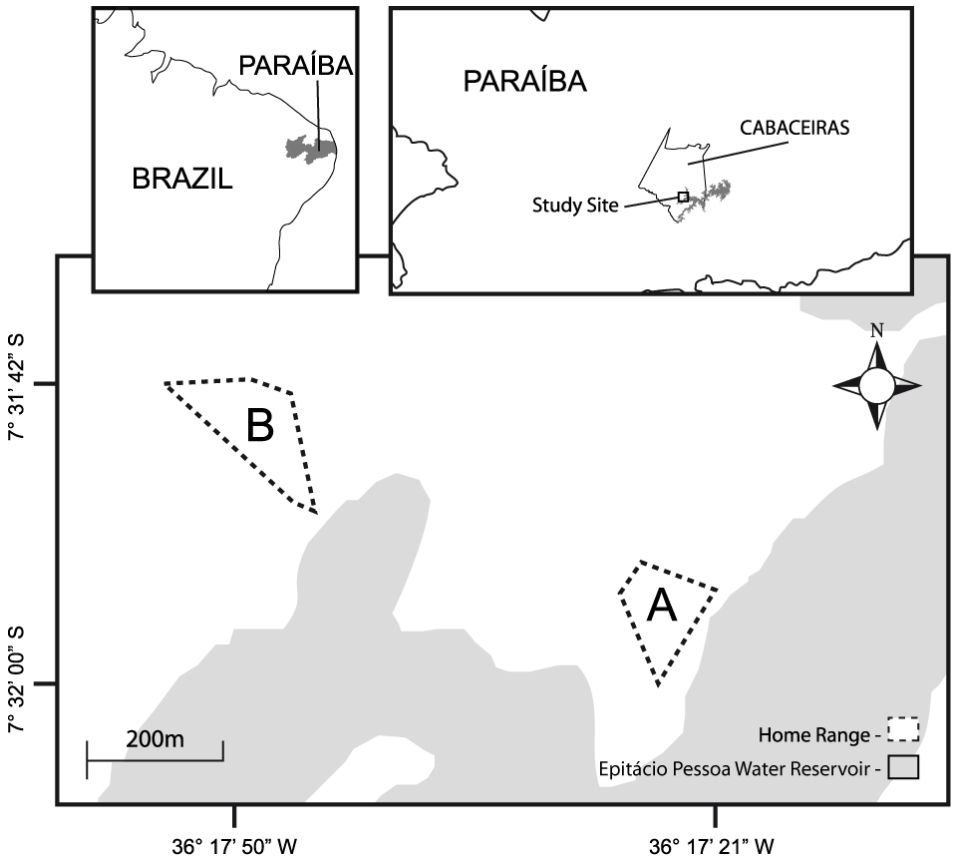

Fig 4. Home ranges of the wild *Callithrix jacchus* study groups (A and B) in the semi-arid environment of Caatinga.

Sleeping sites and activity cycle

Study group A used seven sleeping sites and group B used six sleeping sites during the 6 month study period. Neither group used the same sleeping site more than two or three nights in a row with a mean of 1.9 consecutive nights. All the sleeping sites were located in tree forks at the top of the highest trees (approx. mean height 5.72 ± SD 3.12m) connected to the surrounding vegetation. Sleeping sites were situated in *P. juliflora* trees, with the exception of one sleeping site of group A located at the top of a Coconut palm (*Cocos nucifera* – Arecaceae) in the cultivated area. In the *P. juliflora*, the canopy was semi-covered and the sleeping sites could be spotted among the leaves and branches of the trees. On the other hand, the sleeping site located at the Coconut palm was completely covered; as the animals hide among the palm leaves. All group members slept together. The animals exited their sleeping

sites, on average, 5 minutes (± SD 4.3min) after the sunrise and return to sleeping site approximately 15 minutes (± SD 9.8min) before the sunset (Table III).

Table III. **Activity cycle and number of sleeping sites used by the common marmosets in the study period**

Month	Mean time				N° of sleeping sites	
	Sunrise*	Leave sleeping site	Sunset*	Return to sleeping site	Group A	Group B
Nov	4:57	5:07	17:27	17:14	4	5
Dec	5:03	5:14	17:36	17:11	2	4
Jan	5:23	5:24	17:51	17:31	3	3
Feb	5:29	5:31	17:48	17:24	4	3
Mar	5:29	5:33	17:34	17:29	3	4
Apr	5:27	5:31	17:21	17:19	2	3
Mean	5:18	5:23	17:36	17:21		

*Source: http://euler.on.br/ephemeris/index.php

DISCUSSION

Common marmosets inhabiting the Caatinga go beyond morphological adaptations by clearly adjusting their behavior to the constraints imposed by this challenging environment. For instance, gum feeding occurred more extensively during the first hours of the day (until 10am) than reported in previous studies in the Atlantic Forest [Alonso & Langguth, 1989; Maier et al., 1982]. Then, bouts on gum decreased during the resting period to significantly increase again at 2pm. This high dependence of plant exudates may be related to the scarcity of other readily available resources. Amora et al. [2013] observed that, instead of relying mainly on exudate exploitation as a fallback food strategy [Marshall & Wrangham, 2007], marmosets choose alternative food items such as leaves. This strategy was not observed in our two study groups. Their diet consisted mainly of gum, fruits, arthropods and small vertebrates, similarly to the Atlantic Forest common marmosets [Souto et al., 2007].

