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A LUZ ARTIFICIAL A NOITE EM PARQUES URBANOS AFETA OS MORCEGOS OU AS PRESAS DE MORCEGOS?

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Sumário

Resumo

Com a crescente urbanização no mundo é essencial saber como as espécies animais respondem aos impactos desse processo. A iluminação artificial noturna altera ambientes que eram naturalmente escuros a noite para ambientes iluminados, impactando a biodiversidade noturna. Como morcegos são ativos durante a noite a iluminação pode interferir no padrão de atividade e estruturação da comunidade de morcegos em ambientes urbanos. Assim, vou avaliar se a iluminação artificial afeta a atividade dos morcegos, e se esta está relacionada a abundância de presas de morcegos nos parques urbanos. Para isso, testei as hipóteses da atividade de morcegos ser maior próximo aos locais com iluminação artificial, assumindo que a abundância de insetos será maior por serem atraídos pela luz; espécies de voo rápido serão mais ativas próximo à iluminação artificial, e as de voo lento vão apresentar resposta negativa à iluminação artificial; e a última, que as espécies de voo rápido estarão positivamente relacionadas com os artrópodes, pois são mais ativas próximo aos locais com iluminação artificial onde há maior abundância de artrópodes. Verifiquei a atividade dos morcegos por meio de gravações acústicas, e a abundância de artrópodes com armadilhas de cartolina amarela adesiva instaladas em cada um dos locais de amostragem. Foi verificado o efeito direto e indireto da luz artificial sobre a atividade dos morcegos, via abundância de artrópodes, utilizando modelos de equações estruturais. A abundância de artrópodes foi afetada positivamente pela iluminação artificial, e a atividade de morcegos não. No entanto, a atividade dos morcegos foi afetada positivamente pela abundância de artrópodes. A atividade das espécies de voo rápido aumentou em resposta à luz artificial e à abundância de artrópodes. O grupo *Eumops* sp/*Nyctinomops macrotis* mostrou uma resposta negativa a abundância de artrópodes. A atividade de *Eptesicus* sp., espécie de voo lento, teve resposta negativa à luz artificial. A iluminação artificial influencia diretamente a abundância de artrópodes, mas afeta indiretamente a atividade dos morcegos. Este efeito parece ser espécie específico: espécies de voo rápido se beneficiam com a presença da iluminação artificial.

Palavras-chave: artrópodes, ecolocalização de morcegos, ecossistemas urbanos, insetivoria, remanescentes verdes.

Introdução Geral

Urbanização é o resultado de um processo de extrema alteração no uso da terra (Shochat et al. 2006; Grimm et al. 2008). A taxa de mudança na qual as áreas urbanas estão evoluindo é devido ao crescimento natural da população humana, incluindo a migração significativa das áreas rurais para urbanas e a expansão espacial das cidades (Grimm et al. 2008; Montgomery 2008; UN 2012; McDonnell e Hahs 2013). Além disso, projeta-se que mais da metade do crescimento da população urbana ocorra em cidades menores (UN 2012). A urbanização não é um evento concentrado localmente, mas sim um processo disperso e um acontecimento mundial (McDonald 2008). Países desenvolvidos já passaram por amplos processos de urbanização e esse crescimento acontece de forma lenta, diferente do que ocorre em países em desenvolvimento como na Ásia, África e América Latina onde há um grande aumento da urbanização, inclusive em muitos *hotspots* de biodiversidade (Myers et al. 2000).

A urbanização é responsável por um grande declínio da biodiversidade global (Sala et al. 2000). Os efeitos do processo da urbanização operam a partir de escalas locais (por meio da expansão das cidades) e também em escalas globais (por meio da emissão de gases de efeito estufa) (McDonald et al. 2008), agindo diretamente na expansão das áreas urbanas, quanto indiretamente, no crescimento da infraestrutura e mudanças no consumo e poluição (McIntyre et al. 2000; Pickett et al. 2001). Além da remoção da área natural, a expansão das cidades também promove impactos nos ambientes rurais e naturais devido ao aumento da fragmentação e dos efeitos de borda, provocando aumento dos níveis de temperatura e ruído, introduzindo novos estressores antropogênicos em ecossistemas marginais (Grimm et al. 2008) e áreas protegidas próximas (McDonald et al. 2008; McDonald e Marcotullio 2013). No entanto, apesar da transformação radical da terra e da perda de habitat causada pela urbanização, muitas espécies ainda podem persistir em ambientes urbanos e algumas até mesmo experimentar aumentos populacionais (McKinney 2006; Russo e Ancillotto 2015).

A resposta das espécies à urbanização varia de acordo com suas características funcionais. Algumas espécies são tolerantes ao novo ambiente, enquanto outras podem ser beneficiadas e outras espécies são prejudicadas (Russo e Ancillotto 2015). Assim, as pressões geradas pela urbanização atuam como um filtro ambiental, selecionando as espécies a partir das suas características funcionais, permitindo que estas sobrevivam nesses novos habitats (Aronson et al. 2016). As espécies que requerem um habitat mais conservado são geralmente as mais prejudicadas pela urbanização. Geralmente as espécies mais raras e menos tolerantes desaparecem ou mudam as relações com o meio para se manterem nesses ambientes (Kurta e Teramino 1992; Hourigan et al. 2006; Luck et al. 2013).

Além da perda de habitat, fragmentação e efeito de borda gerados no processo de urbanização (Grimm et al. 2008), outros estressores antropogênicos são introduzidos nesse processo. A poluição sonora, gerada por fontes de sons antropogênicos, por exemplo, diminui a riqueza de espécies de aves em ambientes com alta perturbação sonora. Entretanto, facilita o sucesso reprodutivo de indivíduos que nidificam em áreas urbanas como resultado da perturbação da interação predador-presa (Francis et al. 2009). Outro exemplo do impacto dos sons antropogênicos é evidenciado com a espécie de morcego *Myotis myotis* que apresentou um baixo sucesso de captura de presas quando exposto ao som do tráfego de veículos (Schaub et al 2008).

Além do som, outro impacto gerado pela urbanização é a poluição por agentes químicos. A biota aquática é uma das mais impactadas pelos poluentes químicos, sendo observados efeitos negativos na comunidade de peixes e invertebrados aquáticos, que tem a riqueza e abundância diminuídas nos ambientes aquáticos (Kalogianni et al. 2017; Karaouzas et al. 2017). Diversos trabalhos mostram que anfíbios são fortemente afetados por poluentes químicos na água, gerando uma baixa sobrevivência de girinos quando expostos a diferentes compostos químicos e quando estes sobrevivem, apresentam baixa mobilidade e problemas de má formação de algumas estruturas corporais (Carey e Bryant 1995; Rowe et al 1998; Rubbo e Kiesecker 2005; Relyea e Diecks 2008).

Entre esses impactos a poluição luminosa vem ganhando destaque (Longcore e Rich 2004; Gaston et al. 2013). Poluição luminosa é definida pela alteração dos níveis de luminosidade na paisagem noturna provocada por fontes de iluminação artificial (Falchi et al. 2011; Kyba e Hölker 2013). A iluminação artificial tem aumentando em resposta à crescente urbanização, do crescimento das populações humanas, do desenvolvimento econômico e dos avanços nas tecnologias de iluminação que proporcionam benefícios econômicos, comerciais, recreacionais e de segurança (Hölker et al. 2010a). A iluminação artificial cresce em média 6% ao ano e a poluição luminosa é tratada por ecólogos como uma ameaça a biodiversidade (Hölker et al. 2010a, b), pois 30% dos vertebrados e mais de 60% dos invertebrados são noturnos (Hölker et al. 2010b). O crescente aumento da iluminação artificial no ambiente noturno afeta fortemente os padrões naturais desses animais. Um dos efeitos da poluição luminosa é a capacidade de atrair para a fonte de iluminação artificial alguns animais ou repelir outros. Consequentemente, afetando esses animais na procura de alimentos, reprodução e comunicação, e alterando a estrutura das comunidades noturnas (Longcore e Rich 2004). Assim, a compreensão de como a iluminação artificial afeta as comunidades em ambientes urbanos será de grande valor para a conservação de espécies em ambientes urbanos, e para que as novas cidades sejam planejadas já pensando na minimização de efeitos negativos na biodiversidade.

Diversos grupos animais são afetados pela iluminação artificial, principalmente os noturnos. Estudos recentes vêm demonstrando que aves migratórias noturnas diminuíram suas rotas de voo e selecionaram habitats menos conservados em resposta a iluminação artificial (Cabrera- Cruz et al. 2018; McLaren et al. 2018). O comportamento reprodutivo das aves também foi afetado. Machos que ocupavam territórios periféricos a iluminação artificial vocalizaram significativamente mais cedo e apresentaram um maior sucesso na obtenção de parceiros extrapares (Kempenaers et al.2010). Consequentemente também é observado um aumento no período de atividade das aves quando expostas a iluminação artificial (de Jong et al. 2017; Raap et al. 2017).

Em tartarugas marinhas também foi observada uma relação negativa entre a densidade de locais de desova a medida que havia aumento na intensidade de iluminação artificial (Weishampel et al. 2016; Hu et al. 2018). Anfíbios apresentaram baixa sobrevivência de girinos, baixa velocidade de movimentação e ficaram mais susceptíveis ao parasitismo quando expostos a iluminação artificial (May et al. 2019). Também foi observada mudança no comportamento de algumas espécies de sapos, quando expostos a iluminação artificial. Estes vocalizaram durante toda a noite com maior gasto de energia quando comparado a locais sem a iluminação artificial (Dias et al. 2019).

Em mamíferos o efeito da iluminação artificial tem sido observado em diferentes grupos. Marsupiais apresentaram uma redução nos níveis de melatonina e consequente um aumento no período da gestação (Robert et al. 2015). Em pequenos mamíferos não voadores foi observado um aumento nas distâncias percorridas durante a noite, e a redução na área de sobreposição dos indivíduos quando expostos a iluminação artificial (Hoffmann et al. 2018; 2019). Assim, esses trabalhos mostram que mesmo níveis muito baixos de poluição luminosa podem interferir no comportamento e na fisiologia dos mamíferos noturnos. Essa constatação é preocupante pois das espécies de mamíferos noturnas, mais de 1300 espécies são de morcegos, representantes da ordem Chiroptera,(Fenton e Simmons 2014) e com a expansão das áreas iluminadas, a cobertura de habitats adequados e naturalmente escuros diminuem rapidamente (Hölker et al. 2010a; Stone et al. 2015; Falchi et al. 2016)

Em geral, a urbanização afeta negativamente a atividade e abundância dos morcegos (Jung e Threlfall 2016). Curiosamente os morcegos são uma das ordens de mamíferos com maior riqueza de espécies registradas em ambientes urbanos (Santini et al. 2019). Essa riqueza pode estar relacionada às estruturas urbanas, como edifícios e pontes, que se assemelham com os abrigos naturais dos morcegos (Ávila-Flores e Fenton 2005; Jung e Kalko 2010). Entretanto, por possuírem hábito noturno, morcegos se tornam passíveis de impacto com a expansão da iluminação artificial (Stone et al. 2015). O efeito da iluminação artificial nos morcegos interfere diretamente na eficiência de forrageio das espécies (Rowse et al. 2016). A iluminação artificial atrai uma grande abundância de artrópodes como Lepidopteras, Coleoptera e Dipteras geralmente predados morcegos (Eisenbeis 2006; van Langevelde et al. 2011) e os morcegos se aproveitam da luz para aumentar sua eficiência de forrageio (Rydell 1992, 2006). Essa relação já foi observada em locais próximos as fontes de iluminação artificial onde há maior atividade de morcegos e consequentemente são os locais onde há maior abundância de artrópodes (Ávila-Flores e Fenton 2005; Jung e Kalko 2010).

Em geral, artrópodes são fortemente afetados pela iluminação artificial com aumento do número de espécies atraídas para as fontes de iluminação artificial durante a noite (Eisenbeis 2006). A composição espectral da luz pode influenciar no grau de atratividade dos insetos (van Grunsven et al. 2014; Longcore et al. 2015), e variáveis como comprimento de onda, saturação de cor e brilho da luz são características importante que influenciam a atração de insetos (Antignus 2000). van Langevelde et al. (2011) observaram que luzes com menores comprimentos de onda atraíram uma maior riqueza e abundâncias de espécies de mariposas. Estas luzes podem atrair em média mariposas com maior massa corporal, maior dimensão de asa e olhos maiores. Além do comprimento de onda, outras características influenciam a atratividade de insetos pela iluminação artificial, como a saturação da cor e brilho da luz (Antignus 2000). Os Dípteros, por exemplo, são mais atraídos por luz ultravioleta (UV), luz azul e verde (Burkett et al. 1998; Burkett e Butler 2005), enquanto Lepidópteros são atraídos pela luz UV e azul (Solano Lamphar e Kocifaj 2013; van Langevelde et al. 2011). Já Hemípteros são mais atraídos por luz azul e luzes brancas de baixa intensidade (Pacheco-Tucuch et al. 2012).

Consequentemente, a atividade das espécies de morcegos responde as características da luz artificial, como o tipo de lâmpada (Rowse et al. 2016). Frank et al (2019) observaram na Costa Rica, que a atividade dos morcegos foi maior próximo as lâmpadas florescentes de cor azul e branca. Entretanto, essa resposta variou entre as espécies de morcegos. *Pipistrellus pipistrellus* teve menor atividade próximo a lâmpadas de LED (Light Emitting Diode, em inglês) em relação às lâmpadas de vapor de mercúrio (MV, em inglês). O contrário foi encontrado para espécies do gênero *Myotis*, que apresentou maior atividade próximo as lâmpadas de LED (Lewanzik e Voigt 2017). Lâmpadas de LED emitem baixas quantidades de raio UV, atraindo menos insetos (Longcore et al. 2015) refletindo no resultado observado para *P. pipistrellus*, e diferente do resultado observado para o gênero *Myotis*, que normalmente são intolerantes a iluminação artificial. As lâmpadas de LED são menos prejudiciais do que as MV (Gorresen et al. 2015).

No geral, é observado que a atividade de morcegos insetívoros é maior próximo aos locais com iluminação artificial (Jung e Kalko 2010; Rowse et al. 2016; Frank et al. 2019). No entanto, esse efeito da iluminação artificial afeta de forma diferente as espécies de morcegos insetívoros. Espécies de voo rápido, que possuem hábito de forrageio em áreas abertas, são mais tolerantes e são frequentemente registradas próximas à iluminação artificial (Rowse et al. 2016). Forrageadores de área aberta possuem asas longas e estreitas e necessitam de um voo rápido para se manterem no ar, assim, utilizam chamadas de ecolocalização de banda estreita de alta intensidade e baixa frequência para detectarem os insetos a longas distâncias (Norberg e Rayner 1987; Rydell 2006; Kalko et al. 2008). Morcegos de áreas abertas quando forrageam próximos aos locais iluminados, voam acima dos postes de iluminação artificial e no momento da captura dos insetos passam pela luz (Jung e Kalko 2010).

