UNIVERSIDADE FEDERAL DA PARAÍBA

CENTRO DE CIÊNCIAS EXATAS E DA NATUREZA

PROGRAMA DE PÓS-GRADUAÇÃO EM CIÊNCIAS BIOLÓGICAS

ÁREAS DE CONCENTRAÇÃO: ZOOLOGIA

ISADORA COSTA HAMSI

COMPORTAMENTO E REPRODUÇÃO EM POLEIRO DE QUATRO ESPÉCIES DE MORCEGOS SINANTRÓPICOS NEOTROPICAIS

João Pessoa – PB

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Dissertação apresentada ao Programa de Pós-Graduação em Ciências Biológicas de Universidade Federal da Paraíba como um dos requisitos para obtenção do título de Mestre em Ciências Biológicas: Zoologia.

Orientador: Prof. Dr. Patrício Adriano da Rocha

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Ata da 333ª Apresentação e Banca de Defesa de Mestrado de Isadora Costa Hamsi

Ao(s) vinte e nove dias do mês de julho de dois mil e vinte, às 10:00 horas, no(a) Ambiente Virtual, da Universidade Federal da Paraíba, reuniram-se, em caráter de solenidade pública, membros da banca examinadora para avaliar a dissertação de mestrado de **Isadora Costa Hamsi**, candidato(a) ao grau de Mestre em Ciências Biológicas. A banca examinadora foi composta por orientador(es) **Dr. Patrício Adriano da Rocha, UFPB**; e examinadores **Dr. Erich Arnold Fischer, UFMS/MS** e **Dra. Valeria da Cunha Tavares, UFPB/PB**. Compareceram à solenidade, além do(a) candidato(a) e membros da banca examinadora, alunos e professores do PPGCB. Dando início à sessão, a coordenação fez a abertura dos trabalhos, apresentando o(a) discente e os membros da banca. Foi passada a palavra ao(à) orientador(a), para que assumisse a posição de presidente da sessão. A partir de então, o(a) presidente, após declarar o objeto da solenidade, concedeu a palavra a **Isadora Costa Hamsi**, para que dissertasse, oral e sucintamente, a respeito de seu trabalho intitulado **"ECOLOGIA DE ABRIGO DE MORCEGOS SINANTRÓPICOS NEOTROPICAIS".** Passando então a discorrer sobre o aludido tema, dentro do prazo legal, o(a) candidato(a) foi a seguir arguido(a) pelos examinadores na forma regimental. Em seguida, passou a Comissão, em caráter secreto, a proceder à avaliação e julgamento do trabalho, concluindo por atribuir-lhe o conceito **APROVADO**. Perante o resultado proclamado, os documentos da banca foram preparados para trâmites seguintes. Encerrados os trabalhos, nada mais havendo a tratar, eu, **Dr. Patrício Adriano da Rocha**, como presidente, lavrei a presente ata que, lida e aprovada, assino juntamente com os demais membros da banca examinadora.

João Pessoa, 29/07/2020.

[redacted]

Dr. Patrício Adriano da Rocha

[redacted]

Dr. Erich Arnold Fischer

[redacted]

Dra. Valeria da Cunha Tavares

[redacted]

Isadora Costa Hamsi
(discente ciente do resultado)

*Em modo de webconferência, assinaturas digitalizadas são certificadas pelo(a) orientador(a), presidente da banca.

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RESUMO

A substituição de áreas naturais por paisagens antrópicas traz consigo a importância de entender melhor as necessidades de animais sinantrópicos. Os morcegos são o grupo de mamíferos com maior diversidade em áreas urbanas e muitas espécies se abrigam em construções humanas. Diferentes adaptações são necessárias para a vida sinantrópica, entre elas adaptações comportamentais. Buscamos descrever aspectos da história natural de quatro espécies de morcegos sinantrópicos Neotropicais através de sua ecologia de poleiro na região costeira do nordeste do Brasil. Com uso de câmeras infravermelhas coletamos dados sobre a ecologia de duas espécies em poleiros expostos (*Saccopteryx leptura* e *Rhynchonycteris naso*) e duas em poleiros oculto (*Carollia perspicillata* e *Peropteryx macrotis*). Poleiros estavam localizados na fazenda Pacatuba (Sapé) e na UFPB (João Pessoa), ambas no estado da Paraíba. Todas as espécies se empoleiravam em construções humanas próximas a áreas naturais preservadas. O comportamento foi monitorado com o método *scan sample*. Foram registrados os horários de saída e retorno, tamanho médio do agrupamento e sua variação ao longo do ano, comportamentos sociais, orçamento de atividades, razão sexual ao longo do ano e dados reprodutivos. As espécies em poleiros escondidos foram mais ativas, tiveram interações sociais mais frequentes e adotaram poliginia de defesa de recursos, com machos defendendo o poleiro. Por outro lado, as espécies em poleiros expostos foram menos ativas, as interações sociais foram raras ou inexistentes. O *R. naso* adotou poliginia de defesa de fêmea enquanto o *S. leptura* adotou poliandria, este é o primeiro registro de *S. leptura* adotando poliandria. Todos os grupos foram mais ativos durante o período chuvoso que o seco.

Palavras-chave: Orçamento de Atividade, Comportamento, Reprodução, Interações Sociais.

ABSTRACT

Replacement of natural areas with anthropomorphized landscapes brings a need to understand synanthropic animals. Bats are the mammalian group with the largest diversity in urban areas and many species roost in human constructions. describe aspects of the natural history of four species of Neotropical synanthropic bats through their perch ecology in the coastal region of northeastern Brazil. We monitored the roost using Infrared cameras for a year. Bats were divided according to roosting habits as exposed roosts (*Saccopteryx leptura* e *Rhynchonycteris naso*) or cryptic roosts (*Carollia perspicillata* e *Peropteryx macrotis*). Roosts were located in the Fazenda Pacatuba (Sapé) and UFPB (João Pessoa) both in the state of Paraíba, Brazil. Roosts were all in human constructions and near natural areas. Behavior was monitored with scan samples. A qui-square test used to calculate seasonal difference. We found roost strategies to influence behavior, sociality, and reproduction. Species in cryptic roosts were more active, social interactions were more common during the day and they adopted resource defense polygyny. Species in exposed roosts were less active, social interactions were rare and adopted alternative mating systems. This is the first record of *S. leptura* adopting polyandry. All groups were more active in the rainy season than dry season.

Keywords: Activity Budget, Roosting Behavior, Reproduction, Social Interactions

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A Ordem Chiroptera composta por animais conhecidos popularmente como morcegos, os quais se destacam por serem os únicos mamíferos com a habilidade de voo ativo (Bordignon *et al.*, 2017). Seus membros superiores modificados em asas, com o alongamento dos ossos dos dedos e o desenvolvimento de uma fina membrana vascularizada (Cooper and Sears, 2013). Além disso, desenvolveram ossos leves e finos e, na maioria das espécies, a habilidade de ecolocalização (Bordignon *et al.*, 2017). Apesar de possuírem boa visão, a ecolocalização essencial para o deslocamento e forrageio em todas as famílias neotropicais (Fenton, 2013).

A ordem possui mais de 1400 espécies e é a segunda mais diversa dentre os mamíferos, com cerca de 22% de representatividade (Voigt e Kingston, 2015). Recentemente, teve sua filogenia modificada, com as subordens Megachiroptera e Microchiroptera sendo considerados parafiléticas e, assim, desfeitas. As subordens atualmente reconhecidas são Yangochiroptera, composta por Noctilionoidea, Nataloidea, Molossoidea, Vespertilionoidea, e Yinpterochirotera, composta por Rhynopomatoidea, Rhinolophoidea e Pteropodidae (Amador *et al.*, 2018).

Sua habilidade de voo permitiu aos morcegos se dispersar por todo o mundo, com a exceção do Ártico, da Antártica e de algumas Ilhas Atlânticas isoladas (IUCN 2020). Além disso, exploram também uma grande variedade de nichos. Cerca de 65% das espécies alimentam-se de artrópodes, 22% de frutas, 7% são onívoros, 5% de néctar e menos de 1% se alimentam de vertebrados, com este último grupo incluindo hematófagos e piscívoros (Maas *et al.*, 2016). As várias espécies insetívoras têm importância econômica e social, uma vez que desempenham função de controle *top-down*. Como exemplo, foi descrita a redução de até 32% da oviposição de mosquitos *Culex spp*. (Reiskind and Wund, 2009), potenciais transmissores de patógenos (Kaufman *et al.,* 2017), na presença do morcego *Myotis septentrionalis*. Foi demonstrada também a efetividade de outras espécies no controle de pestes agrícolas em fazendas, aumentando significativamente a produção de plantações (Maas *et al.*, 2016).

Além dos serviços prestados diretamente ao ser humano, há também as vantagens indiretas, através de outros serviços ecológicos (Sarmento *et al.*, 2014). Nectarivoros têm a habilidade de polinizar plantas em fragmentos distantes, sendo essenciais para o setor agrícola e para garantir a diversidade genética de populações de plantas silvestres (Barolia and Singh, 2020). Enquanto que frugívoros são responsáveis por dispersar cerca de 50-90% das árvores e arbustos dependentes de vertebrados em áreas de florestas tropicais, uma vez que defecam longe da planta mãe em voo ou em poleiros de alimentação (Barolia and Singh, 2020). Além

disso, como algumas espécies se alimentam principalmente de espécies pioneiras, morcegos têm função essencial na recuperação de áreas degradadas (Silvestre *et al.,* 2016).

A hematofagia é característica de somente três espécies de morcegos, as quais ocorrem exclusivamente na América Latina: *Desmodus rotundus, Diaemus youngi e Diphylla ecaudata* (Johnson, Aréchiga-Ceballos and Aguilar-Setien, 2014). Destas, o morcego vampiro comum*, D. rotundus*, frequentemente, se alimenta de gado e pode transmitir doenças, entre elas a raiva. Apesar da transmissão para humanos ser pouco comum, uma vez que os casos de vampiros se alimentando de humanos são raros, a função de morcegos como reservatórios do vírus tem grande importância para a saúde pública (Gomes and Uieda, 2004; Johnson, Aréchiga-Ceballos and Aguilar-Setien, 2014). As áreas de maior risco são próximas a áreas desflorestadas, com criação de gado extensiva e presença de estradas, onde o contato com animais silvestres é maior (De Andrade *et al.*, 2016).

Apesar de nem sempre harmoniosa, a interação homem-morcego é extensa, em parte por ser um dos animais com maior diversidade em ambientes degradados, agrícolas e urbanos (Bader *et al.*, 2015; Maas *et al.*, 2016). Morcegos sinantrópicos encontram nas cidades menores níveis de predação e abundância de recursos como: frutas em quintais, insetos atraídos pela iluminação artificial e água nas piscinas e outros reservatórios (Ditchkoff, Saalfeld and Gibson, 2006). Além disso, construções humanas se mostram ótimos poleiros diurnos para algumas espécies, uma vez que são resistentes e eficazes na proteção contra predação e intempéries (Russo and Ancillotto, 2015).

Poleiros são importantes aspectos da vida dos morcegos, uma vez que passam grande parte de suas vidas empoleirados (McCracken and Wilkinson, 2000). Os morcegos são um dos animais mais gregários encontrados na natureza, com grupos que permanecem juntos por anos, e podem formar colônias mistas de mais de um milhão de indivíduos (Brooke, 1997; Wilkinson *et al.*, 2019). Algumas espécies dividem seu poleiro com membros de espécies distintas, podendo dar preferência a estes do que a membros de sua própria espécie, como visto com *Pipistrellus kuhlii* e *Hypsugo savii* (Ancillotto *et al.*, 2014). Porém, Kerth (2008) discute que espécies que empoleiram em grupos, mas não apresetam interações cooperativas, sociais ou afiliativas não devem ser consideradas como sociais. Morcegos como *Leptonycteris curasoae* formam grandes maternidades, sem aparentar qualquer interação social, salvo mãe-filhote (Fleming, Nelson and Dalton, 1998). Em contraste, na espécie *Nycticeius humeralis*, as fêmeas foram documentadas amamentando qualquer filhote da colônia, independentemente de seu parentesco (Kerth, 2008). Outros comportamentos sociais já registrados em morcegos são: limpeza, toque de focinho, divisão de comida, cuidado com filhotes alheios e auxílio no parto e pós-parto (Kunz *et al.*, 1994;

Kerth *et al.*, 2003; Bohn, Moss and Wilkinson, 2009; Carter and Wilkinson, 2013; Ancillotto *et al.*, 2014; Rathinakumar *et al.*, 2017).

Morcegos apresentam menos comportamentos agonísticosdo que é encontrado em outros mamíferos (Kerth, 2008). Comportamentos agonísticos previamente registrados em poleiros são: voos rasantes, bater de asas para parecer maior, empurrões, boxear e mostra de dentes, sendo estes comportamentos mais comuns entre machos e comumente atrelado à defesa de recurso e defesa de fêmeas (Porter, 1978; Kerth, 2008). Fêmeas não costumam apresentar comportamentos agonísticos em poleiros (Bradbury and Vehrencamp, 1977b; Kerth, 2008), mas podem apresentar comportamento territorial em áreas de forrageio (Rydell, 1986).