Temperature had no significant effect on gum feeding or foraging activity. Apparently the need to compensate food scarcity overcomes a possible thermal stress caused by high temperatures [Ménard et al., 2013]. Such need seemed to be more evident in juveniles. The extended time on gum feeding and foraging activity by juveniles, when compared to adults, might be related to a reduced capacity to efficiently capture prey items [Schiel et al., 2010]. In order to compensate this lack of experience in obtaining prey items, juveniles would be compelled to make use of the more easily obtainable exudates.

Temperature had an interesting effect on resting behavior: when temperature increased, resting also increased. Researches describe that common marmoset in the Atlantic Forest rest for about two hours [Alonso & Langguth, 1989; Maier et al., 1982; Stevenson & Rylands, 1988]. In our study, adults rested for about four hours. Thus, resting started earlier and lasted longer in the Caatinga than previously reported for Atlantic Forest common marmosets [Korstjens et al., 2010]. Apparently, the higher daily temperature in the Caatinga was the factor that promoted this behavioral adjustment to compensate a possible thermal stress [Hill, 2006; Ménard et al., 2013; Stelzner, 1988].

Higher temperatures also seemed to have an effect on locomotion behavior: when temperature increased, locomotion decreased. Still, locomotion revealed to be more frequent than reported for the Atlantic Forest common marmosets [e.g. Alonso & Langghut, 1989]. However, home range sizes were within the variation range described in the Atlantic Forest [Alonso & Langguth, 1989; Hubrecht, 1985; Maier et al., 1982; Pontes & Monteiro da Cruz, 1995; Scanlon et al., 1989; Stevenson & Rylands, 1988]. Thus, instead of using a larger home range due to food scarcity as suggested by Passamani and Rylands [2000] for *C. geoffroyi*, common marmosets in the Caatinga seem to compensate such shortage by exploring more intensively their territory and relying more on gum sources [Rylands, 1984]. It is possible that to maintain and defend a bigger territory in this hot semi-arid environment implies in a higher lost of energy to regulate body temperature [Pyke, 1979].

Despite the behavioral adjustments, the activity cycle was quite similar to that found in the Atlantic Forest common marmosets. As in previous studies [Alonso & Langguth, 1989; Maier et al., 1982; Stevenson & Rylands, 1988] common marmosets in Caatinga also leave their sleeping site just after the sunrise, and return to sleep shortly before sunset [Maier et al., 1982; Stevenson & Rylands, 1988]. Up to seven sleeping sites per group were used during our study period (6 months), and each site was not used more than three nights in a row. Reports on the number of sleeping sites for common marmosets in the Atlantic Forest vary considerable in previous studies [e.g. Alonso & Langguth, 1989: N = 15 (11 months); Pontes & Soares, 2005: N = 5 (10 months); Silva & Monteiro da Cruz, 1993: N = 2 (20 months); Stevenson & Rylands, 1988: N = 1 – 4 (4 months)]. The main factors that defines the choice of sleeping sites by *C. jacchus* in the Atlantic Forest are: tall trees with closed canopy by a dense tangle of vines, lianas and leaves [Maier et al., 1982; Silva & Moneiro da Cruz, 1993]; and the availability and location of immediate sources of food like gum [Pontes & Soares, 2005]. Sleeping sites are selected to provide overall comfort and safety [Anderson, 1984; Aquino & Encarnación, 1986; Chapman, 1989; Di Bitteti et al., 2000; Li et al., 2006]. As dense canopies like in the Atlantic Forest are unavailable in the Caatinga, sleeping sites were located in more open canopies. Still, as in the Atlantic Forest, the animals chose to sleep close to gum trees.

Overall, common marmosets inhabiting the Caatinga exhibited a number of behavioral differences when compared to the Atlantic Forest living conspecifics. Feeding adaptations for exudates exploitation might have facilitated common marmosets to occupy an environment such as the Caatinga [Amora et al., 2013]. However, their survival ability in such a challenging ambient can only be fully understood when the behavioral dimension is taken into account. Our findings confirm that common marmosets adjust behavioral patterns in order to deal with the high temperatures and resource scarcity that characterize the semi-arid Caatinga,

and highlight their success to survive across a wide range of different environmental conditions.

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ANEXO

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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.

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