Entretanto espécies que possuem voo lento e que forrageiam em ambiente com mais obstáculos, como bordas de matas, em geral, apresentam intolerância a iluminação artificial e raramente são registrados próximos aos locais iluminados (Rowse et al. 2016). Os forrageadores de borda possuem asas largas e curtas que facilitam a manobrabilidade em ambientes com muitos obstáculos (Norberg and Rayner 1987) e por conta dessa morfologia, a exposição aos predadores é uma das prováveis explicações para essa intolerância (Jones e Rydell 1994; Rydel et al 1996). Além disso, a estratégia de captura de presas também pode estar relacionado a essa intolerância, pois essas espécies são adaptadas para caçar presas em ambientes com muitos obstáculos (Norberg e Rayner 1987) e como os postes de iluminação pública estão localizados em áreas semi-abertas/abertas, esses locais podem não ser propícios para o forrageio dos morcegos de voo lento. Com isso, a proliferação da iluminação artificial tem o potencial de alterar a estrutura da comunidade de morcegos insetívoros aéreos, selecionando as espécies que se beneficiam e restringindo as que evitam locais com iluminação artificial (Stone et al. 2015; Rowse et. al. 2016; Frank et al. 2019).

Grande parte do conhecimento acerca do impacto da iluminação artificial sobre os morcegos provém de trabalhos que foram realizados no hemisfério norte (Gorresen et al. 2015; Rowse et al. 2016; Lewanzik e Voigt 2017). Poucos trabalhos sobre o efeito da iluminação artificial nos morcegos foram realizados na região neotropical (Jung e Kalko 2010; 2011; Frank et al. 2019). Há, portanto, muito a se descobrir sobre como os morcegos neotropicais respondem a iluminação artificial. Em especial no Brasil onde há um aumento significativo da urbanização (Klink e Machado 2005; Strassburg et al. 2017). Em recente revisão foram registradas 87 espécies de morcegos em ambientes urbanos (Nunes et al. 2017) no Brasil, representando aproximadamente metade da ordem presente no país. Entretanto, grande parte dos trabalhos realizados são relacionados a saúde pública em relação as possíveis doenças que os morcegos são potenciais vetores (Nunes et al. 2017). Poucos são os trabalhos que abordam questões ecológicas dos morcegos em ambientes urbanos no Brasil, como feito por Silva de Araújo e Bernard (2016). Esses autores observaram que a atividade de morcegos insetívoros em remanescentes verdes de áreas urbanas é maior do que nos locais onde esses remanescentes não estão presentes.

Nesse contexto que o meu trabalho se insere. O estudo foi conduzido na cidade de Brasília, Distrito Federal do Brasil. Brasília é uma cidade nova, com 59 anos, com uma população de aproximadamente 3 milhões de habitantes (IBGE 2019), totalmente inserido no Bioma Cerrado. Está cercada por extensas áreas de agricultura. Brasília possui um clima com duas estações bem definidas: de outubro a março é período chuvoso, e de abril à setembro o período de seca. Brasília está localizada a 1.000 metros do nível do mar (GDF 2019). Brasília é uma cidade bosque, com uma grande cobertura arbórea. Uma das características de Brasília são os Parques Urbanos, frequentemente utilizados pela população para atividade de recreação. Esses parques possuem em sua composição a vegetação nativa do bioma Cerrado (IBRAM 2013) e assim podem ser utilizados pela fauna local.

Meu objetivo é avaliar como a iluminação artificial afeta os morcegos insetívoros nos parques urbanos de Brasília, a capital de um país megadiverso sem estudos que avaliem como os morcegos respondem à presença de luz artificial em ambientes urbanos. Vou testar as seguintes hipóteses: a primeira é que a atividade dos morcegos insetívoros será maior próximo aos locais com iluminação artificial, pois a abundância de insetos também será maior próximos aos locais com iluminação artificial; a segunda, é que a atividade das espécies de voo rápido será maior próximos aos locais com iluminação artificial, enquanto as espécies de voo lento apresentarão uma resposta negativa à iluminação artificial, provavelmente para evitar a exposição a predadores em áreas abertas; e a terceira, as espécies de voo rápido estarão positivamente relacionadas com ordens de artrópodes, pois são mais ativas próximo aos locais com iluminação artificial onde há maior abundância de artrópodes.

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Nocturnal artificial light in Urban Parks: Does it affect bats or bats' prey?

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Running tittle: Artificial light: Does it affect bats or bats' prey.

Highlights

- Artificial lights lure insects, thus attracting bats, in a bottom-up effect system.
- The response is species specific, with fast-flying bat species being more tolerant to light.
- Fast flying bats are positively correlated with arthropod orders.

Abstract

Increasing global urbanization turns essential the understanding of the role of artificial lighting at night (ALAN) on bat's activity and community structuring in urban environments. We aimed to evaluate if artificial lighting influences the bat's activity and prey abundance in urban parks. We hypothesized that bat activity would be higher near sites with ALAN, supposing that the abundance of insects, attracted by the light, would be higher. Second, we expected that the activity of fast-flying species would be higher near ALAN while slow-flying species would present a negative response to ALAN, probably to avoid exposition to predators in more illuminated areas. Third, fast-flying species are positively related to arthropod orders, because both are positively related to ALAN source. We established bat activity through acoustic recordings. We measured arthropods abundance using yellow sticky traps installed in each sampling site. We checked the direct and indirect effect of artificial light on bat activity, via arthropod abundance using structural equation models. The abundance of arthropods was positively influenced by ALAN, while bat activity was not directly affected. However, bat activity changed positively with arthropod abundance. The activity of most fast-flying species increased in response to artificial light and arthropod abundance. *Eumops* sp/*Nyctinomops macrotis* group presented a negative response to arthropod abundance. The activity of slow-flying species *Eptesicus* sp. presented a negative response to artificial light. ALAN poses a direct influence on arthropod abundance, indirectly affecting bat activity, though this effect is species-specific, with fast-fly species benefiting with ALAN.

Keywords: arthropods, bat echolocation, green remnants, insectivory, urban ecosystems

1. Introduction

One of the leading causes of global biodiversity decreasing is urbanization (Sala et al., 2000) because it converts natural habitats into artificial environments composed of human constructions. This process initially produces habitat fragmentation (Strassburg et al., 2017) and later noise pollution (Bunkley, McClure, Kleist, Francis, & Barber, 2015), and artificial lighting (E. G. Rowse, Lewanzik, Stone, Harris, & Jones, 2016). Those processes act as environmental filter structuring communities in urban environments (Aronson et al., 2016) selecting species that present functional traits that enable them to survive in this new habitat. Some species, like free-tailed bats (Molossidae) and evening bats (Vespertilionidae), possibly are more tolerant or even favored by urbanization, according to their ecological requirements, occurring in both urban and suburban environments (Santini et al., 2019). Species that require conserved natural habitat are usually hampered by urbanization, with rare or less tolerant species disappearing, or changing their ecology (Avila-Flores & Fenton, 2005; Hourigan, Johnson, & Robson, 2006; Kurta & Teramino, 1992; Loeb, Post, & Hall, 2009; Luck, Smallbone, Threlfall, & Law, 2013).

Artificial lighting at night (ALAN) is one of the most detrimental stresses caused by urbanization. The rapid increase of ALAN is affecting a considerable portion of the global biodiversity because approximately 30% of vertebrates and over 60% of invertebrates are nocturnal (Hölker, Wolter, Perkin, & Tockner, 2010). Recently studies have shown that birds (Kempenaers, Borgstrom, Loes, Schlicht, & Valcu, 2010), turtles (Bourgeois, Gilot-Fromont, Viallefont, Boussamba, & Deem, 2009), amphibians (Wise, 2007) and insects (van Langevelde, Ettema, Donners, WallisDeVries, & Groenendijk, 2011), have their activity patterns affected by ALAN. Animals can be attracted or repelled by light pollution, and are affected in foraging, reproduction, and communication. Therefore, altering nocturnal communities' structures

(Longcore & Rich, 2004). Thus, understanding how ALAN affects communities in urban environments will be of worth value for urban planning actions.

Although bats are the mammal order with the highest diversity in urban areas and a primary component of urban nocturnal communities, (Nunes, Rocha, & Cordeiro-Estrela, 2017; Santini et al., 2019) there is still a lack of knowledge on how they use urban environments and the role they may have in maintaining ecological processes in urban matrices, especially in the Neotropical region. There is an urgency and global priority on urban bat studies (Bernard et al., 2012; Pacheco & Sodré, 2010; Russo & Ancillotto, 2015) because they are highly prone to be affected by ALAN (Stone, Harris, & Jones, 2015). Some studies have observed that bat communities in urban areas are restricted to few species specially composed of generalist species of frugivore, nectarivore and insectivore species (Frank, Gabbert, Chaves-Campos, & LaVal, 2019; Jung & Kalko, 2010). Because urban areas are already associated with low bat diversity (Russo and Ancilloto 2015), it is vital to understand how ALAN affects different bat species and their activity in green remnants of urban environments, to avoid the loss of bat species at local scales.

It is possible to classify aerial insectivore bats into functional guilds based on whether they forage in open areas or edge spaces near environmental clutter (Denzinger, Tschapka, & Schnitzler, 2018). Studies have shown that artificial lights benefit aerial insectivore bats that catch prey on the wing, while other bats are not benefited (Jung & Kalko, 2010; Lewanzik & Voigt, 2017). There are also studies registering that fast-flying bats, open-air foragers –like Molossidae- are attracted to artificial lights, whereas slow-flying bats, cluttered environment foragers –like vespertilionids - are not. The latter evade artificial lights to avoid exposition to predators (Jones & Rydell, 1994; Jung & Kalko, 2011). It seems that the type of functional guild and the flying speed of the bats are essential traits that will determine the ability of aerial insectivores to deal with artificial lights of different types (Frank et al., 2019; Lewanzik & Voigt, 2017).

However, studies evaluating the relationship between bat fauna and resource availability in urban environments are still scarce, especially in Neotropical areas, where the urbanization process happens without planning, and the maintenance of green areas in urban centers is not a priority (Nunes et al., 2017; Pickett et al., 2001; Silva de Araújo & Bernard, 2016). Few studies are dealing with the effects of artificial light on bats in the Neotropical region, and they refer to cities with neighboring tropical forest environments (Avila-Flores & Fenton, 2005; Frank et al., 2019; Jung & Kalko, 2010). We aim to assess how ALAN affects insectivorous bats in urban parks (UP) of a highly populated city surrounded by cerrado (savanna) vegetation and extensive farming. Therefore, we are testing the following hypothesis: the first is that bat activity is higher near sites with ALAN, because the abundance of insects is also higher; the second, is that the activity of fast-flying species is higher near ALAN while slow-flying species present a negative response to ALAN, probably to avoid exposition to predators in open areas; and the third, that fast-flying species are positively related to arthropod orders, as they are more active near the ALAN source where there is higher abundance of arthropods.

2. Material and Methods

2.1. Study Area

Brasília is a densely green city located within the Cerrado. The climate is characterized by a very marked dry period, from April to September, and a rainy season, from October to March. Brasília is located about 1,000 meters above sea level (GDF, 2019). We selected six urban parks located within Brasília. Two are multi-use parks: named Olhos d’Água – OAEMP -

with 21.54ha, and Asa Sul Multi-use Park – ASMP - with 21.73ha. The other Parks are named ecological parks: Dom Bosco Ecological Park – DBEP - with 131.14ha; Águas Claras Ecological Park – ACEP – with 86.10ha, Ezechias Heringer Ecological Park – EHEP – with 306.44ha, and Burle Marx Ecological Park –BMEP - with 280ha (Figure 1). All urban parks have typical Cerrado vegetation, with small portions of gallery forest, and some species of exotic plants. They are open to the public during the day and broadly used by the local population for recreational purposes (IBRAM, 2013).

2.2. Data Collection

To estimate the effects of artificial lighting in bat activity and arthropod availability, we selected eight sites in each park (four sites in lit areas and four sites in unlit areas), with a minimum distance of 130m between sites. High-pressure sodium (HPS) lamps were present in all of the Urban Parks sampled. Because of the small area with artificial light available in DBEP, only two sites in lit treatment we selected in this area, totaling 46 sampling sites. We collected data twice in each season, from September/2018 to February/2019. We registered artificial lighting intensity (in lux, with Instrutemp ITLD 270I) in each sampling site.

To assess insectivorous bat activity, we placed AudioMoth ultrasound detectors (vs. 1.0.0, Open Acoustic Devices, UK) installed at a 3-m-height pole or trees from the ground (Figure 2), recording at frequencies from 0 to 384Hz. Recordings were performed every 5 minutes (1-min recording, 4-min interval) during 12 hours, starting at sunset. Recorded files were analyzed in Raven Pro (vs. 1.5. Cornell Lab of Ornithology, USA) and bat passes were considered as a sequence of pulses with intervals smaller than 1s between them (Fenton, Jacobson, & Stone, 1973). Calls were identified to species-level whenever possible, using an identification guide written by Arias-Aguilar et al. (2018) that sampled bats in Cerrado. We measured the main acoustics characteristics of the pulse such as minimum and maximum frequencies (kHz), peak frequency (kHz), duration of the pulse (ms), and the interval between pulses (ms) to proceed with bat sound identification. We assigned species to functional guilds (open vs. edge forager) following Denzinger et al. (2018), and as fast or slow flier following Jung and Kalko (2010). Because the public light pole structure could be found within the park or in the street outside the parks, the recorders were installed under the lit areas and were placed as close as possible to the artificial lighting pole (Figure 2).

To quantify resource availability, we measured arthropod abundance by conducting captures with 25×50cm yellow sticky traps (BioControle, Brazil), installed at a 5-m-height pole from the ground approximately 2m apart from the ultrasound detectors (Figure 2). During all night, sticky traps were checked every hour, we use pens with different colors and geometrical shapes that represented each hour. Those sticky traps were then taken to the laboratory to proceed with the arthropods identification and were identified to the family level under the criteria of (Rafael, Melo, Carvalho, Casari, & Constantino, 2012)**.**

2.3. Data analysis

We developed a Structural Equation Model (SEM) to assess how direct and indirect predictors associated with ALAN affect insectivorous bat activity and buzz ratio. We included artificial lighting intensity, represented by lux, and hour after sunset (1 to 12) as exogenous (indirect) factors, which would indirectly affect bat activity. As an endogenous (direct) factor, which would directly influence bat activity, we included only arthropod abundance (considered number of arthropods/hour). We also developed different SEMs to evaluate how direct and indirect predictors affect the activity of most abundant bat species, with over 100 individual passes.

We conducted a Redundancy Analysis (RDA) to evaluate how different bat species respond to different arthropod families throughout the night comparing matrices containing data for bats (dependent variable) and arthropods (independent variable) (Legendre & Legendre, 1998). Bat species matrix was transformed (Hellinger distances) (Legendre & Gallagher, 2001) in order to determine the relationship between the occurrence of each bat species and the arthropods orders via Multiple Regression Models (Legendre, 2005; Legendre & Gallagher, 2001). Statistical significance for the RDA was based on permutation tests of pseudo-F values computed as the ratio between constrained and unconstrained ordination (Legendre & Legendre, 1998). Species groups were then visually identified (RDA graphics) based on the strength of their relationship with arthropod orders. Only the most abundant bat species and arthropod orders with more than 10 individuals were used for the analysis.

We conducted all analysis on R software (vs. 3.5.2, R Core Team, 2018) by using packages “Vegan” (Oksanen et al., 2008) for RDA, and “sem” (Fox et al., 2017) and “Lavaan” (Rosseel, 2012) for SEM.