A organização social dos morcegos se divide em três categorias mais comuns: 1) único macho com várias fêmeas (poliginia), 2) vários machos com várias fêmeas e 3) único macho com única fêmea (monogâmia). A depender da espécie a organização pode manter-se durante todo o ano, recebendo o nome de fixa, ou ocorrer apenas no período reprodutivo, sendo chamada de sazonal (McCracken and Wilkinson, 2000). Morcegos conformam-se à tendência identificada em mamíferos, dos quais mais de 90% das espécies são caracterizadas por poliginia (Racey and Entwistle, 2000). Na maioria das espécies, fêmeas dão à luz a um filhote por gestação, com algumas exceções como nos gêneros *Lasiurus* e *Eptesicus*, que podem gerar mais de um filhote por vez (ver Taylor, 2019). Podem apresentar uma ou múltiplas gestações no ano (monoestria ou poliestria, respectivamente), as quais podem ser sazonais ou assazonais. Filhotes normalmente mamam até atingirem o tamanho adulto, o que costuma levar algumas semanas, mas a maturidade sexual é tardia para o tamanho, sendo mais comum com cerca de três anos (Kurta and Kunz, 1987).

Na maioria das espécies, filhotes nascem altriciais, isto é, sem pelos e incapazes de voar até chegar a 90% do tamanho adulto (Racey and Entwistle, 2000). Cuidados parentais incluem limpeza do filhote, amamentação, regurgitação de sangue (no caso do morcego vampiro, *D. rotundus*), termorregulação, interações sensoriais e transporte durante forrageio ou para poleiros alternativos e recuperação (Kunz and Hood, 2000). Apesar da fêmea ser comumente quem cuida dos filhotes, existem espécies em que o macho fornece alguns cuidados (*e.g*. machos de *Carollia perspicillata* protegem filhotes caídos e os direcionam as mães) (Porter, 1979b).

O hábito exclusivamente noturno e ou crepuscular dos morcegos oferece um grande desafio a pesquisadores. Além disso, a maioria das espécies vocaliza, principalmente, em altas frequências, possuem coloração discreta, seus poleiros costumam ser altamente inconspícuos e os indivíduos mostram-se sensíveis à presença de observadores humanos. Para a pesquisa

efetiva do grupo, os métodos de coleta de morcegos tiveram que se adaptar a esses desafios (Bradbury, 2016).

Como a observação direta do grupo é difícil, artefatos tecnológicos de detecção têm sido usados para a coleta eficaz de dados confiáveis da história de vida dos morcegos (ex. Pereira *et al.*, 2018; Rocha *et al.*, 2017). Registros acústicos com gravadores de ultrassom permitem uma melhor amostragem de morcegos não-Phyllostomidae, auxiliando tanto em inventários quanto em estudos ecológicos de uso de hábitat e atividade noturna (Denzinger and Schnitzler, 2013; Whitby *et al.*, 2014; Arias-Aguilar *et al.*, 2018). O uso de câmera térmica infravermelha pode estimar o tamanho de uma população de milhares de morcegos, além da atividade noturna de forrageio de uma espécie e, também, auxiliar na criação de medidas de conservação (Frank *et al.*, 2003; Horn, Arnett e Kunz, 2008; Ammerman *et al.*, 2009). A aplicação de câmeras remotas com infravermelho permite a observação direta de morcegos em seu poleiro com o mínimo de interferência, permitindo um estudo mais detalhado e confiável do seu comportamento natural (Codd, Sanderson and Branford, 2003; Ramanantsalama *et al.*, 2019). Estudos que utilizam estas tecnologias esclarecem dados muito importantes e vêm crescendo a cada ano, mas têm como desvantagem o custo financeiro, que pode ser limitante (Ditchkoff, Saalfeld and Gibson, 2006).

Descrição das espécies estudadas:

O Brasil apresenta cerca de 15% das espécies de morcegos do mundo, com mais de 180 espécies registradas. Estas espécies estão distribuídas em nove famílias, todas pertencentes à subordem Yangochiroptera (Amador *et al.*, 2018).

Família Phyllostomidae

É a família mais rica do Brasil, com 93 espécies e 10 gêneros, possui representantes em todos os biomas e estados do país. É caracterizada, principalmente, por uma folha nasal membranosa na extremidade do focinho em forma de lança ou folha (Batista *et al.,* 2017).

Carollia perspicillata (Linnaeus, 1758): tamanho médio de Cabeça-Corpo de 42,5 a 62 mm, antebraço de 37,5 a 45 mm, cauda de 10 a 15 mm, completamente, inserida no uropatágio, que está preso ao calcâneo; peso de 17 g; lábio inferior em forma de V com uma verruga grande central e pequenas verrugas marginais; folha nasal curta e triangular; coloração varia de castanho-acinzentado até cor de ferrugem clara. Fórmula dentária: i 2/2, c 1/1, pm 2/2, m 3/3 = 32 dentes (Sekiama, Rocha and Peracchi, 2013). Esta espécie é encontrada do México até a

América do Sul. No Brasil, só não existem registros no extremo Sul (Gardner, 2008). Já foi capturada em habitat florestal, áreas reflorestadas, ambiente degradado e urbano. Abriga-se em ocos de árvores, fendas de cavernas, folhagem e construções humanas (Sekiama, Rocha and Peracchi, 2013). A espécie apresenta poliestria bimodal sazonal, gestação de quatro meses e costuma dar à luz a apenas um filhote (Fleming, Hooper and Wilson, 1972; Coelho, 2005). É preferencialmente frugívora, forrageando nos sub-bosques. Alimenta se de preferência de Piperaceae do gênero *Piper*, mas também de espécies de Solaceae, Moreaceae, Clusiaceae e Urticaceae, além de complementar sua dieta com pólen, folhas e insetos (Fleming, 1987; Batista *et al.*, 2017; Rocha *et al.*, 2017).

Família Emballonuridae

Tem distribuição Pantropical, ocorrendo na África, Península Árabe, no Sul da Ásia e nas Américas. Nas Américas, ocorre do México até o Sudeste do Brasil. No Brasil, é registrada apenas uma subfamília, com 7 gêneros e 17 espécies. Caracterizada pela presença de bolsas glandulares em machos de grande parte das espécies, que produzem odores fortes para atrair fêmeas, que por sua vez, possuem a bolsa reduzida ou atrofiada. A cauda corresponde à metade do uropatágio e o perfura dorsalmente. O segundo dígito da mão é composto pelo metacarpo, e o terceiro possui duas falanges (Esbérard, Ferraciolo and Tavares, 2017).

Peropteryx macrotis (Wagner, 1843): possui comprimento de 53 a 65 mm, antebraço de 38,3 a 48 mm, cauda de 11 a 18 mm e peso de 3 a 9,2 g. Não apresenta banda de pele interligando as orelhas. Sua cor varia de cinza a marrom avermelhado, com a região dorsal um pouco mais clara. Fórmula dentária: i 1/3, c 1/1, pm 2/2, m 3/3 = 32 dentes (Yee, 2000). Ocorre do México ao Peru, Bolívia, Paraguai e Brasil (Yee, 2000; Díaz *et al.*, 2019). Dentro do Brasil só não foi registrado na região Sul (Esbérard, Ferraciolo and Tavares, 2017). Esta espécie é frequente em áreas de borda, sendo encontrada em florestas primárias e secundárias, savanas, áreas de cultivo e matrizes urbanas (Handley-Jr, 1987; Simmons and Voss, 1998; Barboza-Marquez *et al.*, 2013). Abriga-se em cavernas, fendas, construções humanas e ocos de árvores, com grupos de 1 a 10 indivíduos; mas em determinadas situações, o grupo pode chegar a 80 indivíduos (Beltrão *et al.,* 2015; Nogueira *et al.,* 2007; Yee, 2000). Apresenta poliestria, gestação de 4 a 4,5 meses. Possui dimorfismo sexual, onde as fêmeas são maiores do que os machos (Yee, 2000). A espécie é insetívora, alimenta-se principalmente de Dípteras e Coleópteras (Bradbury e Vehrencamp, 1976a). São forrageadores aéreos de borda, usualmente encontrados em estratos mais altos e próximos a habitações humanas, ao redor de luzes artificiais (Denzinger,

Tschapka e Schnitzler, 2018; Yee, 2000) e muito comumente em sobre corpos d'água (P.A. Rocha, comunicação pessoal).

Rhynchonycteris naso (Wied-Neuwied, 1820): Espécie pequena, cabeça-corpo de 37 a 46 mm, antebraço de 35 a 40 mm, cauda de 11 a 16,84 mm. A espécie é caracterizada pelo focinho alongado pontudo e pela presença de tufos de pelo branco na região dorsal do antebraço. A pelagem do dorso é grisalha com duas linhas brancas, paralelas longitudinais sinuosas, não possui bolsas glandulares, o calcâneo é maior que a tíbia. Fórmula dentária: i 1/3, c 1/1, pm /2, m 3/3 = 32 dentes (Plumpton and Jones-Jr., 1992; Peracchi and Nogueira, 2008). Foi encontrada no Sul do México, na América Central, e na América do Sul até Peru, Bolívia e Brasil (Salas *et al.* 2013). A espécie é encontrada em florestas primárias, secundárias e áreas de cultivo(Reis *et al.*, 2013). Indivíduos empoleiram-se em poleiros expostos, como troncos, galhos, fendas, entrada de cavernas e habitações humanas (Esberárd *et al.,* 2017). As colônias têm de 3 a 80 indivíduos, que se mantêm imóveis, com ocasional balanço sincrônico quando o vento bate, para parecerem mais com a vegetação e disfarçar comportamentos como autolimpeza e urinar (Knörnschild *et al.*, 2009). Apresentam poliestria bimodal, de caráter assincrônico, com um filhote por gestação (Bradbury and Vehrencamp, 1977b). Os animais são insetívoros, se alimentam principalmente de Dípteros, Coleópteros, Tricópteros e Quironomídeos (Esberárd *et al.,* 2017). São forrageadores aéreos de borda, geralmente sobre corpos de água e durante o crepúsculo (Denzinger, Tschapka e Schnitzler, 2018; Plumpton e Jones, 1992).

Saccopteryx leptura (Schreber, 1774): Comprimento de Cabeça-Corpo de 52 a 69 mm, antebraço de 36 a 38 mm, cauda de 8 a 17,7 mm, peso de 3,8 a 6,4 g. Os animais desta espécie são caracterizados por pelagem dorsal marrom clara, com listras dorsais sinuosas menos pronunciadas do que as das outras espécies do gênero; ventre mais claro, podendo ser marrom-acinzentado; orelhas pontudas, com a margem superior externa côncava e trago com bordas dentadas, e uma bolsa glandular no propatágio. Fórmula dentária: i 1/3, c 1/, pm 2/2, m 3/3 = 32 dentes (Peracchi and Nogueira, 2008). Apresenta registro do Sul do México até Peru, Brasil e Bolívia (Hood *et al.*, 2007). A espécie é encontrada em florestas primárias e secundárias, fazendas e ambientes urbanos (Esberárd *et al.,* 2017). Abriga-se em troncos de árvores grandes e construções humanas, em locais expostos e bem iluminados. A espécie se reproduz antes do período chuvoso e aparenta ser monogâmica, com grupos compostos de 1 a 9 indivíduos (Bradbury and Vehrencamp, 1977a). São animais insetívoros, que se alimentam principalmente de Coleópteras e Himenópteras (Reis and Peracchi, 1987; Nogueira, Peracchi and Pol, 2002). São forrageadores aéreos de borda (Denzinger, Tschapka and Schnitzler, 2018). As colônias apresentam área específica de forrageio, a qual é defendida (Barboza-Marquez *et al.*, 2013).

2. OBJETIVOS:

Objetivo Geral

Descrever aspectos da história natural de quatro espécies de morcegos sinantrópicos Neotropicais através de sua ecologia de poleiro na região costeira do nordeste do Brasil.

Objetivos Específicos

- Calcular o orçamento de atividadede cada espécie, isto é: a frequência das atividades e sua distribuição em diferentes horários e estações.
- Comparar o orçamento de atividades entre as espécies e correlaciona-lo com o hábito de empoleiramento das mesmas.
- Descrever as interações sociais entre os membros dos grupos estudados levando em conta seu sexo e sazonalidade.
- Descrever os aspectos reprodutivos das espécies estudadas (tais como a organização social e ciclo reprodutivo) e seus efeitos na atividade do grupo.

3. CAPÍTULO I

Roost Ecology of Neotropical Synanthropic Bats

Abstracts

Replacement of natural areas with anthropomorphized landscapes brings a need to understand synanthropic animals. Bats are the mammalian group with the largest diversity in urban areas and many species roost in human constructions. But different species have particular roost strategies and needs. We monitored roost ecology of four Neotropical synanthropic bats for a year using Infrared cameras, two in exposed roosts (*Saccopteryx leptura* e *Rhynchonycteris naso*) and two in cryptic roosts (*Carollia perspicillata* e *Peropteryx macrotis*). We found roost strategies to influence behavior, sociality, and reproduction. Species in cryptic roosts were more active, social interactions were more common during the day and they adopted resource defense polygyny. Species in exposed roosts were less active, social interactions were rare and adopted alternative mating systems. This is the first record of *S. leptura* adopting polyandry. All groups were more active in the rainy season than dry season. We concluded that studied bats were highly fitted to manmade roosts but are still dependent on natural areas for foraging and alternative roosting, highlighting the importance of green environments in anthropic landscapes.