3. Results

3.1. General Results

We performed twenty-four nights of sampling, where 13,824 sound files were recorded in the WAV format. We used 12,821 files for the analyses, totaling 769,260 minutes sampled. The 1003 files were not used due to recording problems. We recorded a total of 11,773 individual passes and 1,683 feeding buzzes. Six thousand two hundred thirty-three passes were in lit sites, and 5,540 in dark sites and 954 feeding buzzes in the lit site and 729 in the dark site. We managed to identify 11.015 bat passes from four families, 14 genera, and 20 species. The Molossid family was the most registered, with 5,690 passes in the lit sites and 3,607 passes in the unlit site, followed by the Vespertilionid family with 107 passes in the lit sites and 1,226 passes in the unlit sites. The Emballonurid Family was the third most registered, with 72 passes in the lit sites and 293 in the unlit sites. (Table S1). *Molossus molossus* (n = 4,945; 42.01%), followed by *Eumops* sp./*Nyctinomops macrotis* (n = 1,212; 10.29%) and *Molossus currentium* (n = 1,013; 8.61%) were the most abundant species.

Ninety-six sticky plates were installed for arthropod sampling during the 24 sampling nights and 91 sticky plates were used for analysis. Five sticky plates were not used because of problems in the traps. We captured 3,447 arthropods, from which 3,343 were identified as ten orders and 32 families, among insects and arachnids. The most abundant in general were Diptera (n = 2,436; 70.7%), followed by Hemiptera (n = 726; 21.1%) and Coleoptera (n = 92; 2.7%). The most common orders in the lit and unlit site is Diptera, Hemiptera, and Coleoptera (Table S3).

3.2. Effect of ALAN on Bat Activity and Arthropod Abundance

Artificial lighting increased the general abundance of arthropods (estimate = 0.285, p < 0.01) but did not affect bat activity (estimate = 0.001, p = 0.75) nor buzz ratio (estimate = 0.001, p = 0.51) directly. The latter was positively affected only by arthropod abundance (p < 0.01 for both) (Figure 3). Among the most abundant species, activity of fast-flying species *M. molossus* (estimate = 0.177 p < 0.01), *Molossus* sp1 (estimate = 0.012, p < 0.01), and *Cynomops* sp1 (estimate = 0.024, p < 0.01) were positively affected by arthropod abundance but had no direct response to ALAN. Activity of *Eumops* sp./*N. macrotis* was not affected by ALAN but was negatively affected by arthropod abundance (estimate = -0.013, p = 0.037). Activity of *Eumops perotis* and *M. currentium* increased in areas near ALAN (estimate = 0.014, p < 0.01 and estimate = 0.021, p = 0.001, respectively) and with higher arthropod abundance (estimate = 0.005, p = 0.033 and estimate = 0.060, p < 0.01, respectively). Activity of slow-flying species

Eptesicus furinalis (estimate = -0.024, p = 0.001) and *Eptesicus brasiliensis* (estimate = -0.031, p = 0.012) were negatively affected by ALAN, being higher in the dark areas of the parks. Activity of *Peropteryx macrotis*, *Peropteryx trinitatis*, and *Eumops* sp1 was not affected by ALAN or arthropods abundance.

3.3. Bats Species × Arthropod Group

Redundancy Analysis (RDA) significantly classified bat species groups according to arthropod orders presence throughout the night (F = 4.08, p = 0.001). First axis explained 21.3% of species variation in relation to hour after sunset and second axis explained 16.1% of total variation. Two main groups were observed. The first group included most of Molossidae species (*M. molossus*, *Molossus* sp1., *M. currentium*, and *Cynomops* sp1.) were explained by arthropod orders (Diptera, Hemiptera, Coleoptera, Hymenoptera and Aranae) responding to the same temporal pattern. Second group was formed by *Eumops* sp.*/N. macrotis*, *Eumops sp, E. perotis, E. furinalis*, *E. brasiliensis*, *P. macrotis* and *P. trinitratis*, with no relationship to the arthropods present in the records (Figure 4).

4. Discussion

4.1 Effects of ALAN on Bat Activity and Arthropod Abundance

In general, the increased bat activity near artificial light is a result of the higher resource availability provided in those illuminate areas as shown by several studies conducted in Europe, North and Central America (Frank et al., 2019; Rowse, Harris, & Jones, 2016). The relationship between higher arthropod abundance and bat activity is well-documented in literature with studies done in forest environments (Avila-Flores & Fenton, 2005; Jung & Kalko, 2010). However, little is known about how this relationship takes place in open areas, such as savanna habitats. This is the first study evaluating how insectivorous bats in an urban environment within a Neotropical Savanna respond to light presence, showing indirect effects of ALAN on bat activity by the increasing arthropod abundance around ALAN poles. Light presence lures insects, thus attracting bats, in a bottom-up effect system, corroborating our study first hypothesis that bat activity is higher near sites with ALAN, because the abundance of insects is also higher. We observed more activity of fast-flying species, such as *M. molossus*, *M. currentium, Molossus* sp1, *E. perotis* and *Cynomops* sp1. near ALAN sites, when compared to slow-flying species such as *E. furinalis and E. brasiliensis*. Thus, confirming our second hypothesis that the activity of fast-flying species is higher near ALAN while slow-flying species present a negative response to ALAN, probably to avoid exposition to predators in open areas. We also observed that *M. molossus*, *M. currentium, Molossus* sp1 and *Cynomops* sp1. are related to arthropod order, partially confirming our third hypothesis that fast-flying species is positively related to arthropod orders, as they are more active near the ALAN source where there is higher abundance of arthropods. However, the large molossids (*Eumops sp/Nyctnomops macrotis, Eumops spp and E. perotis*) were unrelated.

Another factor influencing ALAN effects on bat activity is the type of light used for public illumination (Stone, Wakefield, Harris, & Jones, 2015). Lewanzik & Voigt (2017) observed higher bat activity in areas with mercury vapor lamps when compared to LED lamps. However, according to Rowse et al. (2016), sodium vapor lamps, which are used to illuminate urban parks in our study area, had similar effects on bat activity when compared to LED lamps. In our study area, overall bat activity was not significantly different between lit and unlit treatments, but for sure, sodium vapor lamps attracted arthropods as was observed in previous studies (Eisenbeis & Hänel, 2009).

We observed that ALAN adequately attracted Diptera; however, the vespertilionid *E. furinalis*, a predator of this order (Aguiar & Antonini, 2008) was intolerant to light presence, which could reduce the service provided by this bat species as a population regulator of those insects. This situation may be especially detrimental because Diptera is considered one of the most critical insect order regarding public health issues in Brazil, because of its role as vector of different diseases (Lourenço & Rodrigues, 2017). Increased abundance of arthropods near urban ALAN areas can result in a shift in the food chain of bats preying in urban ALAN areas, with significant shift on diet consumed items compared to the diet of bats foraging far from artificial lights (Cravens, Brown, Divoll, & Boyles, 2018; Holzhauer et al., 2015; Manfrin et al., 2017).

Studies conducted in the Neotropical region observed that the traits of slow flight and edge spaces bats are not predictors of a light-avoidant species (Frank et al., 2019; Jung & Kalko, 2010). In our study, the species with these traits, *P. macrotis* and *P. trinitatis*did not have their activity affected by ALAN and neither by the abundance of arthropods. Though, *E. furinalis* and *E. brasiliensis* had their activity negatively affected by ALAN. The difference between our results and those of the others carried out in the Netropical region may be related to the regional factor, since the Cerrado has savannah vegetation and large open areas, the presence of artificial lighting may not be beneficial for slow-flight and edge spaces, increasing the exposure to predators.

Contrary to slow-flight species, most Molossidae species, considered fast-flying species, were positively influenced by the higher arthropod abundance brought by ALAN presence, either directly (*E. perotis* and *M. currentium*) or indirectly (*M. molossus*, *Molossu*s sp1, *Cynamops* sp1). High activity levels of fast-flying bats foraging near artificial lights have been recorded in previous studies conducted in Neotropical and European forests (Frank et al., 2019; Jung &

Kalko, 2010, 2011; Stone, Wakefield, et al., 2015). Because molossids are fast in flight, with little maneuverability to cluttered habitats, they are well adapted to forage in open spaces such as cities (Denzinger et al., 2018) , and more likely to escape from predators as they can fly faster from predators during foraging time (Jones & Rydell, 1994).

Three species, *M. molossus*, *Eumops* sp./*Nyctinomops macrotis*, and *M. currentium* accounted for 60.9% of all recorded bat passes, suggesting a dominance of few species in urban environments, as observed in previous studies (Azam et al., 2018; Jung & Kalko, 2010; Lewanzik & Voigt, 2017). In Panama, over 95% of recorded passes in urban areas were from molossids, a rate significantly higher than the one found in natural areas (Jung & Kalko, 2010). Artificial lighting may be acting as an environmental filter selecting species adapted to the new scenario provided by urbanization (Aronson et al., 2016), especially fast-flying species, such as molossids, leading to a pattern observed in urban areas that are entirely different from those observed in natural habitats.

4.2 Bats Species × Arthropod Group

We observed temporal segregation on insectivorous bat activity based on the presence of arthropod groups, as demonstrated by the Redundancy analysis (RDA) results. Small fast-flying species of Molossidae (*M. molossus, M. currentium, Molossus* sp1 and *Cynomops* sp1) are the first to show up at night (Figure 4), and this behavior is related to the activity of the most abundant arthropod orders registered in this study. These molossids species are more active in the early evening (Table S5 and Figure S1, S2, S3 and S8) as indicated by the SEM analyses. Large molossids (*Eumops* sp./*N. macrotis*, *Eumops sp, E. perotis*) and *E. furinalis*, *E. brasiliensis*, *P. macrotis* and *P. trinitatis*compose the group not related to any of the most abundant arthropod orders (Figure 4). These species showed no variation in activity in response arthropod abundance, except *E. perotis* (Table S3). For the small molossids, our results corroborate the results of Jones & Rydell (1994) who observed species that feed on small arthropods emerging during the first hours of the night.

On the other hand, larger species such as *Eumops* sp*./N. macrotis, Eumops* sp*, E. perotis* feed on larger arthropods and do not depend on the abundance of the smaller arthropods present in the first hours of the evening, foraging through all the night (Jones & Rydell, 1994) (Figure S5, S6 and S7). In our study the three most recorded arthropod orders (Diptera, Hemiptera, and Coleoptera) are among the main items consumed by molossids (Bohmann et al., 2011; Fenton et al., 1998; Lee & McCracken, 2002), suggesting that arthropods abundance may be explaining how bat species separate themselves throughout the night. The absence of Lepidoptera in our records, other common item in molossids diet (Bohmann et al., 2011; Fenton et al., 1998; Lee & McCracken, 2002) may be a result of the employed method of capture. Stick traps are selective in arthropods capture (Tang et al., 2016). Although, our results recorded the same orders, Diptera, Hemiptera, Coleoptera, Orthoptera and Hymenoptera, that are known to compose the diet of the species *E. brasiliensis, E. furinalis, P. macrotis and P. trinitatis* (Aguiar & Antonini, 2008; Garcia, Machado, Nunez, Delgado-Jaramillo, & Aular, 2011). Our RDA results for these bat species, from the families Vespertilionidae and Emballonuridae, corroborate what was observed in SEM, where their activity was not correlated with the abundance of arthropods. (Figure 4) (Table S5). This result may be an indicative of the effects of urbanization on those bat families, usually adapted to forage in cluttered or background cluttered areas (Kalko, Handley, & Handley, 1996).

The higher abundance of Molossidae species in our study areas suggests they are highly tolerant to urban environments and are benefited from the high abundance of arthropods near the

ALAN. Furthermore, the presence of molossids in urban environments may also be related to higher roost availability in those areas since human-made structures can be similar to natural cracks used by molossids species (Gaisler et al. 1998, Keeley and Keeley 2004). Additionally, the presence of species intolerant to ALAN, such as *E. brasiliensis* and *E. furinalis* may be due to the high level of afforestation in the city of Brasília. Straka, Wolf, Gras, Buchholz, & Voigt, (2019) observed that a dense tree cover might potentially minimize effects of ALAN in intolerant species, which highlights the importance of preserving natural remnants in the urban area in order to preserve insectivorous bat communities and their ecosystem services (Silva de Araújo & Bernard, 2016).

5. Conclusion

The activity of insectivorous bats is indirectly affected by ALAN, which positively affects the abundance of arthropods, in a bottom-up effect. We also concluded that fast-flying bats that forage in open areas benefit from ALAN, with greater activity near the illuminated sites. The presence of species that are intolerant to ALAN in our study, such as *E. furinalis* and *E. brasiliensis*, may be an indication of the importance of urban parks, and the importance of green remnants. These structures can be significant for the maintenance and conservation of the populations of bats.

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7. Figures

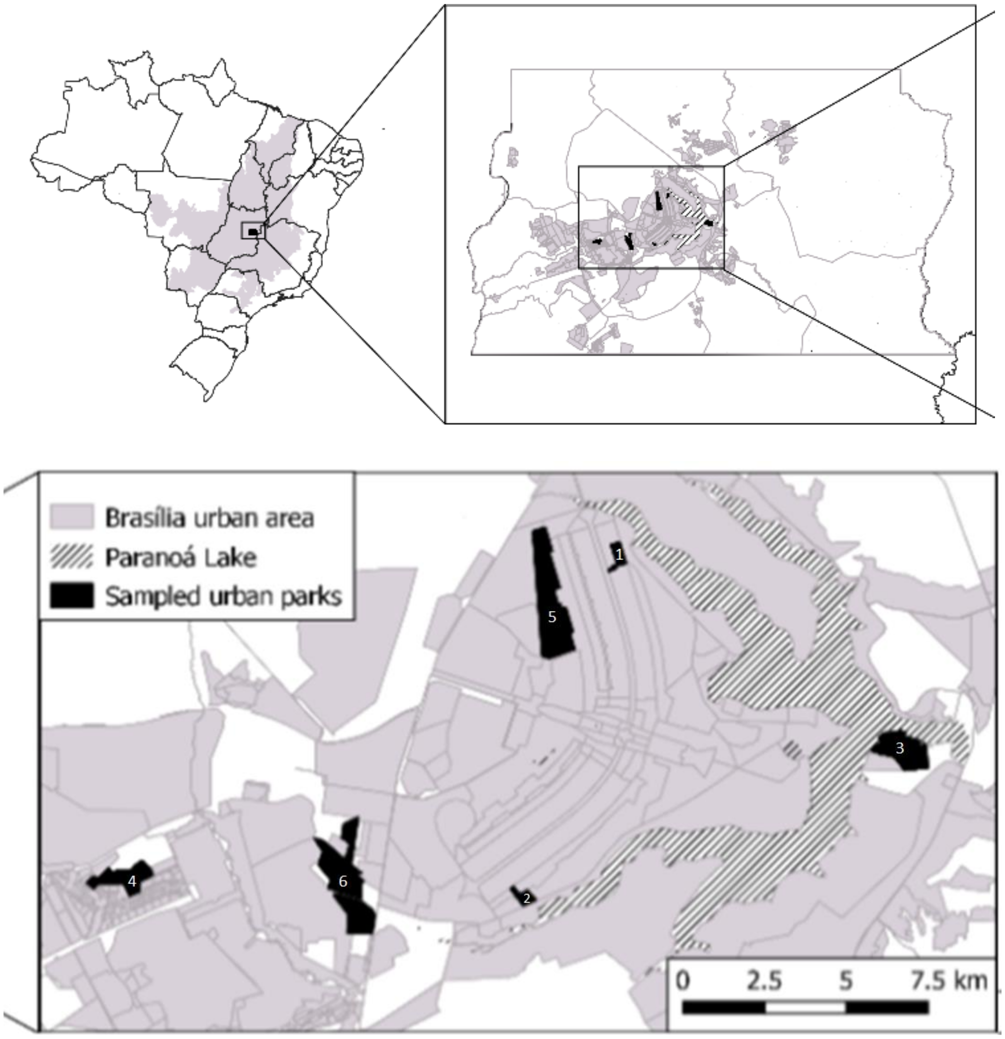

Figure 1. Study area showing Federal District within Cerrado and Brazil, and location of the six analyzed Urban Parks (UP) within Brasília urban matrix. 1 = OAEMP – Olhos d’Água Ecological Multi-use Park, 2 = ASMP – Asa Sul Multi-use Park, 3 = DBEP – Dom Bosco Ecological Park, 4 = ACEP – Águas Claras Ecological Park, 5 = BMEP – Burle Marx Ecological Park and 6 = EHEP – Ezechias Heringer Ecological Park.

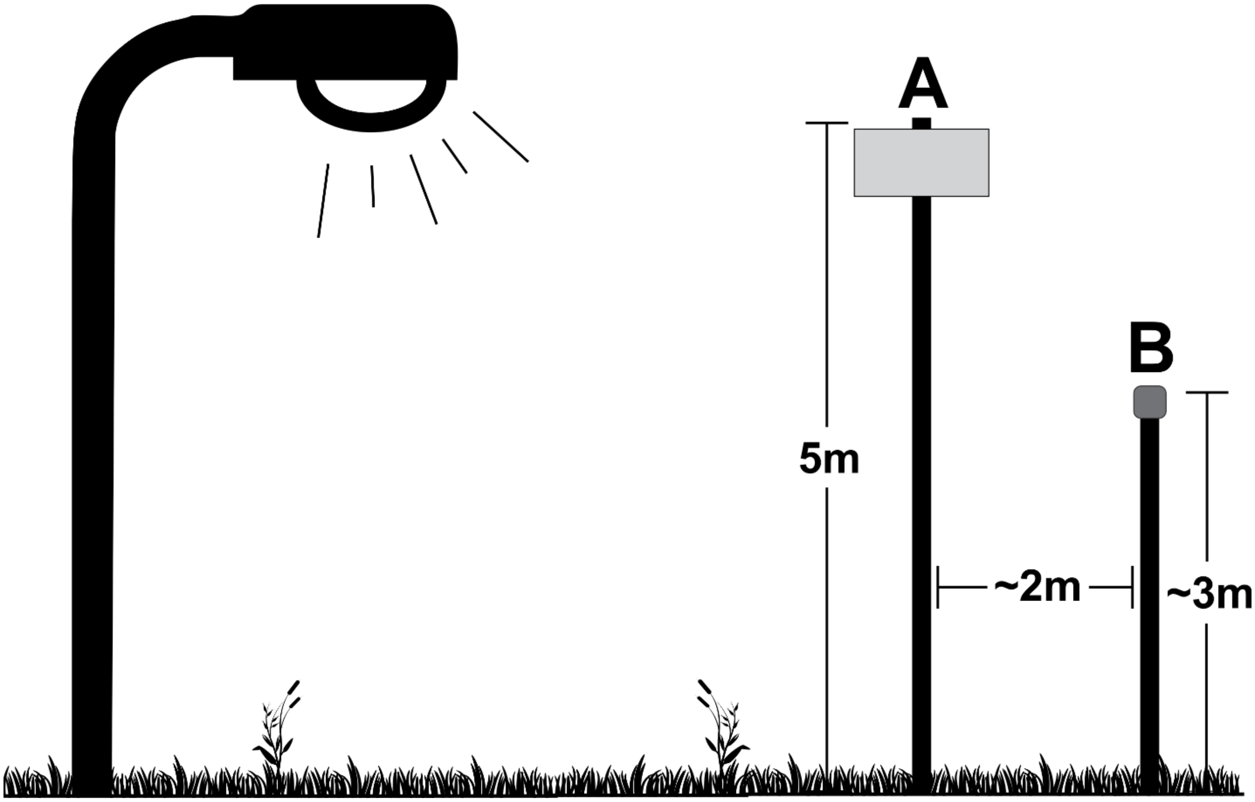

Figure 2: Scheme of how recorder (B) and sticky trap (A) were positioned and the distance of both was approximately 2 meters. The recorders (B) installed at approximately 3-m-height pole or tree and the sticky trap (A) installed at a 5-m-height pole. The distance of both, recorder and the sticky trap, from the artificial light source varied in each park.

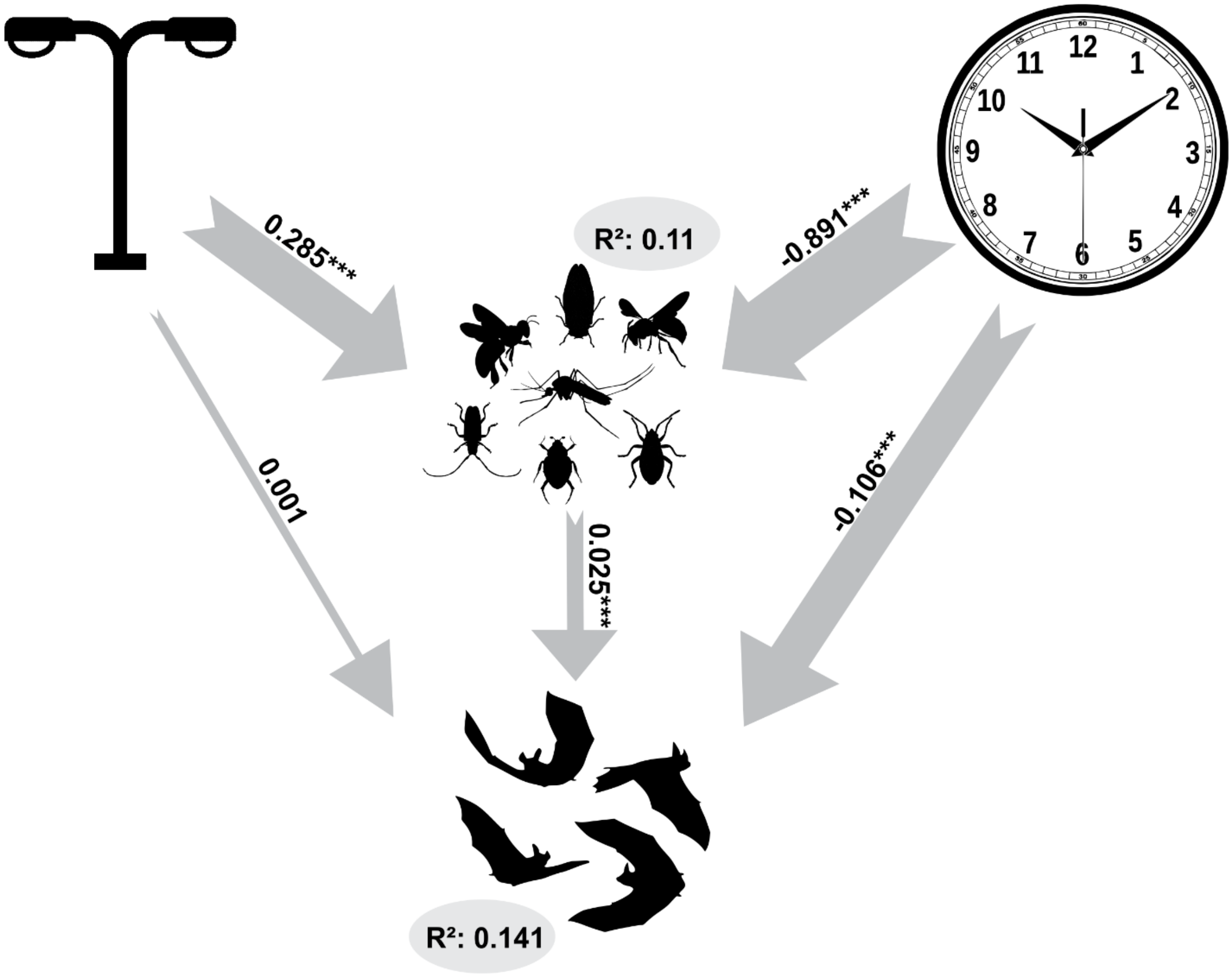

Figure 3. Structural Equation Model for bat species and arthropod orders located in the city of Brasília, Federal District of Brazil, from September/2018 to February/2019. Arrow width represents relative strength of each effect and significant effects are indicated with asterisks (*p<0.05; **p<0.01; ***p<0.001). Determination coefficient (R^2) is represented in gray circles to both dependent variables (bat activity and insect abundance).

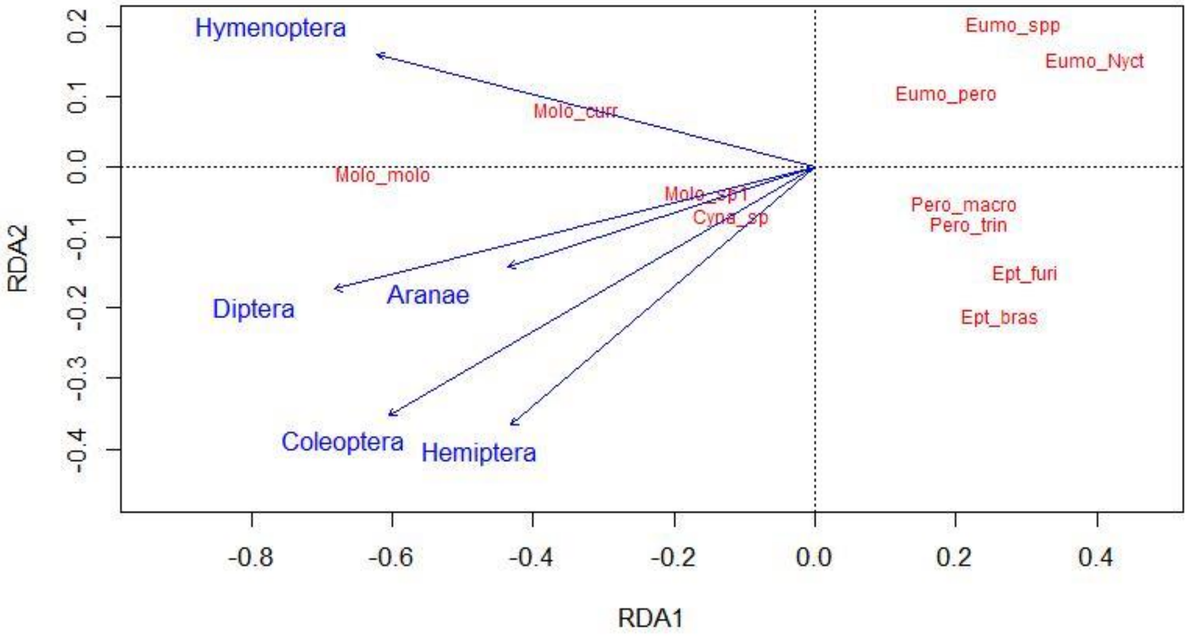

Figure 4. Redundancy Analysis (RDA) biplot showing the relationship between bat species and arthropod orders located in the city of Brasília, Federal District of Brazil, from September/2018 to February/2019. First axis represents 21.3% or variation according to night hours and axis 2 represents 16.1% of total variation. *Note:* Molo_molo: *M. molossus,* Molo_curr: *M. currentium*, Molo_sp1: *Molossus sp1*, Cyno_sp: *Cynomomops* sp1, Eumo_spp: *Eumops* spp, Eumo_pero: *E. perotis*, Eumo_Nyct: *Eumops* sp/ *Nyctinomops macrotis*, Pero_macro: *P. macrotis*, Pero_trin: *P. trinitratis*, Ept_furi: *E. furinalis*, Ept_bras: *E. brasiliensis.*

8. Supplementary Material

Table S1. Bat species recorded in Urban Parks located in the city of Brasília, Federal District of Brazil, from September/2018 to February/2019 in lit and unlit treatments with its respective passes number and relative abundance (RA). Species were classified into functional guilds as either open-air foragers or edge foragers based on Denzinger et al.(2018), and as fast or slow fliers based on Jung & Kalko (2010).

Family Species	Foraging	Passes in unlit areas	Passes in lit areas	RA (%)
Emballonuridae				
Peropteryx macrotis	Slow edge	175	55	1.95
Peropteryx trinitatis	Slow edge	118	17	1.15
Molossidae				
Cynomops sp1	Fast open	290	300	5.01
Cynomops planirostris	Fast open	30	36	0.56
Cynomops spp.	Fast open	23	20	0.36
Eumops sp./*Nyctinomops macrotis*	Fast open	503	709	10.29
Eumops spp.	Fast open	275	408	5.8
Eumops perotis	Fast open	96	138	1.99
Molossus currentium	Fast open	311	702	8.61
Molossus molossus	Fast open	1831	3114	42.01
Molossus rufus	Fast open	0	5	0.04
Molossus sp1	Fast open	153	155	2.62
Molossops temminckii	Fast open	38	52	0.76
Molossops spp.	Fast open	17	41	0.49
Nyctinomops laticaudatus	Fast open	9	6	0.13
Promops nasutus	Fast open	7	2	0.08
Promops centralis	Fast open	1	1	0.02
Promops spp.	Fast open	23	1	0.2
Phyllostomidae				
NI		14	6	0.17
Vespertilionidae				
Eptesicus brasiliensis	Slow edge	622	21	5.46
Eptesicus furinalis	Slow edge	499	55	4.71

Continue Table S1

Family Species	Foraging	Passes in unlit areas	Passes in lit areas	RA (%)
Histiotus diaphanopterus	Slow edge	1	0	0.01
Histiotus velatus	Slow edge	7	1	0.07
Lasiurus blossevillii	Slow edge	3	1	0.03
Lasiurus cinereus	Slow edge	13	6	0.16
Lasiurus ega	Slow edge	28	13	0.35
Myotis albescens	Slow edge	4	1	0.04
Myotis lavali	Slow edge	18	0	0.15
Myotis spp.	Slow edge	30	9	0.33
Rhogeessa hussoni	Slow edge	1	0	0.01
NI		400	358	6.44
TOTAL		5540	6233	100

Table S2: Bat species recorded in each Urban Parks sampled in the city of Brasília, Federal District of Brazil, from September/2018 to February/2019 in lit and unlit treatments with its respective passes number. OAEMP – Olhos d'Água Ecological Multi-use Park, ASMP – Asa Sul Multi-use Park, DBEP – Dom Bosco Ecological Park, ACEP – Águas Claras Ecological Park, BMEP – Burle Marx Ecological Park and EHEP – Ezechias Heringer Ecological Park.