Keywords: Activity Budget, Roosting Behavior, Reproduction, Social Interactions

INTRODUCTION

Natural habitats are rapidly being replaced with anthropic landscapes, such as urban areas and farmlands (Diniz-Filho *et al.*, 2009; Xie *et al.*, 2018). Habitat loss and fragmentation have a strong negative impact in biodiversity and ecosystem functions (Thompson, Rayfield and Gonzalez, 2017). However, natural and non-natural habitats are not binary states and anthropic matrix have varying degrees of natural areas (e.g. parks and natural reserves) (Fardila *et al.*, 2017). These natural areas positively influencing the biodiversity of anthropic landscapes (Gorresen and Willig, 2004). Many anthropic species are found in association with human constructions, given they are able to retain temperature and humidity and protect against predators, these species as called synanthropic (Voigt and Kingston, 2015; Nunes, Rocha and Cordeiro-Estrela, 2017).

Bats are probably the mammalian group with the largest diversity in anthropic areas (Jung and Threlfall, 2015). In some cases, bats richness and abundance were found to be higher in

intermediate areas, such as suburbs, when compared to natural areas (Russo and Ancillotto, 2015). Still, bats response to human interference is very species-specific and only few opportunistic species can thrive in highly disturbed areas (Russo and Ancillotto, 2014; Bader *et al.*, 2015). Species fitted to anthropic areas are usually generalist, showing a more flexible diet or roost requirements (Ditchkoff, Saalfeld and Gibson, 2006). Some insectivorous bats benefit from artificial lights attracting moths (Spoelstra *et al.*, 2017), while frugivorous and nectarivorous may find off-season fruits and flowers on gardens and parks (Bredt, Uieda and Pereira Pinto, 2002; Diniz, Lima and Machado, 2019). Unnatural sources of water, such as swimming pools or artificial lakes are important resources (Russo, Cistrone and Jones, 2012). Furthermore, many species have found human constructions to be highly suitable for roosting (Bredt, Uieda and Pereira Pinto, 2002; Nunes, Rocha and Cordeiro-Estrela, 2017).

Bats spend most of their lives in roosts, which in turn affects other aspects of its life, such as sociality, reproduction and behavior (Kunz, 1982). Studies on bat roosting mostly focus on roost selection (e.g. Barclay, Faure and Farr, 1988; Brigham *et al.*, 1997; Lausen and Barclay, 2002), roost organization (e.g. Vaughan and O'Shea, 1976; Watkins and Shump, 1981; Rodrigues *et al.*, 2003) and daily or seasonally roost use (e.g. Hirshfeld, Nelson and Bradley, 1977; Hall, 1982; Leonard and Fenton, 1983). Some studies have addressed aspects of bats behavior inside the roost (e.g. Nogueira and Pol, 1998; Kerth, Wagner and König, 2001; Knörnschild *et al.*, 2009), but few have systematically described the activity budget (e.g. Burnett and August, 1981; Codd, Sanderson and Branford, 2003; Connell, Munro and Torpy, 2006). The activity budget is an estimation of the amount of time an individual or group allocates to each activity and can be used to evaluate possible effects of environmental perturbations (Jacobsen and Wiggins, 1982). Changes in behavior are a common adaptations for life in cities (Jokimäki *et al.*, 2011), such as temporal activity patterns, foraging behavior and human tolerance (Ditchkoff, Saalfeld and Gibson, 2006; Møller, 2009). But behavior studies with urban bats are still rare (e.g. Diniz, Lima and Machado, 2019), especially those focused on roosting activity(e.g. Burnett and August, 1981; Bredt and Uieda, 1996; Winchell and Kunz, 1996).

The present study aims to describe aspects of the natural history of Neotropical synanthropic bats within their roost. We examined the roost behavior of four species with distinct roosting habits. *Saccopteryx leptura and Rhynchonycteris naso,* that use exposed roosts and depend on camouflage for protection (Bradbury and Vehrencamp, 1976a), and *Peropteryx macrotis* and *Carollia perspicillata,* that use cryptic roosts (Sekiama, Rocha and Peracchi, 2013; Beltrão *et al.*, 2015).

METHODS

Study Area

The studied roosts are located in two different sites, with distinct levels of disturbance. Both are in the coastal region of Paraiba state, northeast Brazil (Figure 2A). The seasons are divided in rainy, March to August, with an average accumulative precipitation of 262.1 mm and dry, September to February, with an average accumulative precipitation of 57.0 mm (Pereira *et al.* 2012; INMET, 2020) (Figure 1). The climate is tropical, hot, and humid. The main natural vegetation is the Atlantic Rainforest. Temperature variation is low, averaging 26.36 ºC in rainy and 27.33 ºC in dry (Bezerra and Martins, 2001; INMET, 2020).

Federal University of Paraiba (UFPB) campus site, in Joao Pessoa the capital of Paraiba State, (07º2'56" S, 35º09'44"W). The city is one of the greenest capitals in the country with 78,4 % of afforested public road (IBGE, 2010) and two protected units within the city: the Zoobotanic Arruda Câmara Park (hereafter Bica) with 26.8 ha and the Botanic Garden Benjamim Maranhão (hereafter Mata do Buraquinho*)* with 515 ha (IDME, 2011). The campus is a green urban environment, full of native and exotic plants (Bezerra and Martins, 2001) and the Ecological Reserve of the Department of Systematic and Ecology (hereafter ERDSE), estimated to be around 5.64 ha, in its property and the Botanic Garden across the road. The vegetation within the two reserves is predominantly secondary Atlantic Rainforest (Figure 2B) (Bezerra and Martins, 2001; IDME, 2011).

Fazenda Pacatuba, a Private Natural Heritage Reserve in Paraiba State, (7°08'20" S, 34°50′41"W) around 60 km from the state capital. It was created in 1995 to protect a population of red-handed howler monkeys. It has an area of 266.53 ha of Atlantic Forest with the main vegetation of seasonal semi-decidual forest, surrounded by sugar-cane plantation (Silvestre and Xavier 2013). Bats roost in an old abandoned house, in the sugar-cane workers' village, near the reserve (Figure 2C and D). At the time of the study, at least five bat species were found roosting this house: *Carollia perspicillata* (Linnaeus, 1758), *Glossophaga soricina* (Pallas, 1766), *Myotis sp*., *Peropteryx macrotis* (Wagner, 1843) in the basement and *Rhynchonycteris naso* (Wied-Neuwied, 1820) in the balcony.

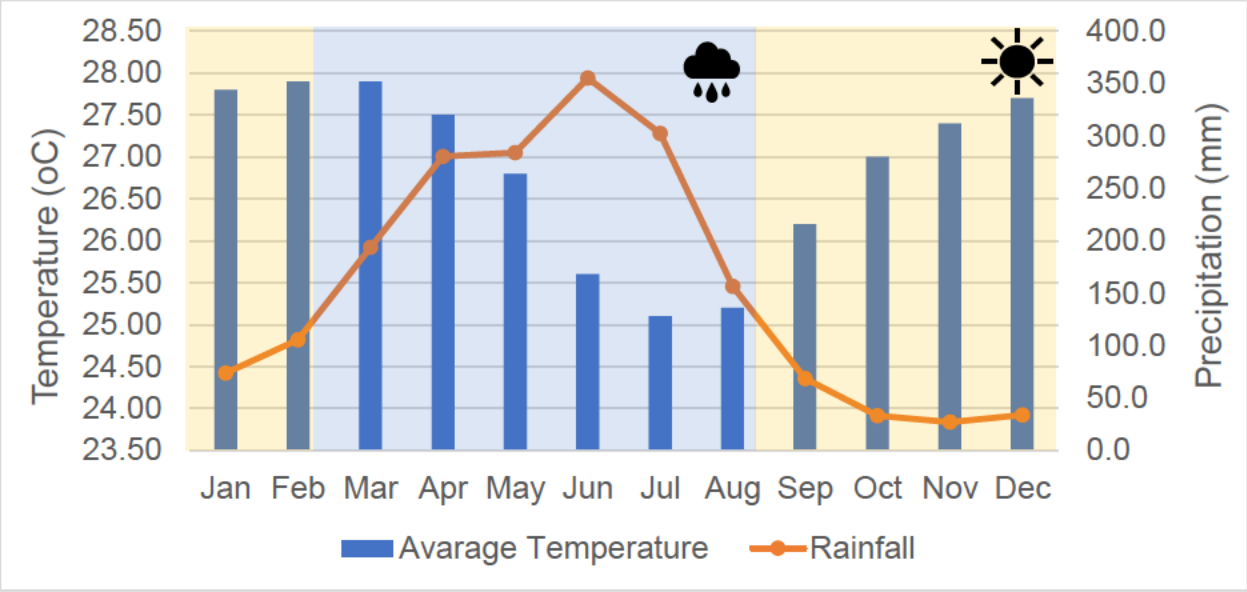


Figure 1: Temperature and precipitation of the coastal region of Paraiba-BR. Joao Pessoa Meteorological station (INMET 2020).

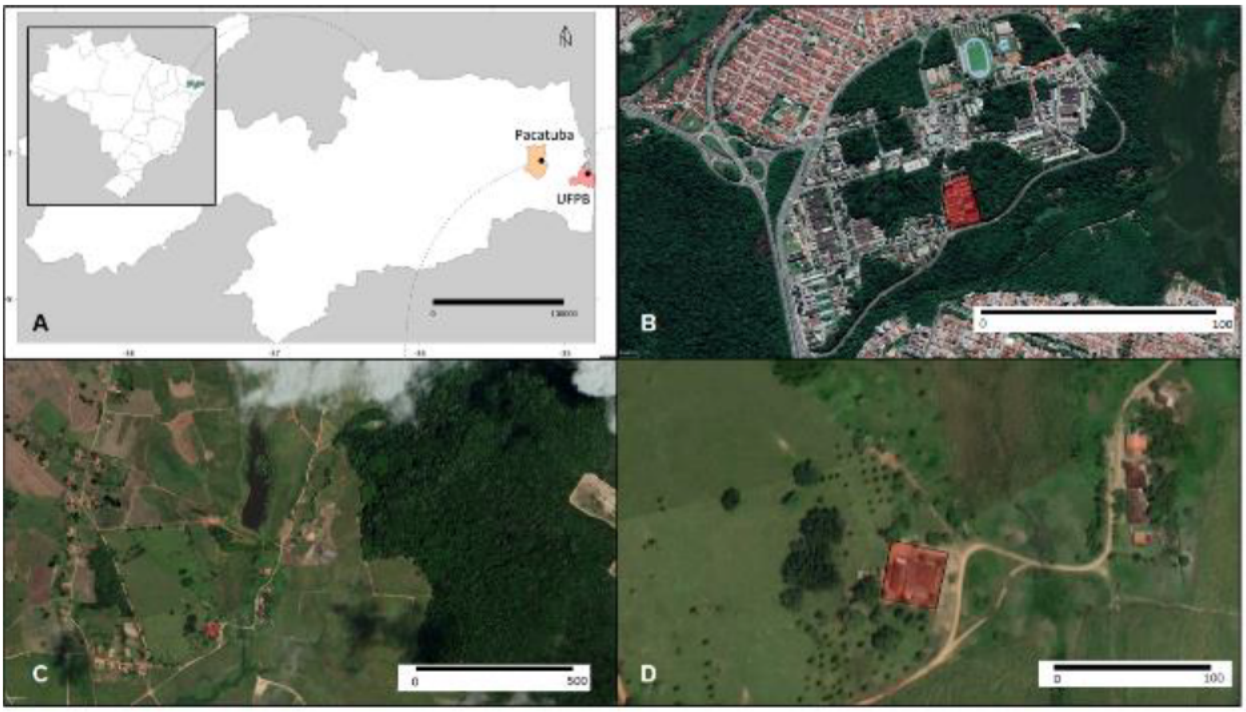


Figure 2: Study areas. A: Geographic location of Pacatuba Farm, Sape and Federal University of Paraiba (UFPB), João Pessoa both in Paraiba-BR. B: Satellite picture of the UFPB, with the Center for Exact and Natural Sciences highlighted. A part of the Botanic Garden Benjamim Maranhão can be seen in the Southwest and the Ecological Reserve of the Department of Systematic and Ecology in the Southeast.

C: Satellite picture of the Pacatuba Farm, with the Abandoned House highlighted and the Private Natural Heritage Reserve visible in the East. D: A closer view of the Abandoned House. The scale is in Km.

Study groups

We acknowledge that different terms have been proposed to address bats units according to social interactions, such as colony, group and society (Kerth, 2008). Nevertheless, to avoid unnecessary confusion, we will henceforth refer to all studied social unities roosting together as a “group” regardless socialty.