Family	OAEMP		ASMP		DBEP		ACEP		BMEP		EHEP	
Species	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit
Emballonuridae												
Peropteryx macrotis	9	26	51	15	22	11	81	0	1	0	11	3
Peropteryx trinitatis	2	3	10	2	14	8	89	0	0	1	3	3
Molossidae												
Cynomops greenhalli	70	60	64	47	30	63	20	19	48	74	58	37
Cynomops planirostris	2	3	10	11	0	1	2	4	7	7	9	10
Cynomops sp.	8	8	2	7	5	3	3	1	3	0	2	1
Eumops sp./*Nyctinomops macrotis*	78	104	106	216	115	128	43	48	48	20	113	193
Eumops spp.	23	17	23	44	60	93	129	10	6	2	34	242
Eumops perotis	0	4	9	6	60	116	22	2	5	5	0	5
Molossus currentium	52	112	50	110	57	185	47	60	26	35	79	200
Molossus molossus	237	372	516	680	183	634	301	208	112	225	482	995
Molossus rufus	0	5	0	0	0	0	0	0	0	0	0	0
Molossus sp.	22	13	34	26	8	40	20	4	9	17	60	55
Molossops temminckii	0	21	22	8	0	2	6	1	2	14	8	6
Molossops spp.	1	5	3	11	3	2	0	0	6	21	4	2
Nyctinomops laticaudatus	0	1	2	1	0	0	0	2	5	2	2	0

Continue Table S2

Family Species	OAEMP		ASMP		DBEP		ACEP		BMEP		EHEP	
	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit
Promops nasutus	3	0	2	1	0	0	1	0	0	1	1	0
Promops centralis	0	0	0	1	0	0	0	0	1	0	0	0
Promops spp.	5	0	1	0	7	0	3	0	0	1	7	0
Phyllostomidae												
NI	3	0	10	6	0	0	0	0	0	0	1	0
Vespertilionidae												
Eptesicus brasiliensis	26	5	154	7	16	3	346	0	79	6	1	0
Eptesicus furinalis	40	2	87	37	2	2	232	0	138	14	0	0
Histiotus diaphanopterus	0	0	0	0	0	0	0	0	1	0	0	0
Histiotus velatus	2	0	1	0	4	1	0	0	0	0	0	0
Lasiurus blossevillii	0	1	1	0	2	0	0	0	0	0	0	0
Lasiurus cinereus	1	3	0	1	10	2	1	0	1	0	0	0
Lasiurus ega	0	0	27	12	1	1	0	0	0	0	0	0
Myotis albescens	2	0	1	0	0	0	1	1	0	0	0	0
Myotis lavali	0	0	4	0	1	0	2	0	9	0	2	0
Myotis spp.	9	2	10	7	1	0	5	0	3	0	2	0
Rhogeessa hussoni	0	0	0	0	0	0	0	0	1	0	0	0

Table S3. Arthropod orders and families recorded in Urban Parks located in the city of Brasília, Federal District of Brazil, from September/2018 to February/2019 in lit and unlit treatments with its respective number of individuals and relative abundance (RA).

FILO **Order** Family	Number in unlit areas	Number in lit areas	RA(%)
ARACHNIDA			
Aranae	**7**	8	0.435
INSECTA			
Blattodea			
Blattellidae	1	0	0.029
Cloleoptera			
Anthicidae	0	1	0.029
Bruchidae	18	27	1.305
Cantharidae	1	0	0.029
Chrysomelidae	13	3	0.464
Coccinelidae	0	5	0.145
Curculionidae	6	3	0.261
Latridiidae	4	3	0.203
Mycetophagidae	1	0	0.029
Staphylinidae	3	0	0.087
Tenebrionidae	1	3	0.116
Diptera			
NI	623	1813	70.67
Hemiptera			
Aleyrodidae	7	31	8.703
Alydidae	1	0	1.102
Aphididae	9	16	0.029
Cicadellidae	217	83	0.725
Fulgoridae	2	0	0.058
Lygaeidae	2	1	0.087
Membracidae	0	2	0.058
Miridae	6	4	0.29
Psyllidae	185	131	9.167
Reduviidae	18	7	0.725
Rhopalidae	0	1	0.029
Ricaniidae	0	1	0.029
Tingidae	1	0	0.029

Continue Table S3

FILO **Order** Family	Number in unlit areas	Number in lit areas	RA(%)
Tropiduchidae	1	0	0.029
Ordem Hymenoptera			
Apidae	0	5	0.145
Braconidae	0	2	0.058
Formicidae	14	26	1.16
Ichneumonidae	0	1	0.029
Vespidae	1	7	0.232
Mantodea			
Mantidae	0	1	0.029
Neuroptera			
Chrysopidae	0	2	0.058
Orthoptera			
Tettigoniidae	7	1	0.232
Thysanoptera			
NI	4	2	0.174
Insecta NI	59	45	3.017
TOTAL	1212	2190	100

Table S4: Arthropod orders and families recorded in each Urban Parks sampled in the city of Brasília, Federal District of Brazil, from September/2018 to February/2019 in lit and unlit treatments with its respective number of individuals. OAEMP – Olhos d'Água Ecological Multi-use Park, ASMP – Asa Sul Multi-use Park, DBEP – Dom Bosco Ecological Park, ACEP – Águas Claras Ecological Park, BMEP – Burle Marx Ecological Park and EHEP – Ezechias Heringer Ecological Park.

FILO **Order**	OAEMP		ASMP		DBEP		ACEP		BMEP		EHEP	
Family	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit
ARACHNIDA												
Aranae	2	1	1	3	0	0	2	1	1	1	1	2
INSECTA												
Blattodea												
Blattellidae	1	0	0	0	0	0	0	0	0	0	0	0
Cloleoptera												
Anthicidae	0	0	0	0	0	1	0	0	0	0	0	0
Bruchidae*	0	5	15	16	2	1	0	4	0	0	1	1
Cantharidae*	1	0	0	0	0	0	0	0	0	0	0	0
Chrysomelidae*	3	0	6	0	1	2	1	0	1	0	1	1
Coccinelidae*	0	1	0	3	0	1	0	0	0	0	0	0
Curculionidae*	2	1	1	0	1	0	0	1	2	1	0	0
Latridiidae	2	1	1	0	0	0	0	0	0	1	1	1
Mycetophagidae	0	0	0	0	0	0	0	0	1	0	0	0
Staphylinidae*	1	0	1	0	1	0	0	0	0	0	0	0
Tenebrionidae*	0	1	0	0	1	2	0	0	0	0	0	0
Diptera												
NI	40	49	213	69	257	1517	61	103	21	38	31	37

Continue Table S4

FILO **Order** Family	OAEMP		ASMP		DBEP		ACEP		BMEP		EHEP	
	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit
Hemiptera												
Aleyrodidae*	1	0	0	1	3	0	0	30	3	0	0	0
Alydidae*	0	0	0	0	1	0	0	0	0	0	0	0
Aphididae*	3	6	3	3	1	2	0	4	1	0	1	1
Cicadellidae*	28	11	65	6	34	14	13	6	51	27	26	19
Fulgoridae*	1	0	0	0	0	0	0	0	1	0	0	0
Lygaeidae*	0	0	0	0	0	0	0	0	2	1	0	0
Membracidae	0	2	0	0	0	0	0	0	0	0	0	0
Miridae*	1	0	1	0	0	1	4	1	0	1	0	1
Psyllidae*	3	6	35	14	5	10	83	63	35	7	24	31
Reduviidae*	15	4	1	0	1	0	1	0	0	2	0	1
Rhopalidae	0	0	0	0	0	1	0	0	0	0	0	0
Ricaniidae	0	0	0	0	0	1	0	0	0	0	0	0
Tingidae*	0	0	0	0	0	0	0	0	1	0	0	0
Tropiduchidae	0	0	0	0	1	0	0	0	0	0	0	0
Ordem Hymenoptera												
Apidae*	0	0	0	1	0	4	0	0	0	0	0	0
Braconidae*	0	1	0	0	0	1	0	0	0	0	0	0
Formicidae*	3	0	3	0	3	20	1	2	1	2	3	2
Ichneumonidae*	0	0	0	0	0	0	0	1	0	0	0	0
Vespidae*	1	0	0	0	0	3	0	2	0	0	0	2

Continue Table S4

FILO **Order** Family	OAEMP		ASMP		DBEP		ACEP		BMEP		EHEP	
	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit	Dark	Lit
Mantodea												
Mantidae	0	0	0	0	0	1	0	0	0	0	0	0
Neuroptera												
Chrysopidae*	0	0	0	1	0	1	0	0	0	0	0	0
Orthoptera												
Tettigoniidae*	0	0	0	0	2	0	1	0	3	1	1	0
Thysanoptera												
NI	0	0	1	0	1	0	0	0	2	2	0	0

Table S5. Parameters estimated for disinfected Structural Equation Models (SEM). Related to response of the Hour after sunset, Arthropod Abundance and Lux to Arthropod Abundance, General Bat Activity, Buzz Ratio, *Molossus molossus*, *M currentium*, *Molossus sp1*, *Cynomops sp1*, *Eumops sp/Nyctinomops laticaudatus*, *Eumops sp1*, *E. perotis*, *Peropteryx macrotis*, *P. trinitratis*, *Eptesicus furinalis* and *E. brasiliensis.* Model of Arthropod Abundance same of all models.

Models	Predictor Variables	Estimate	Std.Err	z-value	P(>|z|)	Std.lv	Std.all	R²
Arthropod abundace	Hour after sunset	-0.891	0.111	-8.002	>0.001	-0.891	-0.236	0.11
	Lux	0.285	0.035	8.018	>0.001	0.285	0.236	
General Bat Activity	Hour after sunset	-0.106	0.013	-8.421	>0.001	-0.106	-0.252	0.141
	Arthropod Abundance	0.025	0.003	7.266	>0.001	0.025	0.223	
	Lux	0.001	0.004	0.325	0.746	0.001	0.01	
Buzz Ratio	Hour after sunset	0.002	0.002	1.032	0.302	0.002	0.033	0.044
	Arthropod Abundance	0.003	0.001	6.442	>0.001	0.003	0.209	
	Lux	>0.001	0.001	0.656	0.512	>0.001	0.021	
Molossus molossus	Hour after sunset	-0.792	0.085	-9.28	>0.001	-0.792	-0.273	0.163
	Arthropod Abundance	0.177	0.023	7.599	>0.001	0.177	0.23	
	Lux	0.036	0.027	1.32	0.187	0.036	0.039	
Molossus currentium	Hour after sunset	-0.075	0.019	-3.94	>0.001	-0.075	-0.115	0.178
	Arthropod Abundance	0.06	0.005	11.581	>0.001	0.06	0.348	
	Lux	0.021	0.006	3.378	0.001	0.021	0.099	
Molossus sp1	Hour after sunset	-0.049	0.011	-4.284	>0.001	-0.049	-0.135	0.042
	Arthropod Abundance	0.012	0.003	3.793	>0.001	0.012	0.123	
	Lux	0.001	0.004	0.291	0.771	0.001	0.009	

Continue Table S5

Models	Predictor Variables	Estimate	Std.Err	z-value	P(>|z|)	Std.lv	Std.all	R²
Cynomops sp1	Hour after sunset	-0.085	0.016	-5.159	>0.001	-0.085	-0.161	0.066
	Arthropod Abundance	0.024	0.004	5.335	>0.001	0.024	0.171	
	Lux	-0.006	0.005	-1.19	0.234	-0.006	-0.037	
Eumops sp/Nyctinomops laticaudatus	Hour after sunset	0.004	0.023	0.165	0.869	0.004	0.005	0.006
	Arthropod Abundance	-0.013	0.006	-2.09	0.037	-0.013	-0.069	
	Lux	0.012	0.007	1.706	0.088	0.012	0.055	
Eumops sp1	Hour after sunset	0.066	0.019	3.436	0.001	0.066	0.11	0.014
	Arthropod Abundance	0.003	0.005	0.548	0.584	0.003	0.018	
	Lux	0.008	0.006	1.296	0.195	0.008	0.041	
Eumops perotis	Hour after sunset	0.031	0.008	3.892	>0.001	0.031	0.122	0.053
	Arthropod Abundance	0.005	0.002	2.133	0.033	0.005	0.069	
	Lux	0.014	0.003	5.621	>0.001	0.014	0.176	
Peropteryx macrotis	Hour after sunset	-0.003	0.017	-0.2	0.841	-0.003	-0.006	0.002
	Arthropod Abundance	>-0.001	0.005	-0.062	0.951	>-0.001	-0.002	
	Lux	-0.007	0.005	-1.243	0.214	-0.007	-0.04	
Peropteryx trinitatis	Hour after sunset	-0.008	0.006	-1.24	0.215	-0.008	-0.04	0.002
	Arthropod Abundance	-0.001	0.002	-0.644	0.52	-0.001	-0.021	
	Lux	-0.001	0.002	-0.63	0.529	-0.001	-0.02	

Continue Table S5

Models	**Predictor Variables**	**Estimate**	**Std.Err**	**z-value**	**P(>|z|)**	**Std.lv**	**Std.all**	**R²**
Eptesicus furinalis	Hour after sunset	-0.081	0.025	-3.254	0.001	-0.081	-0.104	0.021
	Arthropod Abundance	-0.004	0.007	-0.593	0.553	-0.004	-0.019	
	Lux	-0.024	0.008	-3.071	0.002	-0.024	-0.098	
Eptesicus brasiliensis	Hour after sunset	-0.125	0.038	-3.252	0.001	-0.125	-0.104	0.017
	Arthropod Abundance	-0.002	0.01	-0.236	0.813	-0.002	-0.008	
	Lux	-0.031	0.012	-2.516	0.012	-0.031	-0.08	

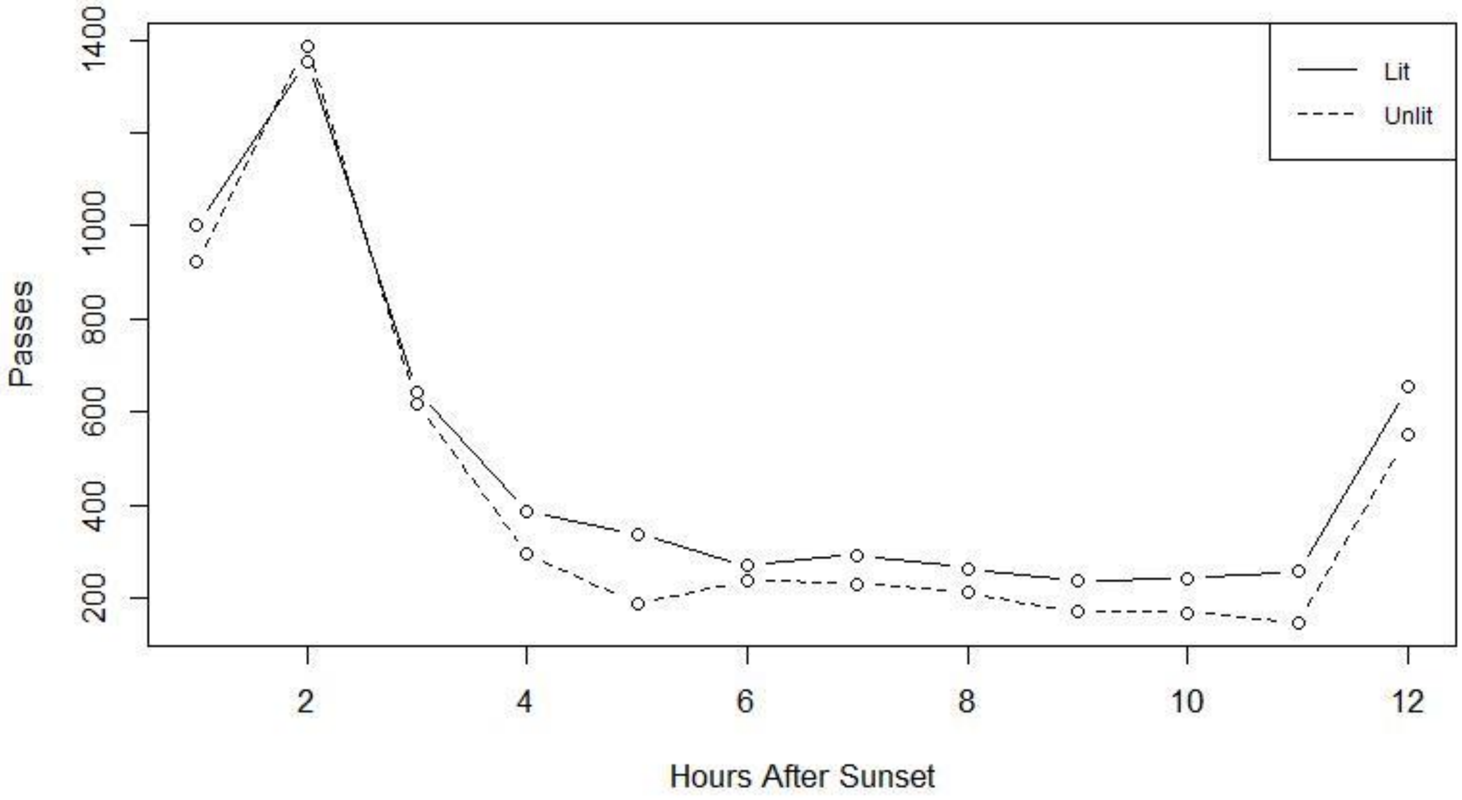

Figure S1: Line graph showing the all bat activity (passes) throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