Groups in the UFPB Campus Site:

The studied groups in UFPB campus site comprise the lesser sac-winged bats, *Saccopterys leptura* (Schreber, 1774). The lesser sac-winged bat received this name due to the presence of a glandular sac on the propatagium, which produces odor in males. It can be identified by its brown back with two parallel sinuous white stripes (Peracchi e Nogueira, 2008). The species occurs from southern Mexico to Peru, Bolivia, and most of Brazil (Hood *et al.*, 2007). It lives in primary and secondary forests, farms, and urban areas (Esberárd et al., 2017). The species roosts on well-lit exposed surfaces, both natural, like trees, and urban, like buildings (Bradbury and Vehrencamp, 1977a). These bats are monogamous and form small groups of one to five adults, including one female, one male and few subadult females (Bradbury and Vehrencamp, 1976a). It is an edge space aerial forager (Denzinger, Tschapka and Schnitzler, 2018) that feeds mainly Coleoptera and Himenoptera (Reis and Peracchi, 1987; Nogueira, Peracchi and Pol, 2002) and defends its foraging site against other groups (Barboza-Marquez *et al.*, 2013).

Three groups have been found in the Center of Exact and Natural Sciences buildings. The groups were named after the building where they roosting at: Department of Systematics and Ecology - DSE, Department of Geography - Geo, and the Unfinished building - Unf (Figure 3). The DSE group roosted on the porch, facing towards the building. This group was composed of six bats, four males and two females. The Geo group roosted on red bricks in the corridor and was much less stable, with one female and 3 to 5 males. Two of the males used to keep a greater distance. The last group, Unf, was formed by one female and two males and roosted on the concrete wall of a construction building corridor. Due to the constant disturbance in the building, this colony moved often inside the building.

Figure 3: *Saccopteryx leptura* roosting in buildings at the Center for Exact and Natural Sciences at the Federal University of Paraiba (UFPB), Joao Pessoa, Brazil. **A**: Location of each group roost. **B**: The Department of Systematics and Ecology group (DSE) group; **C**: The group in the unfinished building (Unf); **D**: The Geography group (Geo). (2018).

Groups in the Pacatuba Farm Site:

Three species roosting at the Pacatuba house were chosen for this study: *Carollia perspicillata*, *Peropteryx macrotis* and *Rhynchonycteris naso*.

Carollia perspicillata is a common bat from the Phyllostomidae family. It is found from Mexico to South America. It is mid-sized, weighing around 17g. Its most distinguishing feature is a V shape inferior lip, surrounded by a mole (Sekiama, Rocha and Peracchi, 2013). The species is common in urban and other disturbed areas and has been found to roost in trees hollows, caves, leaves and human constructions (Sekiama *et al.,* 2013). It is mainly frugivorous, being one of the main dispersers of the genera *Piper*, but can also feed on other fruits, pollen, insects and leaves (Batista *et al.*, 2017; Rocha *et al.*, 2017). It is a narrow space passive/active gleaning forager (Denzinger, Tschapka and Schnitzler, 2018). Their mating system is polygyny and the resident male defends its roost from other males (Williams, 1986). Females have seasonal polyestry, a four-month gestational period and usually give birth to a single pup (Fleming, Hooper and Wilson, 1972; Coelho, 2005).

The studied roost was in a cramped space in the basement with a wood ceiling. The amount of guano on the floor suggests the room has been used by bats for a long time. The group was widely distributed over a large area, so only a portion of it has been recorded. More than 30 individuals have been recorded roosting together at once (Figure 4).

Figure 4: *Carollia perspicillata* group roosting in the basement of the Abandoned House in the Pacatuba Farm, Sape - PB, Brazil (2018).

Peropteryx macrotis, the lesser dog-like bat, has strong sexual dimorphism, with females being a lot bigger than males (Yee, 2000). It is found from Mexico to Peru, Bolivia, Paraguay, and Brazil (Yee, 2000; Díaz *et al.*, 2019). This species has been found to roost in cave entrances, crevices, tree hollows and human buildings (Yee, 2000; Beltrão *et al.*, 2015). Males roost with many females and defend their roost (Smith, 2008). Gestation takes 4 to 4.5 months, results in a single pup and may occur twice a year (Yee, 2000) It is an edge spaces aerial forager found above human constructions, such as roads and light pole (Yee, 2000) and feed mainly on Diptera and Coleoptera (Denzinger, Tschapka and Schnitzler, 2018).

The roost was at the basement entrance. There were at least four agglomarations near each other, one of which was randomly chosen for observation. The observed group was composed of three to five bats of unknown sex (Figure 5).

Figure 5: *Peropteryx macrotis* group roosting near the entrance of the basement of the Abandoned House in the Pacatuba Farm, Sape - PB, Brazil (2018).

Rhynchonycteris naso is a small bat weighing from 3,5 to 6 g and characterized by a long and pointy nose, white fur on its forearm, two parallel sinuous white lines on its back and the absence of a glandular sac (Plumpton and Jones-Jr., 1992; Peracchi and Nogueira, 2008). Distributed from Central America to the north of South America (Salas *et al.*, 2013), the species is found near water bodies where it forages for insects as an edge space trawling forager (Denzinger, Tschapka and Schnitzler, 2018).The bats roosts on exposed surfaces like trees, caves entrances and buildings (Gomes and Esbérard, 2017) Groups are usually small, from three to ten, but can get as big as 80 individuals (Knörnschild *et al.*, 2009). Females have bimodal reproduction and usually give birth to a single pup (Bradbury and Vehrencamp, 1976b)

The studied group roosted on wood planks at the veranda's ceiling and were very well camouflaged. We estimate the group to be composed of 20 to 25 individuals, but only a portion was visible at a given angle (Figure 6). The house was located at around 335m from a lake.

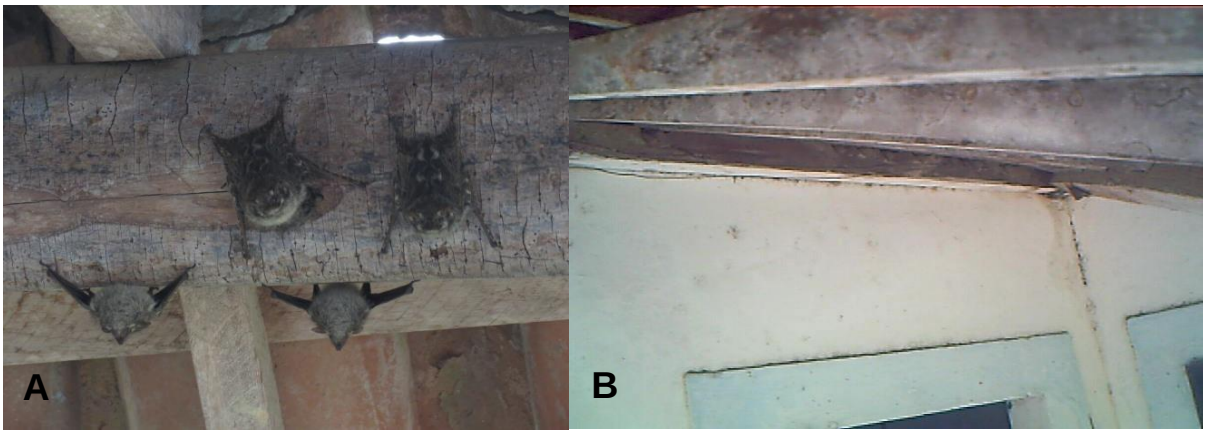


Figure 6: **A**:*Rhynchonycteris naso* group roosting in the porch of the Abandoned House in the Pacatuba Farm, Sape - PB, Brazil. (2018). **B**: camera view of the group.

Data Sampling

Each roost was recorded with an infrared camera trap (Bushnell Trophy Cam 119436). All cameras were set to record 10 seconds videos every 15 minutes to allow for scan sampling data collection (Winchell and Kunz, 1993). Each roost was recorded for 8 days, every month, during a year (Figure 7A). Besides recording at the set 15 minutes interval, the cameras sometimes recorded when movement was detected, this default setting could not be turned off. As a result the total amount of recordings were different for each group.

Data were collected from March 2018 to February 2019. In total, 27,772 videos have been analyzed: 9,588 videos of *C. perspicillata*, 11,082 videos of *P. macrotis*, 4,121 videos of *S. leptura* (only the DSE group), and 2,981 videos of *R. naso.* All videos have been watched by the first author to avoid inter-observer bias.To correctly identify and categorize different behaviors and create an ethogram (Table 1), a set of videos were examined for each group. Additionally, we also computed the number of individuals per roost, presence of pups, and sex of group members.

Complementary data was recorded for the three *S. leptura* groups in the campus. Weekly photos of the groups were taken through February and March of 2018 to follow births and pup development (Figure 7B). Preliminary acoustic data was recorded during daytime in the roost and nighttime in different points in the ERDSE, with two ultrasonic recorders (SM4BAT and AUDIOMOTH). Once the video recording ceased, the groups were captured, measured, and sexed.

Table 1: Behavior ethogram for the scan sampling classification. *Behaviors not frequent enough for data analyses.

Behavior	**Description**
Resting	Not moving any part of the body in a significant manner. Eyes may be open or closed
Swinging	Rapidly swaying from side to side while both feet remain attached to the surface of the roost
Grooming	Licking its wings and torso and scratching itself with hind limb
Relocating	Crawling or flying (If a bat is seen flying but does not land it will not be recorded, as it is not possible to determine if many bats are moving or one circling)
Social Interaction*	Any behavior aimed at another adult bat (eg. Nosing, boxing, shoving, allogrooming)
Flight Practice*	Pup rapidly flapping its wings while hind-legs hold on to the ceiling or wall
Feeding*	Handling and ingesting food
Other*	Other behavior not previously described

Figure 7: Illustration of data collection. A: repositioning of camera trap towards *R. naso* group at *Fazenda Pacatuba.* B: Photo of *S. leptura* on the UFPB campus.

Data Analyses

We analyzed each roosting group separately. To detect differences in behavior frequency between the dry and rainy season, a chi-square test of independence was used. A Bonferoni Z-test was then applied to determine which behaviors were significantly different between the seasons. In the case of the *R. naso*, which used the site as a day and night roost, a paired z-test was also run to test for differences between daytime and nighttime activity. Bats were considered as "Active" whenever they were not resting.

RESULTS

Saccopteryx leptura:

Behavior and Activity

All three groups of *S. leptura* chose roosted in spot high up in the wall. None of them were well camouflaged in the wall, but all of them kept completely still until someone attempted closer contact, prompting the individuals to fly away to the forest fragment. By following the DSE group the roost was identified as always being the same tree.

The DSE group showed a very fixed line positioning, to the point that the wall was marked by urine (Figure 3). However, right after the start of data collection, an air conditioner was installed next to the roost, forcing a few members to change position whenever it was turned on. The Geo and Unf groups had more fluid positioning and the Unf group moved to other locations in the building more than once during data collection due to human disturbances. Eventually, the Unf group setted in a conspicuous external area for air conditioner units that was empty.

Daytime activity budget (Table 2) shows that Resting is predominant (90.54 %) while other behaviors are scarce and have higher frequency before emergence and after return, as bats stayed mostly still throughout the day (Figure 8). A significant difference in activity budget was found between seasons for the daytime roost activity (X^2 = 31.484, df = 3, p = 0.00). There was a significant increase in Resting (p <0.05) and a decrease in Grooming and Swinging (p <0.05) from rainy to dry seasons, while Moving did not differ significantly (p >0.05).

Nighttime roosting activity was not recorded in video, since the group was never present at night. Emergence began around 40 minutes before sunset and return was around 30 minutes after sunrise. There were no records of bats returning at night, meaning that the roost was used exclusively during daytime (Figure 8).

Table 2: *S.* Activity budget of a *Saccopteryx leptura* group roosting in the Federal University of Paraiba, João Pessoa, Paraiba-Br. From March 2018 to February 2019.

Behavior	Rainy		Dry		Year-round	
	Day	Night	Day	Night	Day	Night
Resting	88.54%		92.03%		90.54%	
Swinging	4.51%		3.64%		4.01%	
Grooming	6.35%		4.96%		4.98%	
Moving	0.58%		0.36%		0.47%	

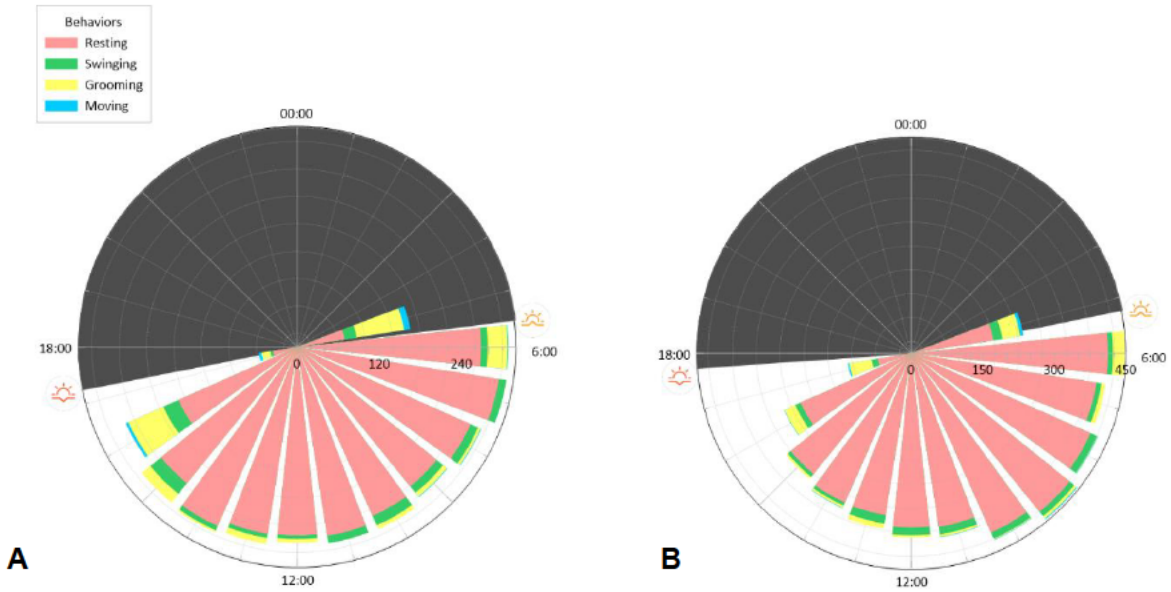


Figure 8: Rosetta diagram illustrating the behavior frequency and distribution throughout the day of a *Saccopteryx leptura* group roosting in a building at the Federal University of Paraiba, João Pessoa, Paraiba-Br: **A**. Rainy season from March to August 2018. **B**. Dry season from September 2018 to February 2019.

Acoustic Behavior

Ultrasound recordings at night in the reserve pointed to two peaks in food activity, one from 17:00-18:00, followed by a decrease in activity reaching zero by 22:00 and rising again for a second smaller peak from 3:00-4:00 (Figure 9). The lack of activity from 22:00-01:00 indicates the group had a night roost in the fragment, but the same was not found. Preliminary recordings in the dayroost of the DSE group showed bats emitting a diverse array of conversational signals throughout the day. These recordings were not further analysed in the current work.

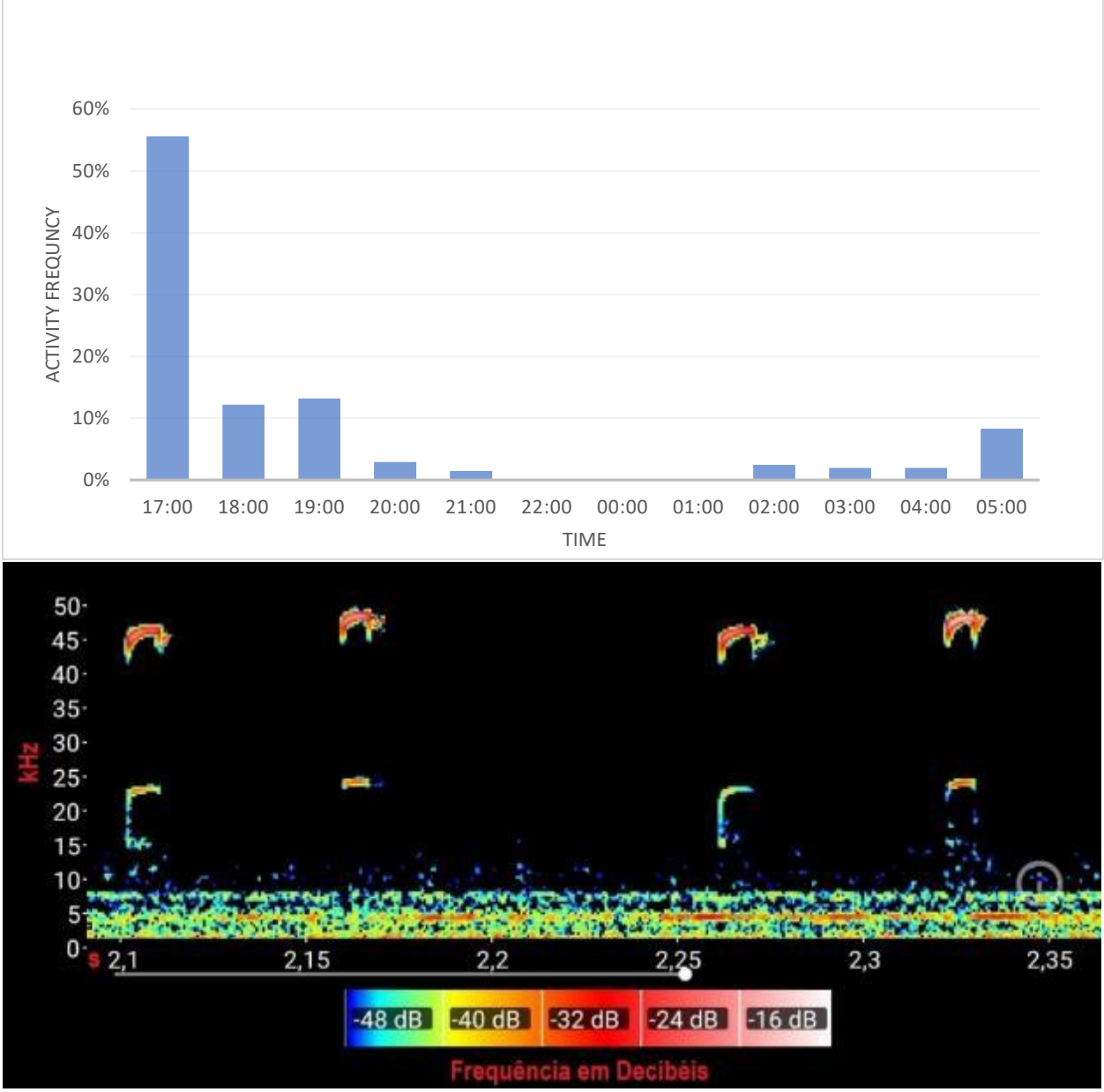


Figure 9: Foraging activity of *Saccopteryx leptura* in the Ecological Reserve of the Department of Systematic and Ecology of the UFPB calculated from echolocation calls. **A**: Average activity frequency from sunset to sunrise. B: Example of *S. leptura* foraging echolocating signals recorded.

Reproduction

No copula attempt was registered and, as such, it was not possible to confirm when gestation began. Pups were first recorded on two groups in the first week of February (end of dry season). About one week all four females from the three groups had given birth to a single pup

each (Figure 10). One month later, the pups began to explore the roost on their own. A pup was seen practicing flight until its mother crawled to it and proceeded to grab it by the wing, retrieving him to nurse (SM1). By April pups roosted a few centimeters from their mothers and nursing was no longer observed. One of the DSE pups left the roost soon after, but the other did not leave the roost until October (Figure 11). In the Geo roost, the juvenile had not left by the end of observations one year later (March 2019) and two satellite males joined.

Pups were carried by their mothers during their first month of life (February). At around one-month old pups were already volant and could forage by themselves. The first time female left pup when emerging to forage the pup spend about 30 minutes swinging and vocalizing (SM2). In the next video the pup was no longer in the roost.

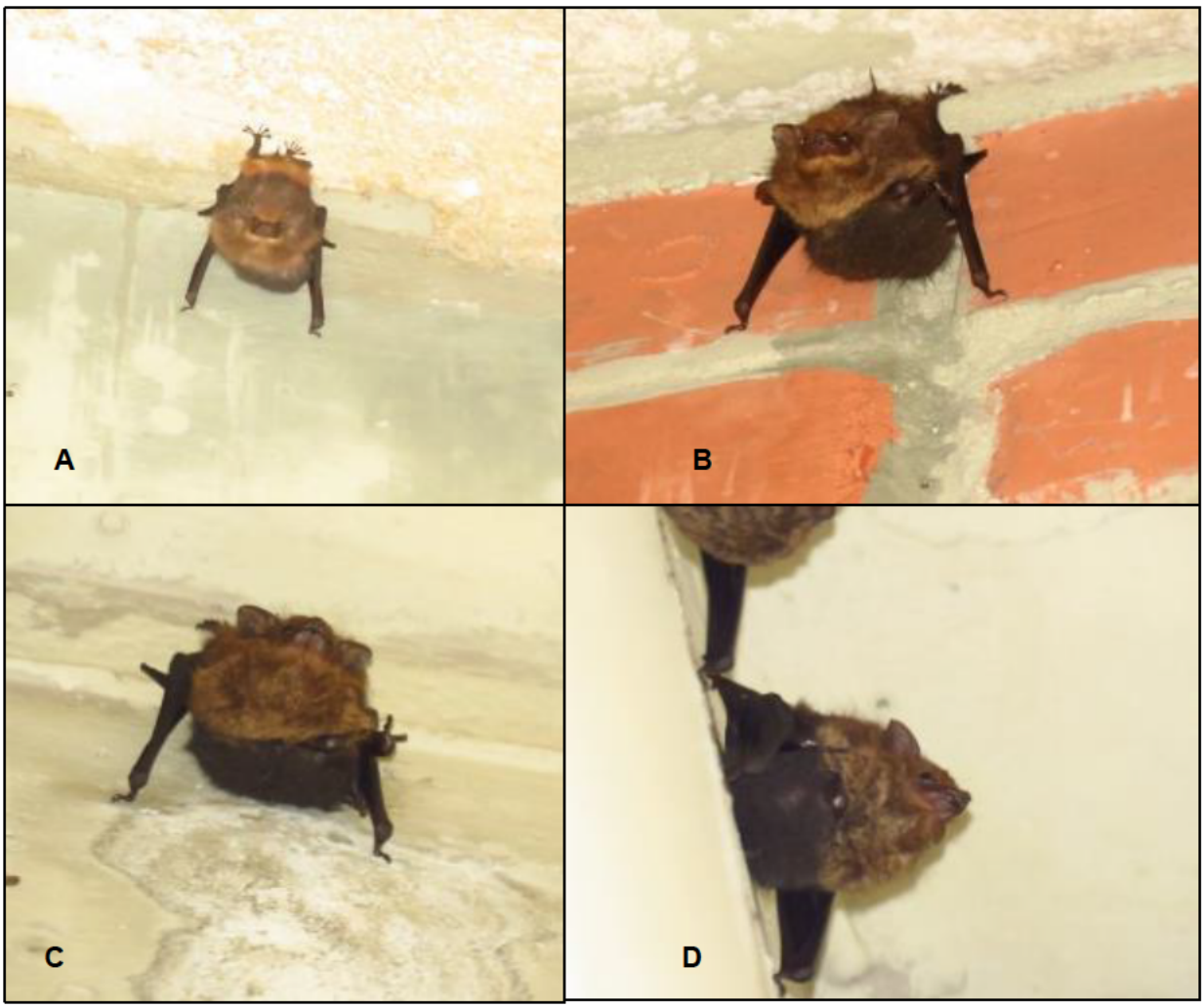


Figure 10: *S. leptura* pups born on the UFPB campus mid-February 2018. A: The Unf mother-pup. The mother had been marked with hair discoloration weeks prior. B: Geo mother-pup. C and D: The two mother-pups from the DSE.

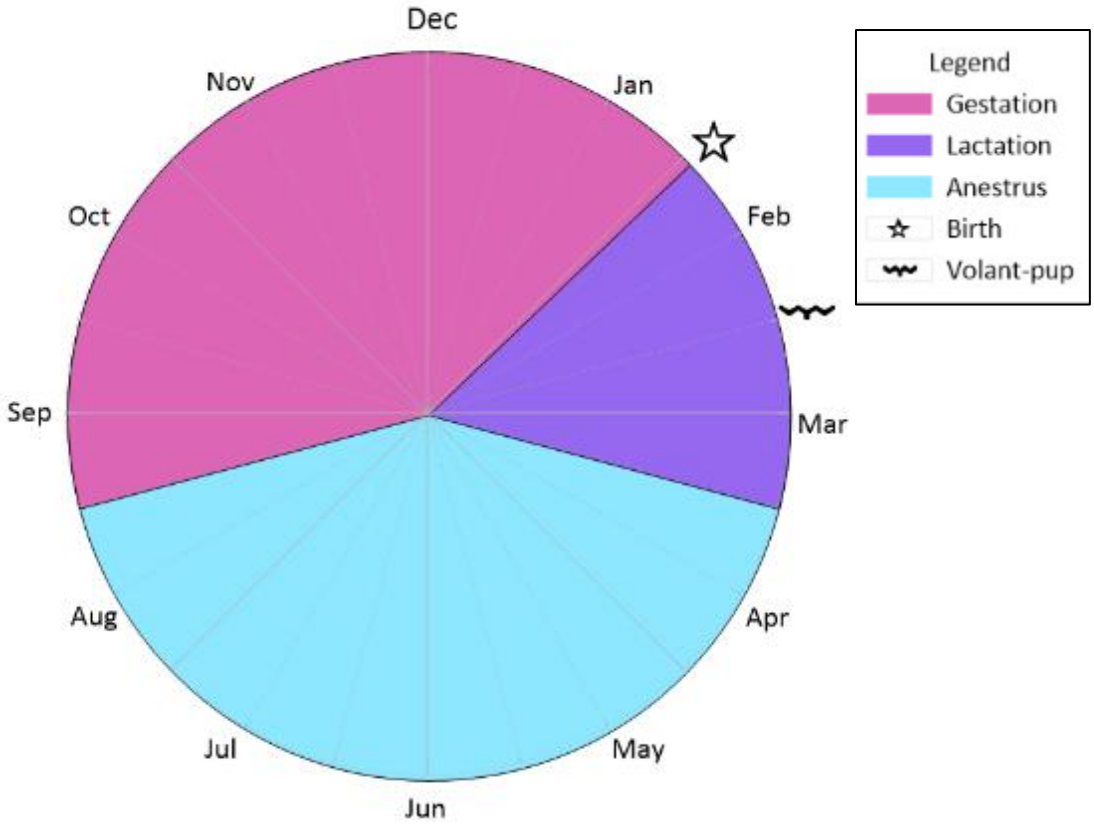


Figure 11: Rosetta diagram illustrating the observed reproductive cycle of the four *Saccopteryx leptura* females roosting at the Federal University of Paraiba, João Pessoa, Paraiba-Br. From March 2018 to February 2019. Parturition was very synchronic between females. Gestation time extrapolated from Bradbury and Vehrencamp (1976).