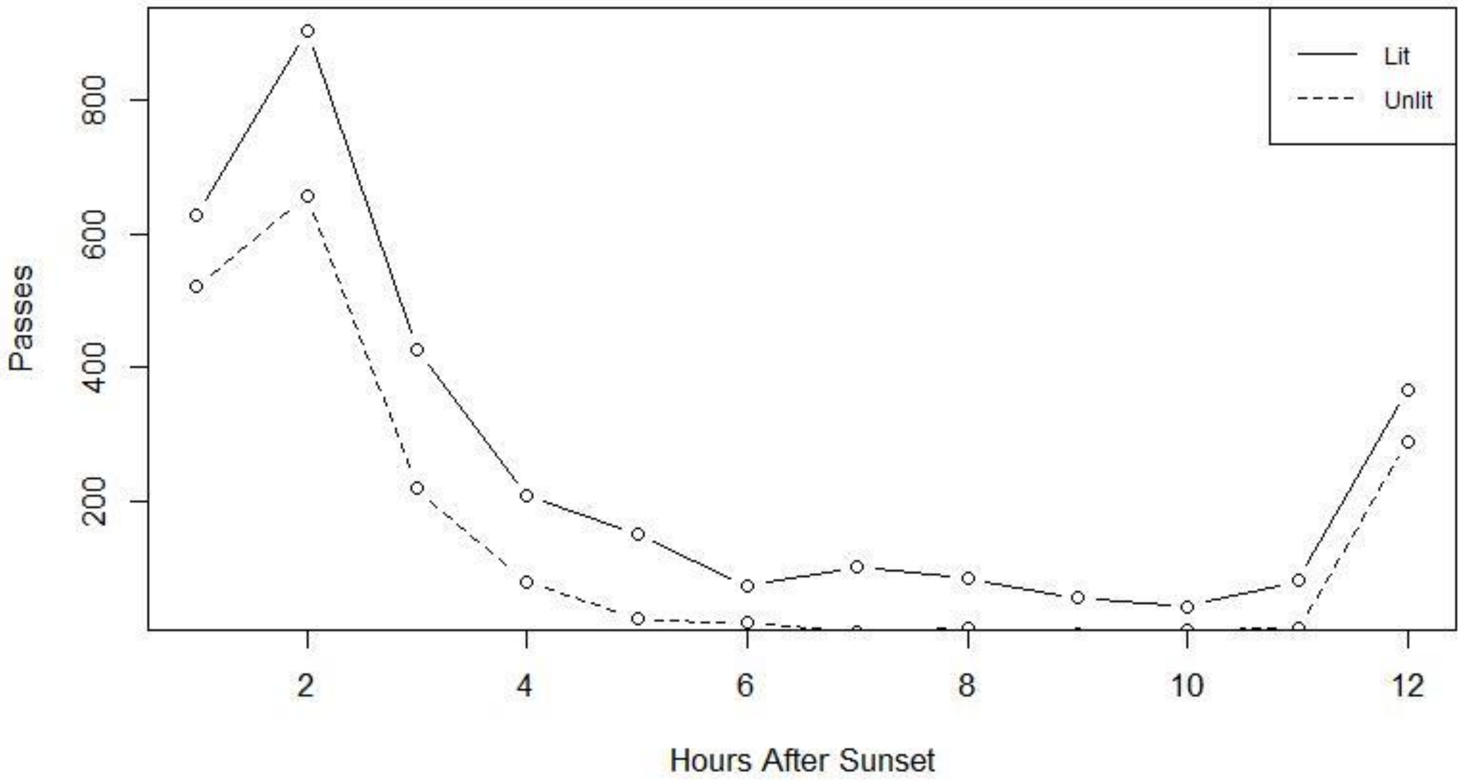

Figure S2: Line graph showing the activity (passes) of the species *M. molossus* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

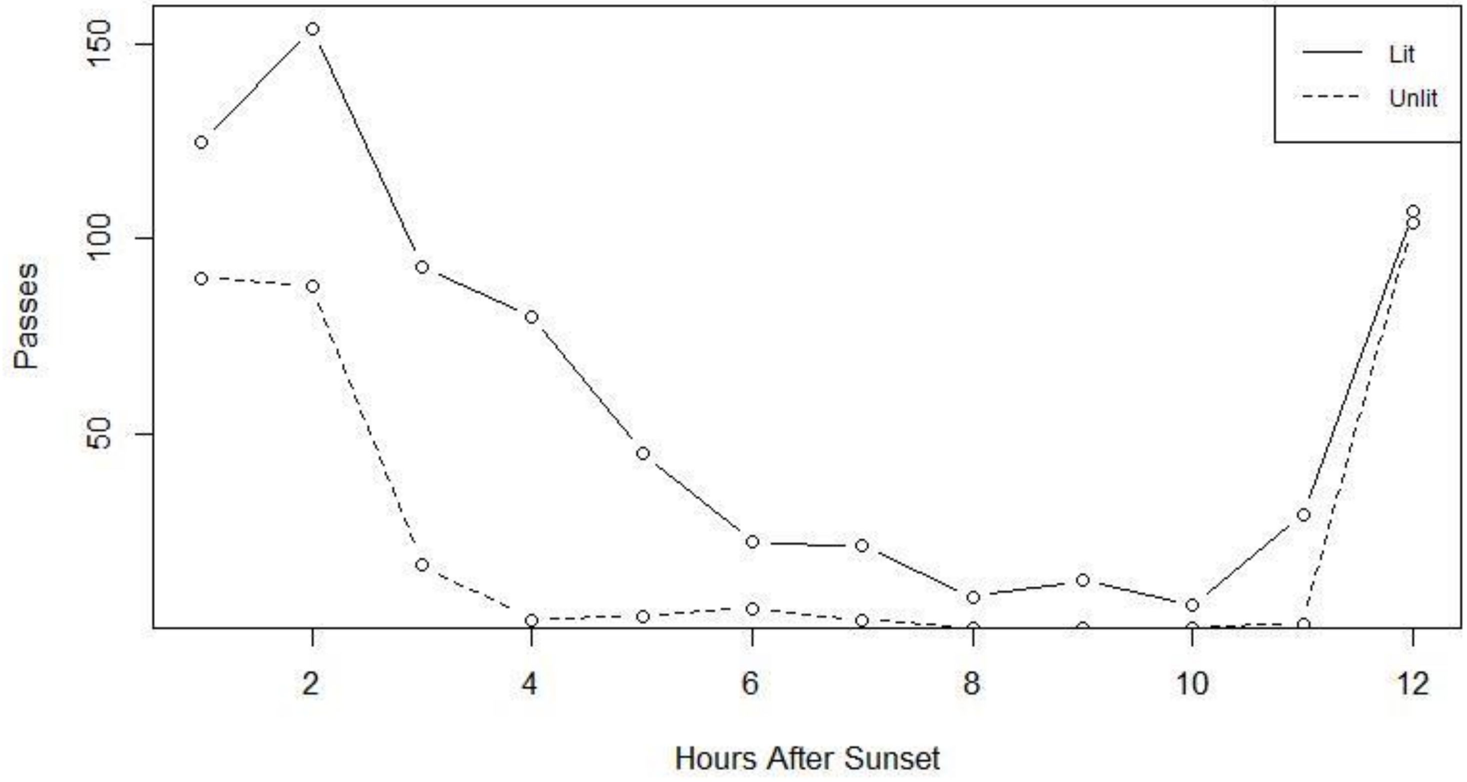

Figure S3: Line graph showing the activity (passes) of the species *M. currentium* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

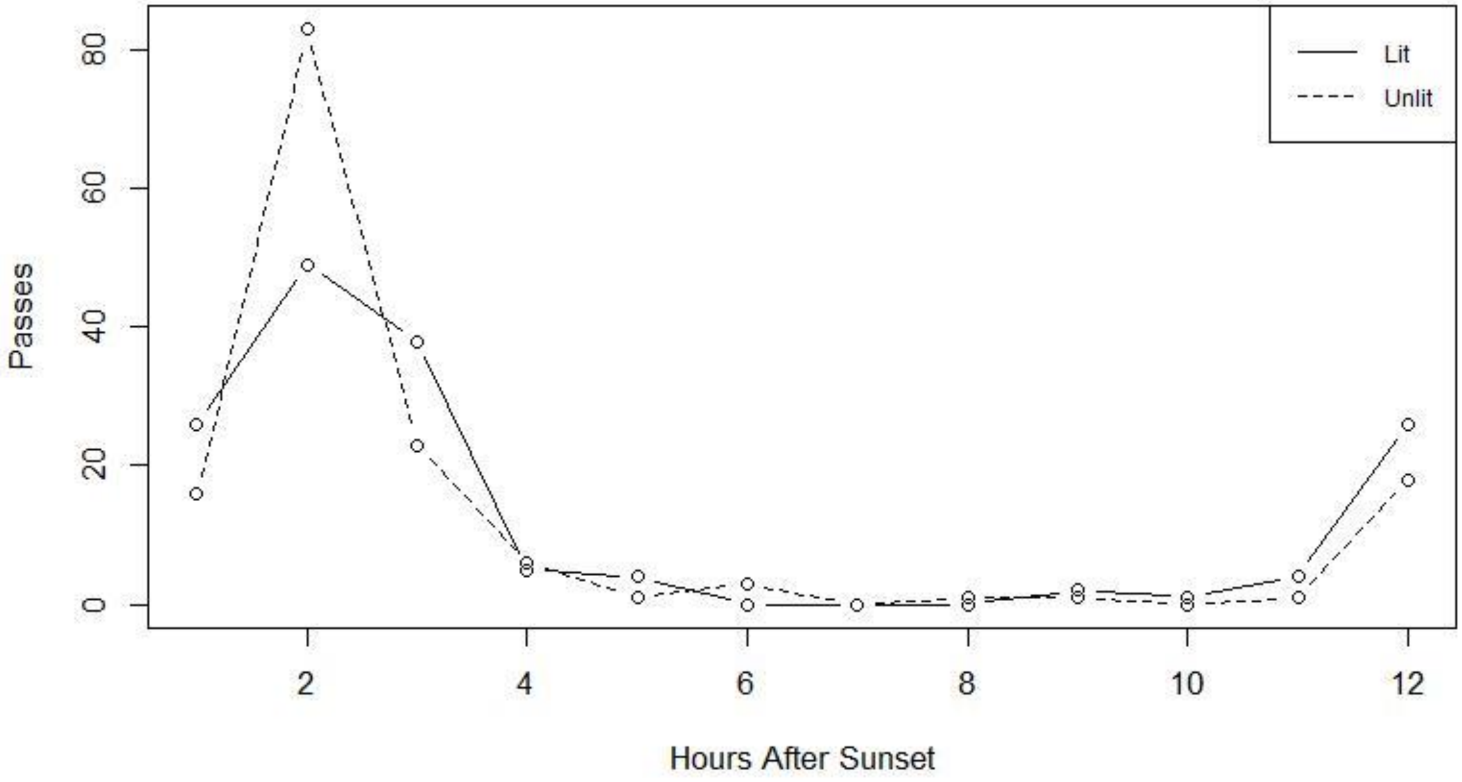

Figure S4: Line graph showing the activity (passes) of the species *Molossus.* sp throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

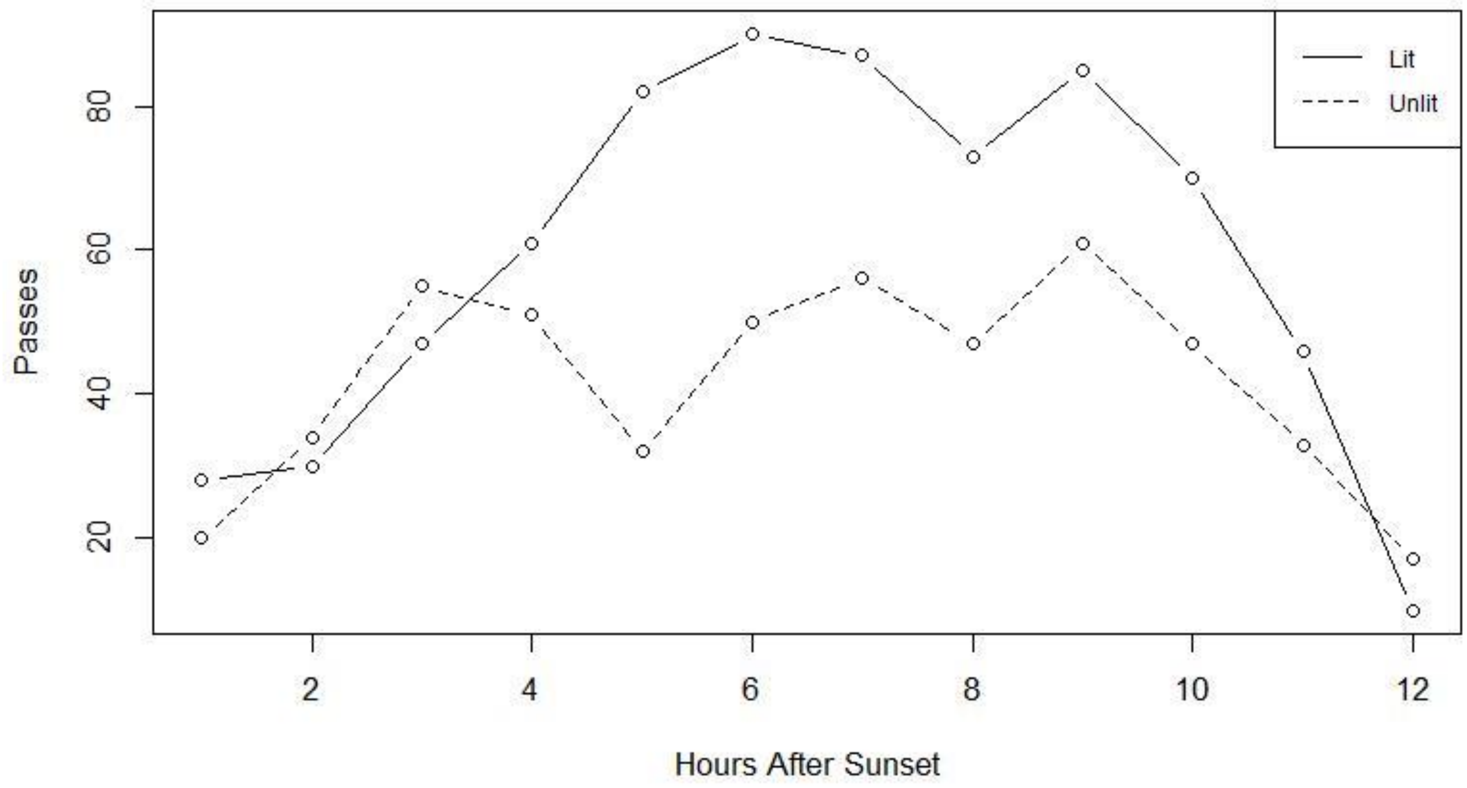

Figure S5: Line graph showing the activity (passes) of the species *Eumops.* sp/*Nyctinomops macrotis* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