Rhynchonycteris naso

Behavior and Activity

During the day, an average of 5.34 (SD = 2.55) bats could be seen on camera. Emergence was synchronized after sunset, with foraging at 18:00 hr. Less than two hours later most of the bats were back (x = 5.07 SD = 2.85). At 4:00 hr. some of the group left again to forage. Daytime and nighttime activity budget had no significant difference when accounting for the foraging ($p>0.05$). During the dry season, the average number of bats on camera was lower at daytime (x = 6.22 SD = 2.97) when comparing to nighttime (x = 7.04 SD = 3.25).

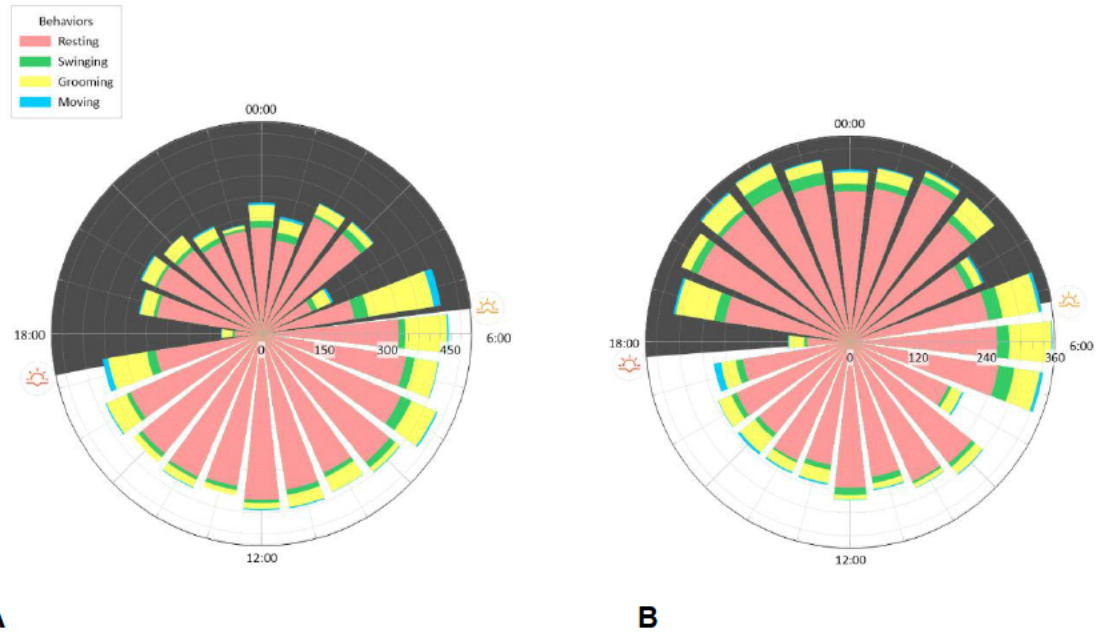
The calculated activity budget showed Resting (84.02%) as predominant day and night, followed by Grooming (10.06%), Swinging (4.27%) and Moving (1.10%) (Table 3) (Figure 12). Animals at Rest were often awake and would sometimes spend hours with open eyes. Grooming

was more common before and after foraging but was also present during the rest of the day. Swinging was often related to urinating and would sometimes be synchronic (SM3). Even though there were few instances of Moving caught on camera, it was very common for the bats to be in a different place in sequential videos, implying they moved more often than recorded. Social interactions happened mostly during nighttime and were all agonistic: pushes and displays (SM4).

A significant difference in activity budget was found between seasons for the daytime (X^2 = 11.456, df = 3, p = 0.009) and nighttime (X^2 = 7.847, df = 3, p = 0.049). During the daytime there was a significant decrease in Grooming (p <0.05) from the rainy to the dry season, but no other behavior differed significantly (p >0.05). None of the nighttime behaviors showed a significant difference between seasons (p >0.05).

Table 3: Calculated Activity budget of a *Rhynchonycteris naso* group roosting an abandoned house in the Pacatuba Farm, Sape, Paraíba-BR. From March 2018 to February 2019.

Behavior	Rainy		Dry		Year-round	
	Day	Night	Day	Night	Day	Night
Resting	82.84%	84.33%	83.94%	85.17%	83.28%	84.77%
Swinging	3.83%	4.05%	4.45%	4.84%	4.08%	4.46%
Grooming	12.30%	10.33%	10.30%	9.17%	11.49%	9.72%
Moving	1.04%	1.29%	1.32%	0.82%	1.15%	1.05%



A **B**

Figure 12: Rosetta diagram illustrating the behavior frequency and distribution throughout the day of a *Rhynchonycteris naso* group roosting an abandoned house in the Pacatuba Farm, Sape, Paraíba-BR: **A**. Rainy season from March to August 2018. **B**. Dry season from September 2018 to February 2019.

Reproduction

Pups were recorded in video February and March of 2018 and 2019 (SM5). Additionally, pups were observed in the beginning March 2017 and the beginning of February 2020 (Figure 13). Flight practices were also seen at night in the beginning of the rainy season (SM6). There was a copula attempt on 13 July 2018 (SM7).

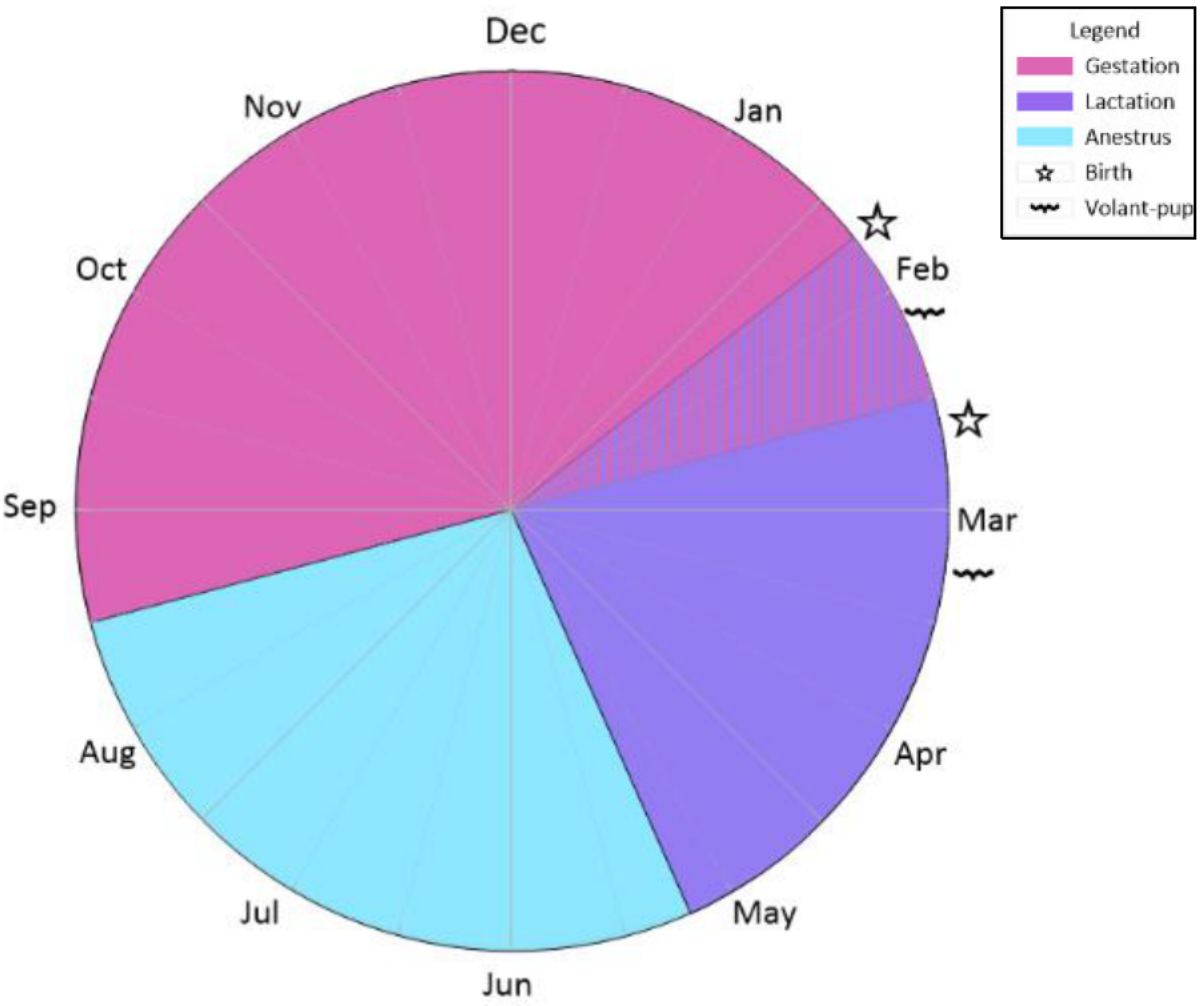


Figure 13: Rosetta diagram illustrating observed reproductive cycle of female of a group of a *Rhynchonycteris naso* group roosting in a building at the Federal University of Paraiba, João Pessoa, Paraiba-Br. From March 2018 to February 2019. Gestation extrapolated from Bradbury and Vehrencamp (1976).

Peropteryx macrotis:

Behavior and Activity

Bats usually stayed at least 3 to 5 centimeters of each other in a line. Other small groups could be seen on the back, and it was common for individuals to fly during the day (SM8).

Daytime activity budget had Resting (73.34%) as the dominant behavior, followed by Grooming (17.87%), Swinging (7.04%) and Moving (1.75%). Swinging seemed to happen mostly when bat urinated (SM9). Animals at Rest were commonly awake and would be looking around

or having its ears move. Nighttime activity budget was not calculated as the group was almost never present (Table 4). There were few cases of interactions when a bat hang himself on another one or pushed each other. Activity was higher on returning to the roost, as there was a Grooming peak before bats settled in. No Grooming peak was seen before emergence. Activity frequency was constant the rest of the day. Usually, individuals were observed to emerge to forage all together half an hour after sunset and only returned half an hour before sunrise, with few instances of night visits to the roost (Figure 14).

A significant difference in activity budget was found between seasons for the daytime roost activity ($X^2 = 19.447$, df = 3, p = 0.00). There was a significant decrease in Grooming and Swinging ($p < 0.05$) from rainy to dry, while Moving and Resting did not differ significantly ($p > 0.05$). Night visits to roost were only registered sparsely in the rainy season and were usually done by a single bat at a time. At the dry season, the roost would sometimes be empty during the day, mostly for unknown reasons, with one instance of all visible bats flying away followed by the passing of a cat (SM10).

Table 4: Calculated Activity budget of a Peropteryx macrotis group roosting an abandoned house in the Pacatuba Farm, Sape, Paraíba-BR. From March 2018 to February 2019.

Behavior	Rainy		Dry		Year-round	
	Day	Night	Day	Night	Day	Night
Resting	73.42%		72.77.%		73.34%	
Swinging	6.74%		9.36%		7.04%	
Grooming	18.17%		15.58%		17.87%	
Moving	1.68%		2.29%		1.75%	

The roost was often used at night by a *Lonchorhina aurita*, but the two species were never seen in the roost at the same time (SM11).

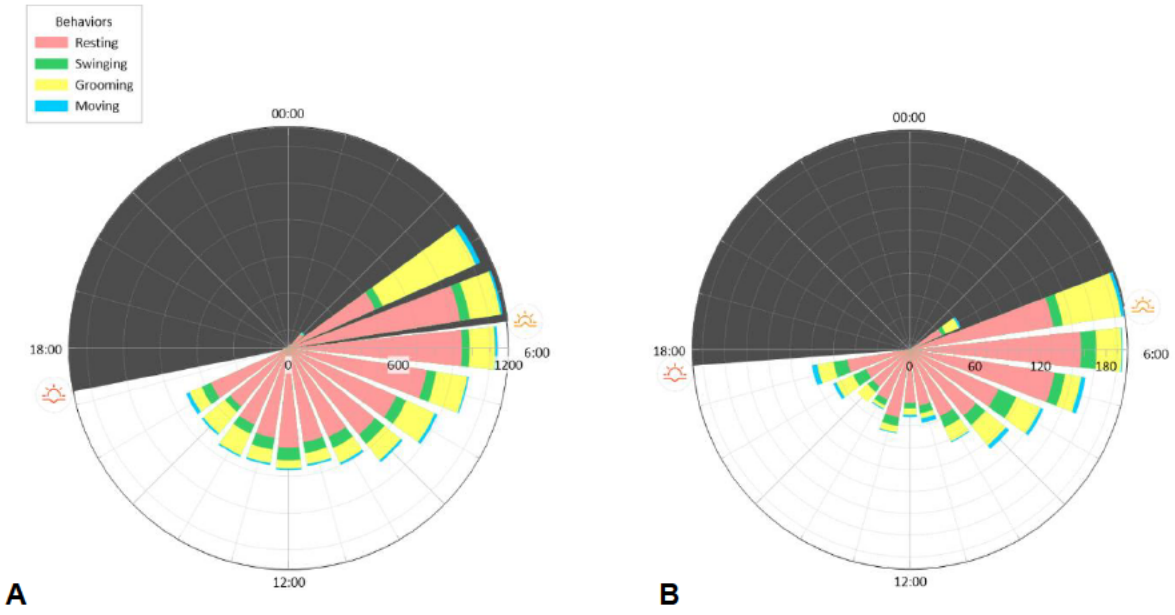


Figure 14: Rosetta diagram illustrating the behavior frequency and distribution throughout the day of a *Peropteryx macrotis* group roosting an abandoned house in the Pacatuba Farm, Sape, Paraíba-BR: **A**. Rainy season from March to August 2018. **B.** Dry season from September 2018 to February 2019.

Reproduction

There were no copula attempts, lactating or gestating females nor pups identified.

Carollia perspicillata:

Behavior and Activity

Bats were observed positioned either alone or in oval clusters. During the dry season this clusters would sometimes reposition in rows following the gaps in between the roof planks. The positioning appeared dynamic, as the clusters changed in size throughout the day.

The roosting bats were highly active, not only at night but also at daytime. In the first two months of recording (March and April) all resting adults were seen with their eyes open regardless of the time (SM12). At least one to three bats were always present in the roost at night. The calculated activity budget (Table 5) shows Resting (60.05%) as the dominant behavior during the day, followed by Swinging and Grooming. At night, the behaviors were more evenly distributed, with Grooming (30.84%) being slightly more common. Activity during the day was higher right before sunset in preparation for emergence and right after sunrise as bats accommodated to rest

(Figure 15A and B). Feeding was registered thirteen times, always during the night (SM13). There were seven cases of feeding on *Piper* (SM14) and five of eating unidentified leaves (SM15). Social interactions were more common at the beginning of the night and have been identified as antagonistic with pushes, grabs and displays (Figure 15C and D). Tandem flights and hovering were also commonly seen during the day and night but were registered as Moving. Swinging was not particularly linked to urinating. Emergence happened with low synchrony from sunset and took around 2 hours until most bats left. Bats returned to roost more gradually during the dry season than the rainy season.

A significant difference in activity budget was found between seasons for the daytime roosting activity (X^2 = 1062.644, df = 4, p = 0.00) and nighttime (X^2 = 551.536, df = 4, p = 0.00). During the day there was a significant increase in Resting (p <0.05) and a decrease in Moving and Swinging (p <0.05) from rainy to dry season, while Grooming and Social Activity did not differ significantly (p >0.05). During the night there was a significant increase in Resting (p <0.05) and decrease in Moving, Grooming and Swinging (p <0.05) from rainy to dry Season. Activity budget was similar throughout the day, but there was still a peak in activity near sunrise and sunset.

At the start of recordings in March (2018), there was an average of 6.13 (SD 7.42) visible bats in the roost. The number of bats increased and stabilized during the subsequent months reaching a peak of 15.36 (SD 4.27) in June. The number than decrease slightly before stabilizing at 13.36 (7.67) in September until December (13.64 SD 3.16). By January 2019, the number of bats in the roost dropping drastically (0.1 SD 0.30). Prior observation of the group in February 2018 observed the same drop in roosting bats. During this drop, only the resident male was observed in the roost with short visits of one or two other bats.

Table 5: Calculated Activity budget of a *Carollia perspicillata* group roosting an abandoned house in the Pacatuba Farm, Sape, Paraíba-BR. From March 2018 to February 2019.

Behavior	Rainy		Dry		Year-round	
	Day	Night	Day	Night	Day	Night
Resting	54.28%	12.23%	70.91%	36.81%	60.05%	24.98%
Swinging	27.91%	26.02%	13.97%	23.15%	22.49%	27.45%
Grooming	11.67%	35.23%	11.56%	29.71%	11.89%	30.84%
Moving	6.03%	26.02%	3.44%	8.46%	5.44%	15.52%
Social Int.	0.11%	10.50%	0.12%	1.89%	0.12%	1.22%

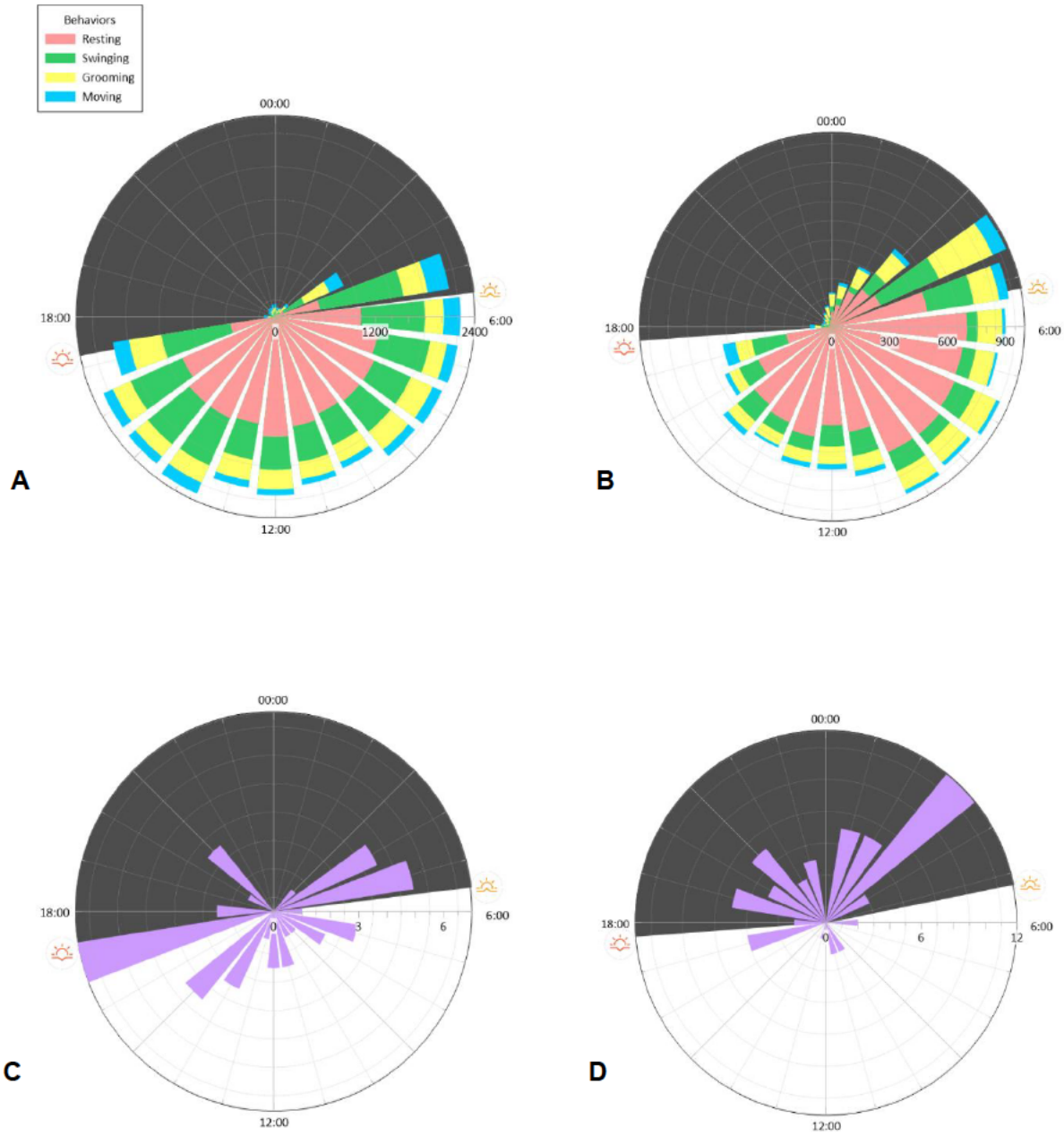


Figure 15: Rosetta diagram illustrating the behavior frequency and distribution throughout the day of a *Carollia perspicillata* group roosting an abandoned house in the Pacatuba Farm, Sape, Paraíba-BR: **A**. Rainy season from March to August 2018. **B**. Dry season from September 2018 to February 2019. **C** and **D:** Social Interactions were plotted separately to allow visualization.

Reproduction

There were two birth periods, one at March in the start of the rainy season and another at June in the end of the rainy season. Births had low synchrony with pups of different sizes recorded

at the same time (SM16). No mother was recorded carrying more than one pup. Four attempts at copula were recorded: 08 of April, 14 of May, 19 of June and 01 of December al on 2018 (SM17).

DISCUSSION

Roost Activity

Daytime

The four studied species have different activity budget. The Rest category is predominant during daytime for all species but vary greatly according to roost choice. *S. leptura* (Rest 90.54%) and *R. naso* (Rest 83.28%) roost on open well-lit sites and have the lowest activity levels. *P. macrotis* (Rest 73.34%), which roosts in an intermediate site, hidden but close to the entrance and well-lit, has moderate activity. *Carollia perspicillata* (Rest 60.05%), which roosts conspicuously deep in the basement, has the highest activity levels. We expected *R. naso* activity to be closer to *S. leptura* than observed in this study given that both depend on camouflage for protection and would need to stay still to avoid predator detection. The higher activity in *R. naso* may be simply due to the group large size. Another possibility is that *R. naso* feels safer in the abandoned house, as it is rarely visited, while the *S. leptura* in the university roost stays still for longer due to constant human presence.

Our group's activity parallels with previous studies when comparing roost sites exposure: 1) *Myotis lucifugus* (Rest 79%) roosted on the ridgepoles of a house (Burnett and August, 1981); 2) *Pipistrellus subflavus* (Rest 77%) roosted in a barn (Winchell and Kunz, 1996); 3) *Leptonycters curasoae* (Rest 74%) roosted in a wide, well-illuminated mine (Fleming, Nelson and Dalton, 1998); 4) *Miniopterus schreibersii bassanii* (Rest 62%) roosted deep in a cave (Codd, Sanderson and Branford, 2003). However, these studies were all done in maternity roosts between parturition and weaning, a period when females rest significantly less (Winchell and Kunz, 1996) and were conducted in temperate climate zones, temperature is a crucial factor in activity levels, especially for small mammals (Dias-Silva *et al.*, 2018).

Winchell and Kunz (1996) theorized that group size might influence Grooming frequency, as larger groups tend to have higher parasitic load. In the present study, the group with the highest Grooming frequency was *P. macrotis* (17.04%), followed by *C. perspicillata* (11.89%), *R. naso* (11.49%) and *S. leptura* (4.89%). Between the two species in exposed roosts, *R. naso*, which has larger groups, showed higher Grooming frequency (n>20) than *S. leptura* (n=6). However, when comparing the four groups, there seems to be no relationship between group size and Grooming

frequency. If there is a tendency for Grooming to increase with group size, it is probably only detectible when comparing same species groups.

Swinging happened on different occasions for *C. perspicillata* and *P. macrotis*: urinating, before and after Moving, as a stretch, before and after Grooming, when there was a commotion on the roost for no detectable reason. But for the two species in cryptic roosts, *S. leptura* and *R. naso,* Swinging was much less common and often linked to urinating. Synchronized swinging was first recorded on *R. naso* (Bradbury and Emmons, 1974) and later shown to happen during gusts of wind as a way for bats to urinate and groom while remaining cryptic (Knörnschild *et al.*, 2009). The Pacatuba group swing synchronically less often than described, possibly because our remote approach allowed bats to behave less cautiously.

We expected *S. leptura* to also present synchronic swing considering the two species are closely related and adopt the same roosting strategy. However, this was not observed. *Saccopteryx leptura* may have no need to develop such behavior, as the groups are a lot smaller, or they have not simply evolved such behavior yet. We also expected to find *S. leptura* leaving the roost to forage in the middle of the day (Bradbury and Emmons, 1974), but this was not detected.

Moving was the least frequent behavior for all species thanks to its higher energy consumption (Burnett and August, 1981), but it was still surprisingly high for *C. perspicillata* (5.44%). Moving during the day in *C. perspicillata* was mostly performed by lone bats changing positions or flying in circles. It is likely that the need to reproduce weights more than the need to save energy for the species. Moving was less frequent than expected in *R. naso* (Bradbury and Emmons, 1974), but constant changes in bats position between consecutive videos suggest it was more common than recorded.

Activity distribution was similar for the four species and corroborates with previous studies that showed activity to increase before emergence and after return (e.g. Bradbury and Emmons, 1974; Kirkwood and Cartwright, 1991; Connell, Munro and Torpy, 2006). Bats returned from foraging with higher levels of activity causing a peak of Grooming, Swinging and Moving. Activity then decreased and was mostly stable throughout the day. Shortly before emergence there was a second activity peak, specially Grooming in preparation for foraging. *Rhynchonycteris naso* had activity peaks before and after both foraging peaks. *Peropteryx macrotis* increase in activity was only after return, with no difference in behavior before emergence.