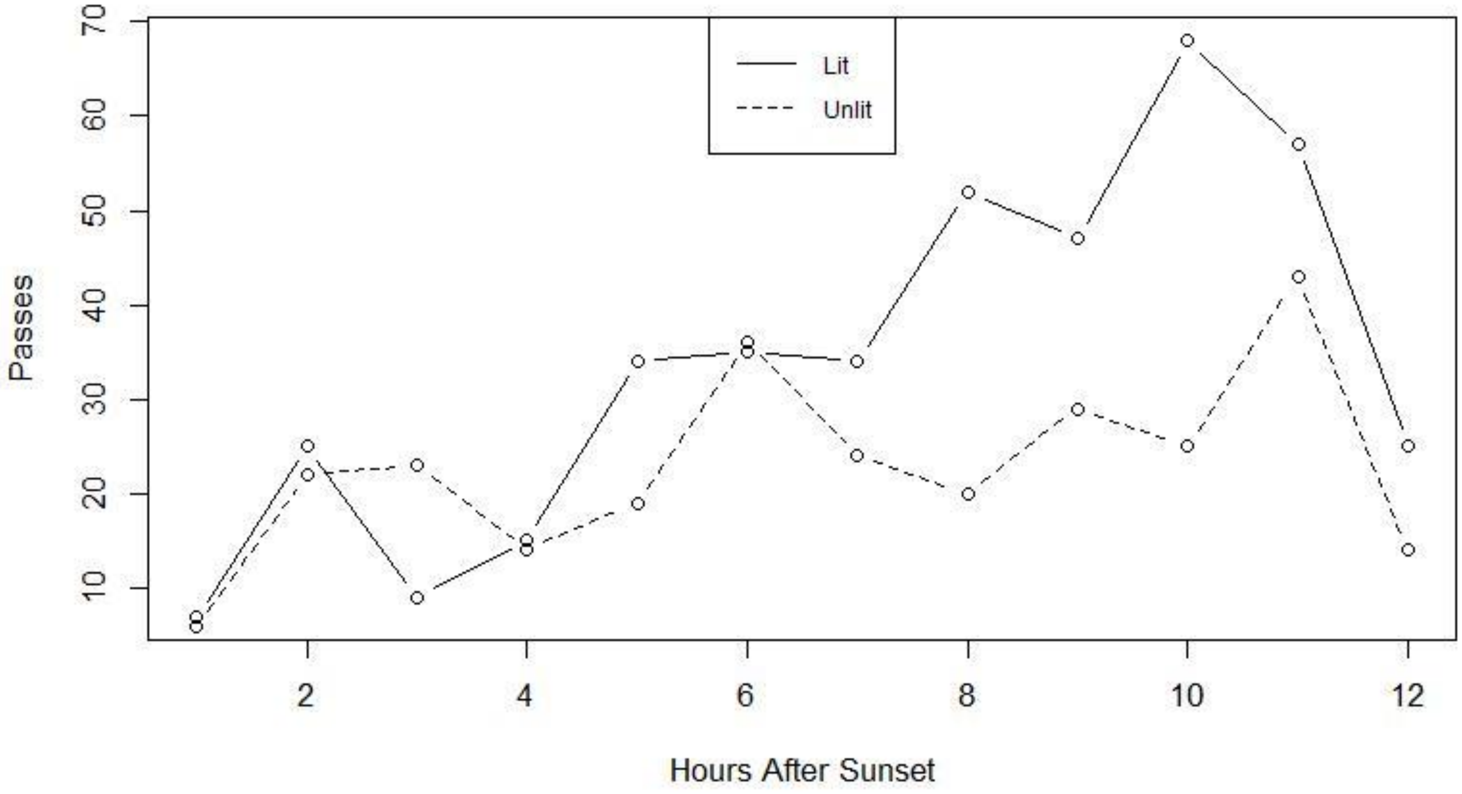

Figure S6: Line graph showing the activity (passes) of the species *Eumops*. spp throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

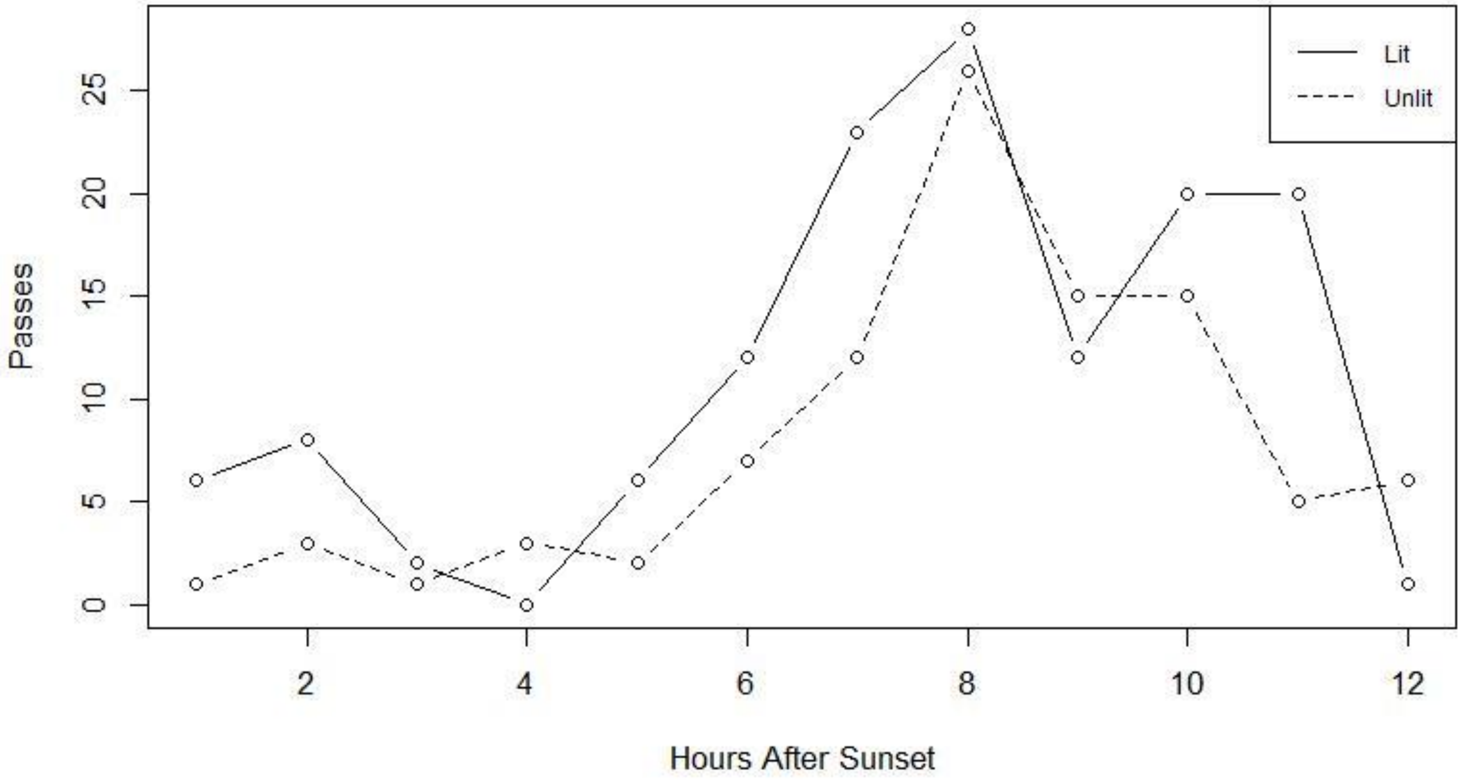

Figure S7: Line graph showing the activity (passes) of the species *E. perotis* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

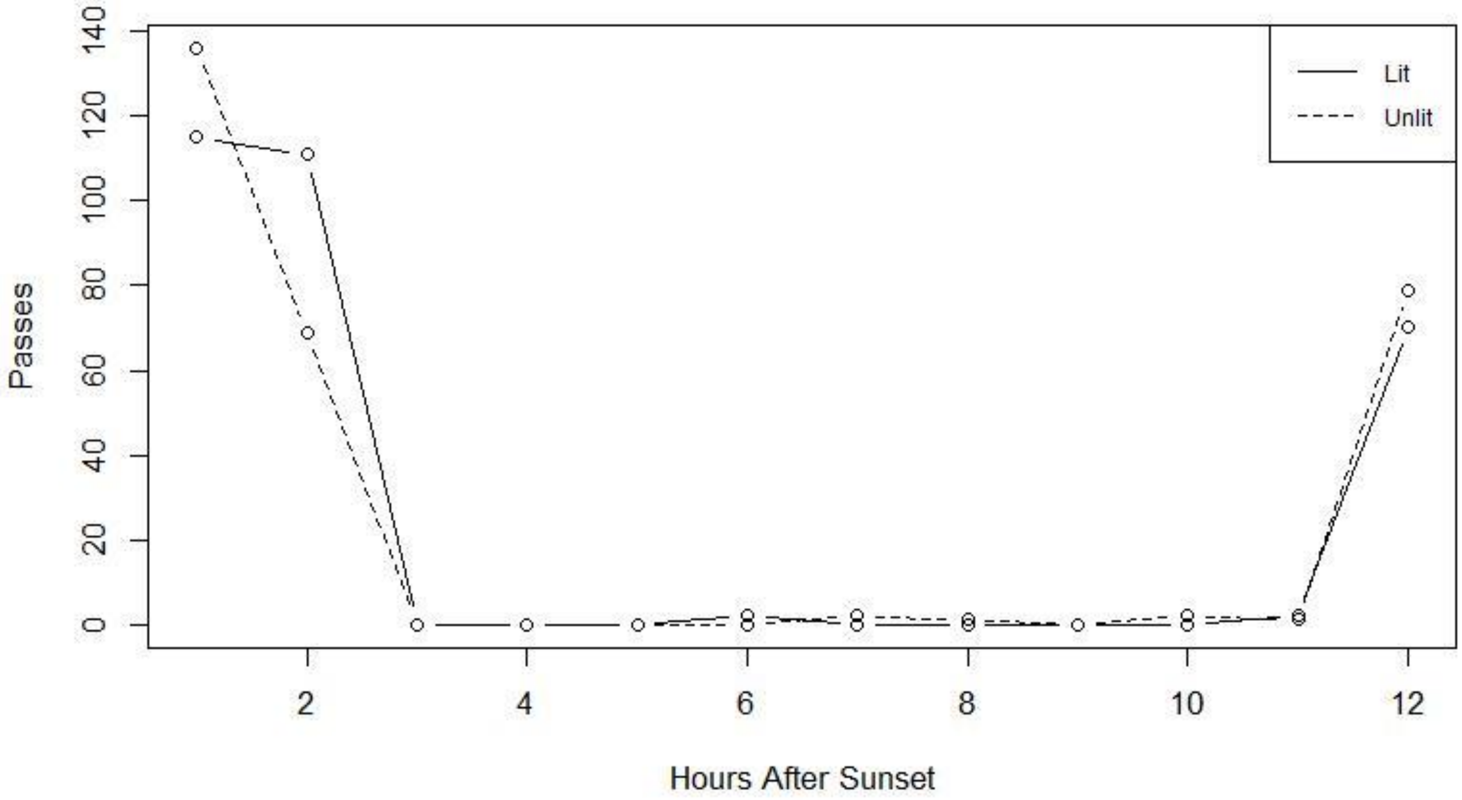

Figure S8: Line graph showing the activity (passes) of the species *Cynamops*. sp throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

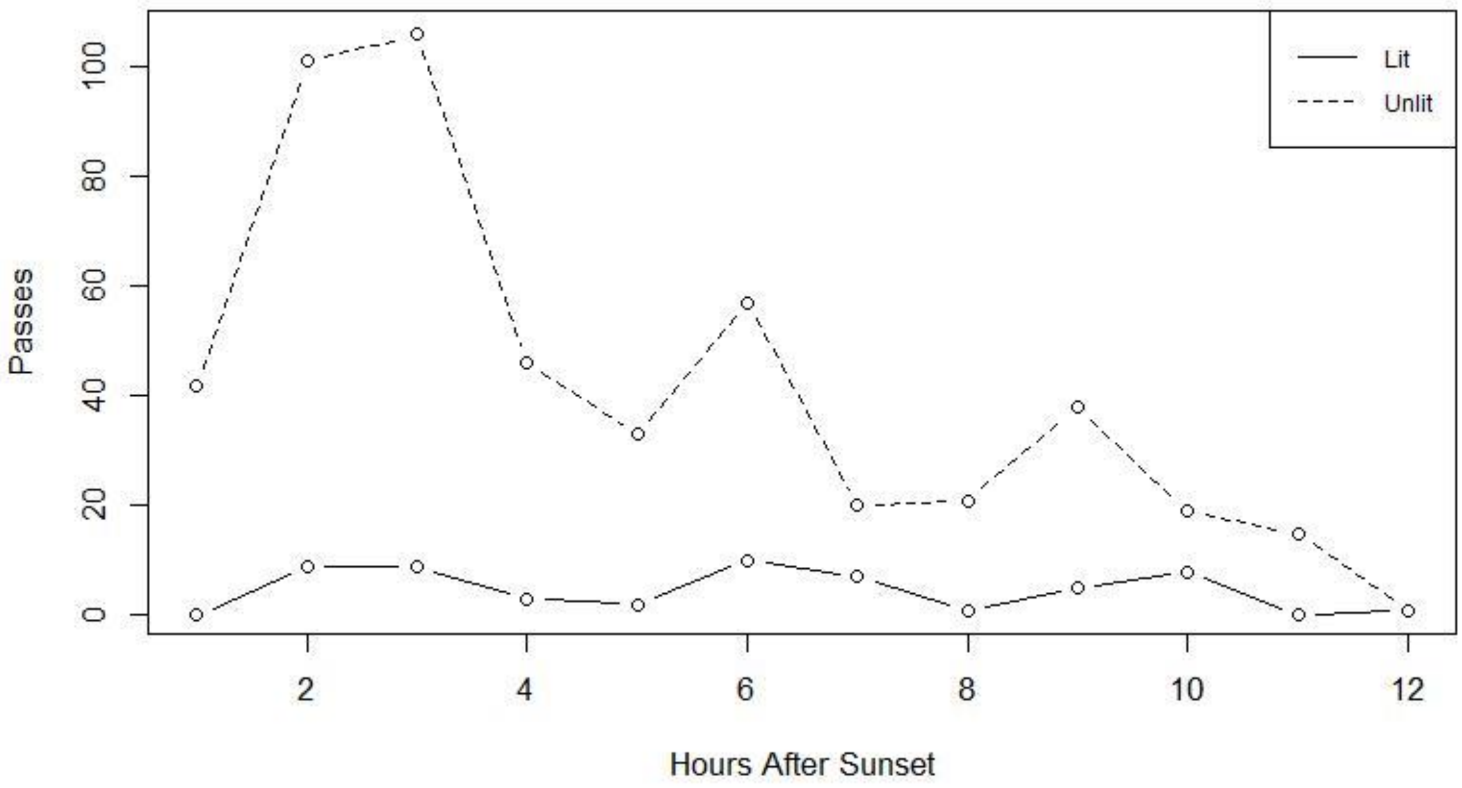

Figure S9: Line graph showing the activity (passes) of the species *E. furinalis* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