All our groups spent a substantial portion of the day awake, not only when active but when at Rest bats were often with open eyes. Though bats are nocturnal, there have been studies suggesting they spend a large portion of the day awake (Fleming, Nelson and Dalton, 1998;

Connell, Munro and Torpy, 2006). We found the literature to be lacking data on sleeping needs for bats (Elgar, Pagel and Harvey, 1988; Zhao *et al.*, 2010).

Nighttime

Emergence varied between the three Emballonuridae: *S. leptura* emerged from the roost at dusk, around 40 minutes before sunset, agreeing with published literature (Bradbury and Emmons, 1974). In turn, *P. macrotis* and *R. naso* emerged shortly after the sunset. *Peropteryx macrotis* was the first to return to the roost (around 4:00 h), *R. naso* returned from the last feeding right before the sunset (around 5:00 h) and *S. leptura* only returned after sunrise (around 5:40 h). The combination of video and acoustic data confirmed *R. naso* and *S. leptura* present a bimodal foraging activity. This agrees with previous studies in *R. naso* (Bradbury and Emmons, 1974; Nogueira and Pol, 1998).

Only *R. naso* and *C. perspicillata* presented enough nighttime activity in roost for analyses. In the *C. perspicillata* roost, emergence and return were synchronized with sunset and sunrise. A few individuals returned to the roost at nighttime, most likely the resident males. This protective behavior of the roost was previously observed in many bats (McCracken and Wilkinson, 2000), including *C. perspicillata* (Lamprecht, 1979; Pereira *et al.*, 2018). As expected, activity was higher at nighttime, with Moving going from 5.44% to 15.52% and Grooming becoming the most frequent behavior (from 11.89% to 30.84%). The roost was used by the male as a feeding perch as observed in *Platyrrhinus lineatus* (Rocha *et al.*, 2017).

In contrast, *R. naso* whole group used the house as a day and night roost. The species forages over bodies of water (Bradbury and Vehrencamp, 1976a) and the lake proximity (335m) removes the need for a nighttime roost. Disregarding foraging, group activity levels of this species was the same between day and night agreeing with previous observations (Nogueira and Pol, 1998).

Social Interactions

Allogrooming is one of the most common affiliative behaviors in bats (Kerth, 2008) and has been observed in *C. perspicillata* (Carter and Leffer, 2015), but was not seen in our group. Recorded agonistic behaviors appeared to be a dispute for mating, as *C. perspicillata* adopts a resource defense polygyny (Porter, 1979a; Fasel, Saladin and Richner, 2016) and *R. naso* adopts female defense polygyny (Günther *et al.*, 2016). Meanwhile, agonistic behaviors were only absent in *S. leptura*, which does not adopt polygyny (Bradbury and Vehrencamp, 1977a).

We expected species in exposed roost to avoid obvious interactions during daytime, to keep the individuals unnoticed (Stevens e Ruxton 2018). *S. leptura* displayed no interaction during daytime *and R. naso* disputes were mostly nocturnal, corroborating previous findings (Bradbury and Emmons, 1974; Günther *et al.*, 2016). Meanwhile*,* disputes were as common during daytime as during the nighttime for *P. macrotis* and *C. perspicillata.* Fights between *P. macrotis* individuals were characterized as overhead flights and some occasional hanging on. It was normal for the conflict to lead to a chase. In *C. perspicillata* roost, most fights happened during daytime and were likely initiated by males trying to take-over the roost from the resident male (Fasel, Saladin and Richner, 2016). But we do not know whether the attempts have ever been successful due to the lack of identification.

Our preliminary audio records in roosting *S. leptura* confirmed bats emitting a diversity of social calls (Bradbury and Emmons, 1974), which suggests a complex acoustic behavior similar to what has been found in *Rousettus aegyptiacus* (Prat, Taub and Yovel, 2016). Further analysis of this data shall be published in the future. Though we agree with the conclusion that more studies in bat visual communication are needed (Chaverri, Ancillotto and Russo, 2018), we believe these studies will greatly benefit from a combined approach.

Mother-pup interactions identified were mostly nursing and grooming. There was an instance of pup retrieving recorded for *S. leptura* and one instance for *R. naso*. Pup retrieval had been previously recorded for *R. naso* (Nogueira and Pol, 1998) and *C perspicillata* (Porter, 1979b)*.* Lack of interaction between pups and other bats (adults and pups) could suggest low sociality, as social skills are usually acquired early on lifetime (Arnold and Taborsky, 2010; Ancillotto *et al.*, 2014).

Behavior and seasonality

Previous works on temperate zone bats found roost activity to increase in warmer months (Watkins and Shump, 1981; Barclay, 1982; Hall, 1982), especially after parturition, with the presence of pups and juvenile (Codd, Sanderson e Branford, 2003; Winchell e Kunz, 1996). Many Neotropical bats reproductive cycles are strongly linked with the rainy season, when food availability is higher (Bradbury and Vehrencamp, 1977b; Mello *et al.*, 2004). Studies on Neotropical bats seasonal roosting activity have not been found.

We found a significant increase in activity in the rainy season when compared to the dry season, for all four monitored species. We expected activity to be influenced by roost choice and exposed species to have low variation between seasons, as previously seen in *R. naso* and *S. leptura* (Bradbury and Emmons, 1974).

Reproduction

Pups have been recorded for all, but the *P. macrotis* group. Parturition in the other three species was seasonal, supporting (Bradbury and Vehrencamp, 1977b) assertion that reproduction patterns in Neotropical bats are mainly linked with the rainy season. *C. perspicillata* was polyestrous and relatively synchronic. Females gave birth at the beginning and at the end of the rainy season corroborating with previous findings (Fleming, Hooper and Wilson, 1972; Porter, 1979a; Williams, 1986). *Rhynchonycteris naso* and *S. leptura* were both monoestrous, with pups recorded at the end of the dry season. By its turn, *S. leptura* presented higher synchrony than *R. naso*.

Previously, *S. Leptura* had been recorded as monoestrous in Trinidad, with parturition at the beginning of the rainy season (Bradbury and Emmons, 1974), and bimodal polyestrous in Costa Rica with a second breeding period at the end of the rainy season (Bradbury and Vehrencamp, 1976a). The three UFPB groups were monoestrous with strong synchrony and parturition was at the very end of the dry season.

Similarly, *R. naso* has been described as monoestrous, with parturition happening with low synchrony at the beginning of the rainy season Costa Rica (Bradbury and Vehrencamp, 1976a). Bimodal polyestrous, with parturition at the beginning and end of rainy season in Brazil and Trinidad (Bradbury and Vehrencamp, 1976a; Nogueira and Pol, 1998). This shows regional variation in bats reproductive strategy. Alternatively, it might be a flaw in the methodology's ability to detect births, since *R. naso* pups are visually indistinguishable from adults after they are just 15 days old (Bradbury and Emmons, 1974), meaning they could have been easily missed in this and previous surveys. But the successful identification of *R. naso* pups in the Pacatuba house at the end of the dry season along three years study strongly suggests that the current group is monoestrous.

Social organization

Saccopteryx leptura

S. leptura groups are described to be composed of equal number of males and females (Bradbury and Vehrencamp, 1976a) and eventual non-reproductive adults, assumed to be offspring from previous years (Bradbury e Vehrencamp, 1976; McCracken e Wilkinson, 2000). Females disperse earlier, at three months of age, while males either set up territories nearby the parents roost or stayed in a non-reproductive state (Bradbury and Vehrencamp, 1977b). This

suggests the pup that left earlier the DSE group was female, while the other, which stayed longer, was male.

In this study, each female was observed as paired with two adult males. It is possible that the extra males were non-reproductive offspring from previous years. However, the DSE juveniles currently observed dispersed before the following reproductive period, conserving the groups structure. Besides, the Geo group had two males joining the group. It is unlikely that the two males were offspring that stayed near the roost for over two years, as they would not be allowed to re-join. Cryptic behavior creates a need for adaptations in social organization, as males cannot easily fight to defend the roost (Günther *et al.*, 2016). We believe the observed *S. leptura* groups to be polyandric.

Peropteryx macrotis

According to Willig (1983) *P. macrotis* groups are composed of several females and one male, suggesting resource defense polygyny, but we did not find more recent studies corroborating with this assertion. The better studied *Peropteryx kappleri* groups consist of many adults of both sexes roosting together (Bradbury and Vehrencamp, 1976a). The observed *P. macrotis* group was small with a stable number of individuals, but we could conclude that the recorded individuals were the same along the seasons, as were not marked. Individuals were seen flying to and from neighbor roosts, which could mean the observed group was a sub-group.

Rhynchonycteris naso

The studied group appeared to be multi-male, multi-female as described by Bradbury e Vehrencamp (1977a), but we did not observe the female subclusters identified by Bradbury e Emmons (1974). Copula attempts and fights have been registered at nighttime, which corroborates with previous studies (Günther *et al.*, 2016). Copula interference (McCracken e Wilkinson, 2000 and Günther et al. 2016) have not been registered, but it is possible that only copula attempts from the dominant male have been recorded.

Carollia perspicillata

We identified resident males with unstable harems at the center and solitary males at the periphery, as described by McCracken e Wilkinson (2000). Resident males are known to defend their territory year-round, even when females might not be present (Williams 1986). During the rainy season, female subgroups were better defined, however their positioning and composition

were not as stable as described by Porter (1979). The observed variation in cluster shape during the dry season, from oval to rows, was probably due to higher temperature instead of social relationships.

Synanthropic fittness

All the Pacatuba and most of the UFPB roosts had signs of long-term use. During the duration of the study, only the *S. leptura* Unf group was disturbed enough to move and the individuals relocated to the same building, suggesting the advantages of synanthropic roosts (Voigt and Kingston, 2015) outweighed the stress caused by constant disturbances. Their new spot was conspicuous, corroborating assertion that synanthropic bats have more flexible roosting. (Ditchkoff, Saalfeld and Gibson, 2006).

Accounting for the systematic and nonsystematic observations from 2017 to 2020, the reproductive success in the UFPB was recognized as high, as all *S. leptura* females managed to give birth during each of the four years. Furthermore, all pups survived until dispersal age. Reproductive success was less clear in the Pacatuba groups. Both *C. perspicillata* and *R. naso* had pups registered on camera, but we do not know what percentage of the female population gave birth. Though the observed *P. macrotis* group had no births, we are not sure if there were any females present in the group. The rate of recruitment is unknown for all species.

Though our bats were fitted to a synanthropic roosts they still depended on the natural areas nearby to forage (Nunes, Rocha and Cordeiro-Estrela, 2017; Denzinger, Tschapka and Schnitzler, 2018). Species have different roost requirements to thrive depending on their strategy and some might need more than one type of roost according to the season or time of day (Mendes *et al.*, 2011). *C. perspicillata* prefers to roost in hollow trees during the dry season (Williams, 1986), meaning our group was likely roosting in the forest remnant nearby. When disturbed *R. naso* and *S. leptura* flew to alternative roosts as described by Bradbury and Emmons (1974). *Saccopteryx leptura* nighttime activity suggests the group has a roost near the foraging sites. To allow bats to thrive in anthropomorphized areas, green spaces, such as parks and natural reserves are important (Nunes, Rocha and Cordeiro-Estrela, 2017). A strategy for urban conservation would be the placement of artificial roosts (Alcalde *et al.*, 2020). Furthermore, educational efforts are required so that the human population can tolerate bats presence in buildings and other structures. Specially with the current fears brought up by bats relationship with Covid-19 outbreak.

CONCLUSION

In this study, we described aspects of Neotropics bats ecology in relation to their roosts. We recorded day and night roosts of three Emballonuridae*: Saccopteryx leptura, Rhynchonycteris naso* and *Peropteryx macrotis*, and a Phyllostomidae: *Carollia perspicillata*. The species were chosen and divided according to their roosting strategy. The *S. leptura* and *R. naso* choose well-lit exposed roosts and relied on cryptic behavior. While *P. macrotis* and *C. perspicillata* choose hidden, cryptic roosts.

The activity budget was correlated with roosting strategy, with species in more cryptic roost being more active. Activity was always higher before emergence and after return, regardless of roost strategy. Swinging was used by expose roosting bats as cover for urinating but happened at random with the cryptic roosting. Grooming was more common in the cryptic roosting and showed no correlation with group size.

Social interactions recorded on camera were all antagonistic (fights) and appeared to be related to resource or female defense strategies. Fights were more common in *C. perspicillata*, rare in *P. macrotis* and *R. naso*, and not recorded in *S. leptura*. The lack of social interaction in pups and affiliative interaction in adults suggest low sociality in the four species, but social vocalization recorded in *S. leptura* indicates sociality might be not visually perceived in.

Roost activity was significantly higher in the rainy season when comparing to the dry season for all species, but the difference between the season varied in each group. It was unclear if the seasonal variation was due to the presence of pups or a general increase in food, as was the influence roosting choice had on such variation.

Pups were recorded in *S. leptura, R. naso* and *C. perspicillata*. *Saccopteryx leptura* and *R. naso* were monoestrous, with parturition occurring at the end of the dry season. Pups were born well develop and became volant before weaning period but stayed in the roost for a few months after. *Carollia perspicillata* was polyestrous, with parturition happening at the beginning and end of the rainy season. The pups took longer to become volant.

4. BIBLIOGRAPHY

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