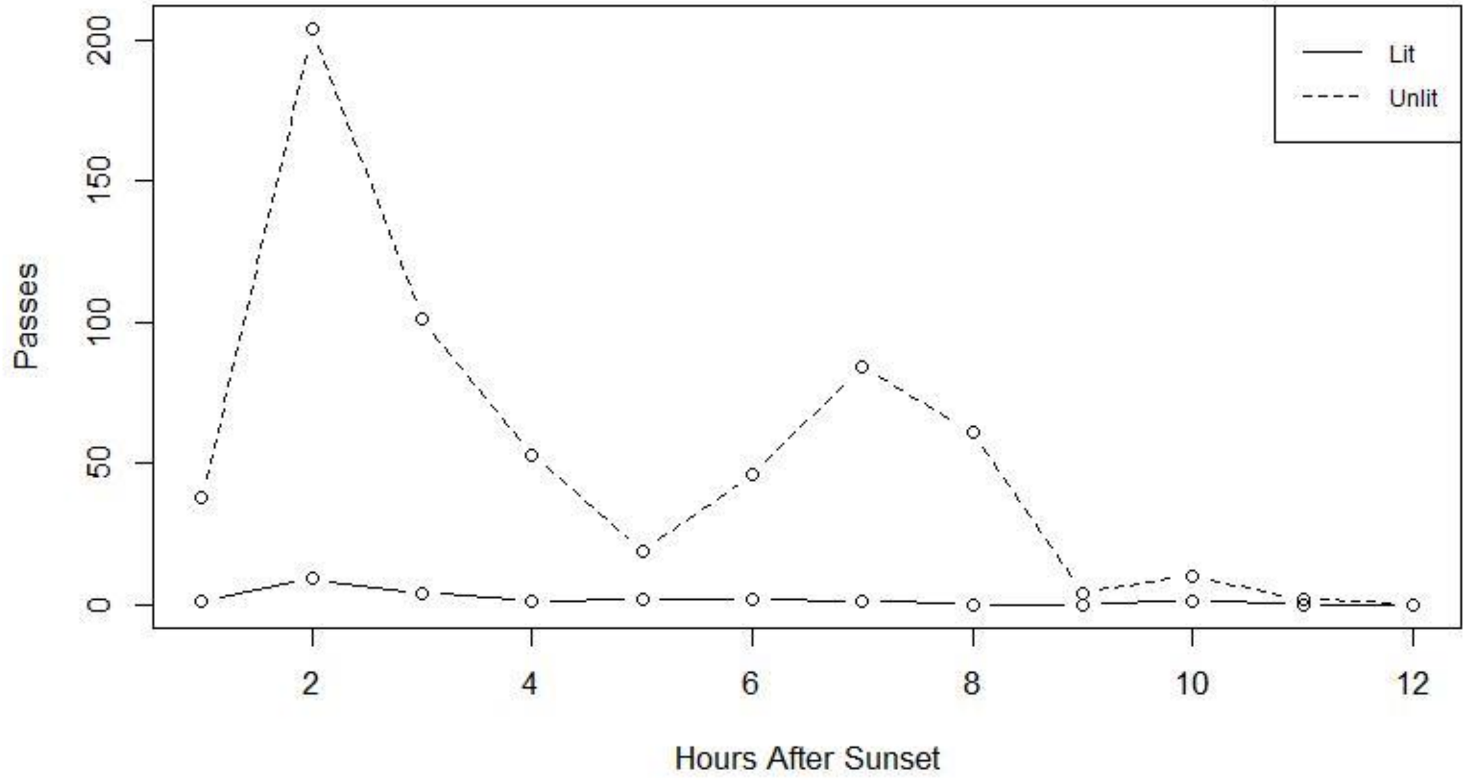

Figure S10: Line graph showing the activity (passes) of the species *E. brasiliensis* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

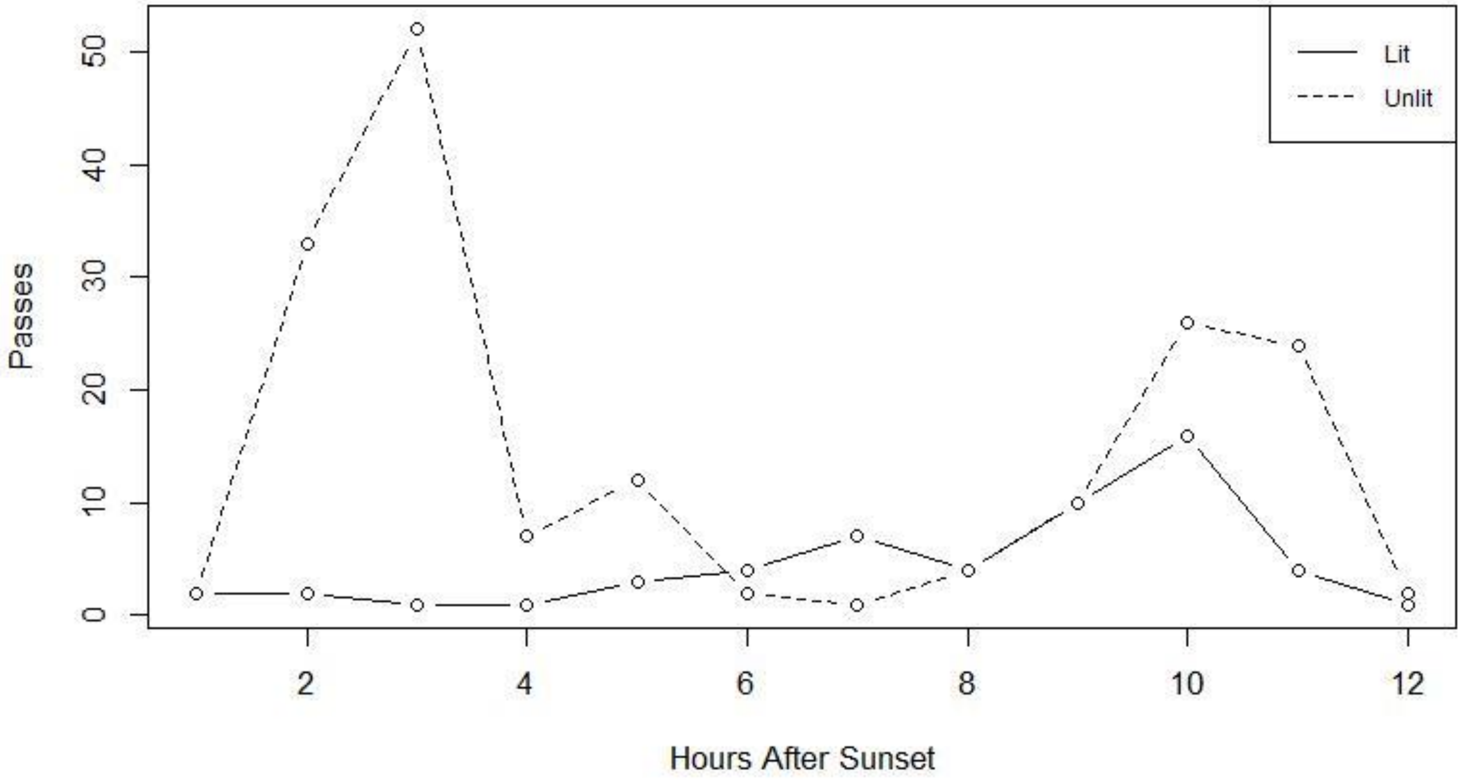

Figure S11: Line graph showing the activity (passes) of the species *P. macrotis* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

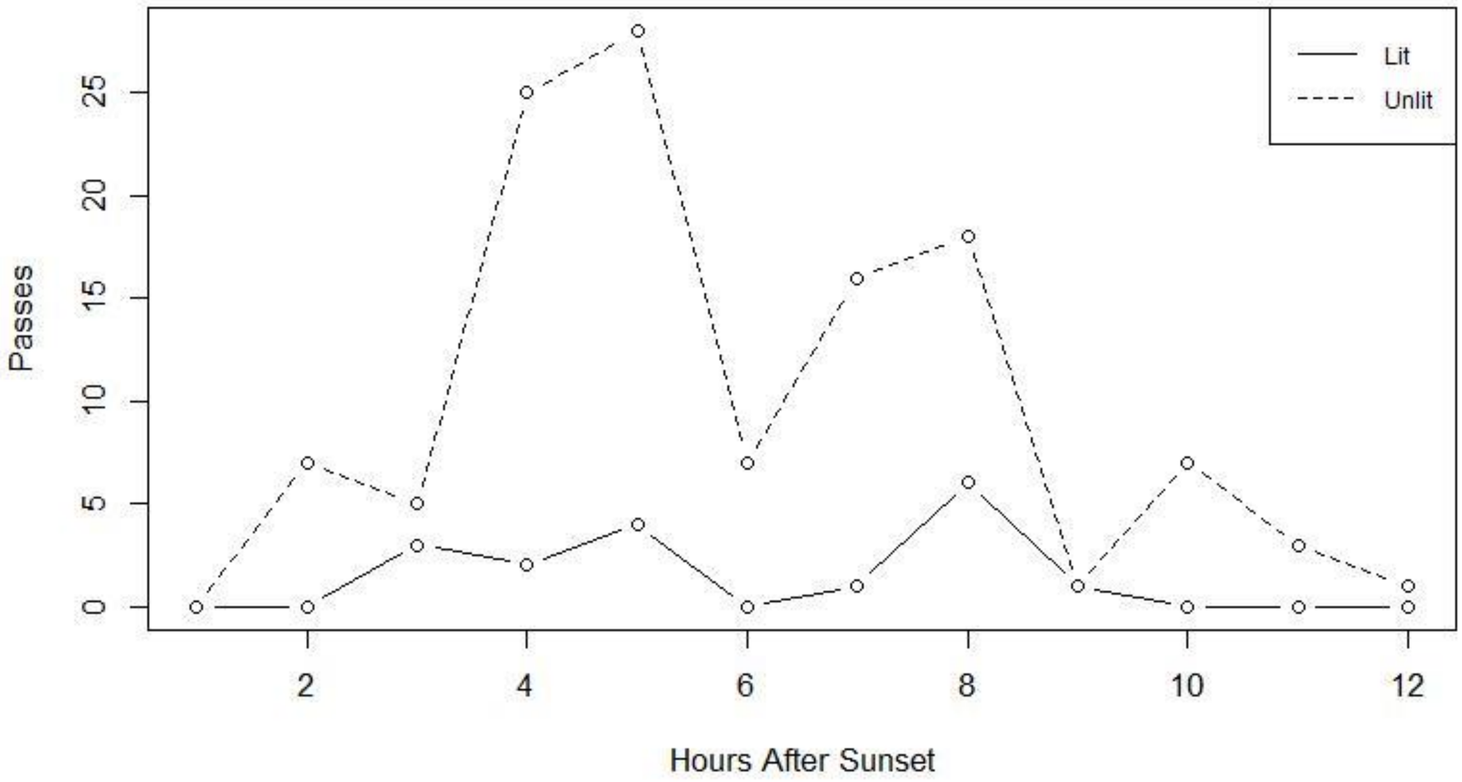

Figure S12: Line graph showing the activity (passes) of the species *P. trinitatis* throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

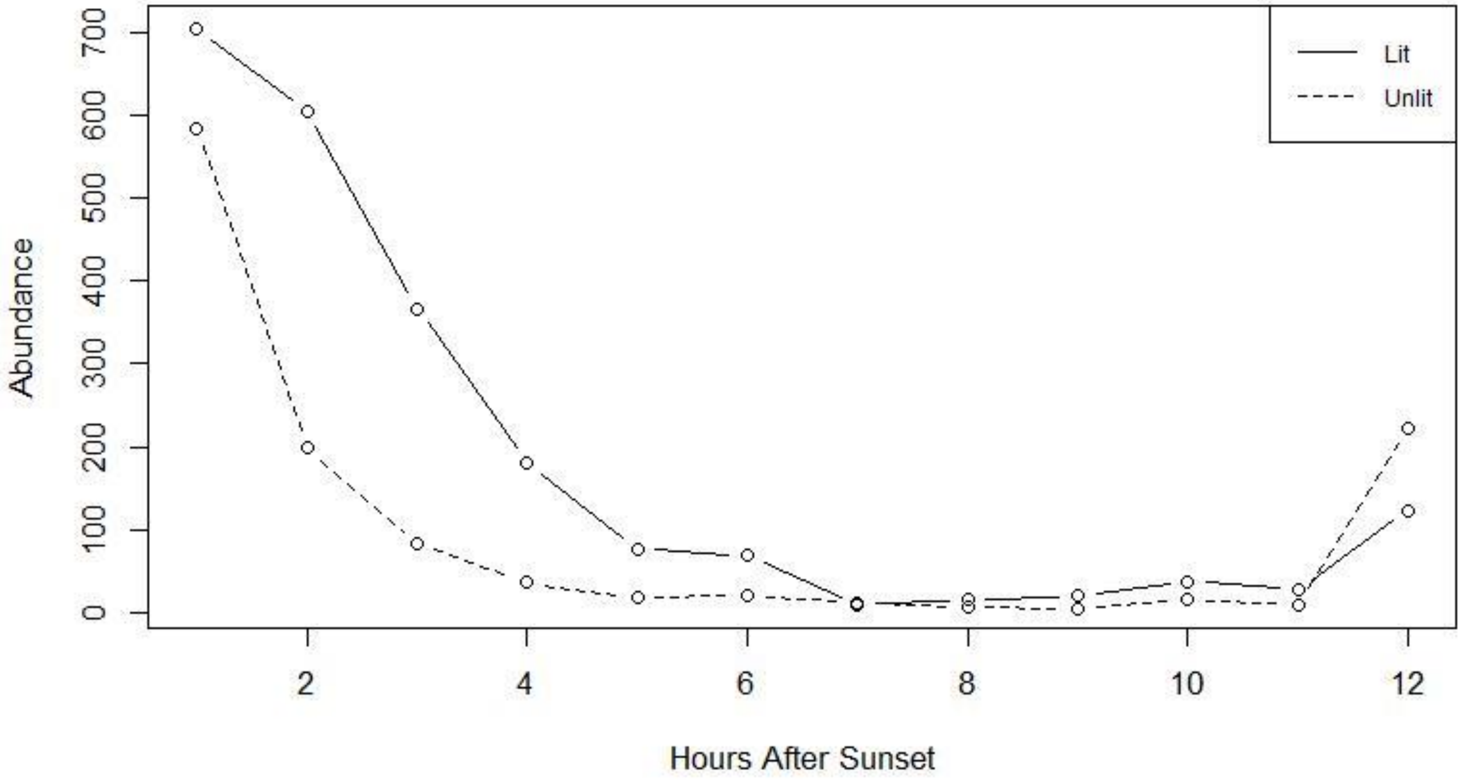

Figure S13: Line graph showing the abundance of the individuals of arthropods throughout the night (hours after sunset). Continuous line are the lit sites and dotted lines are the unlit sites.

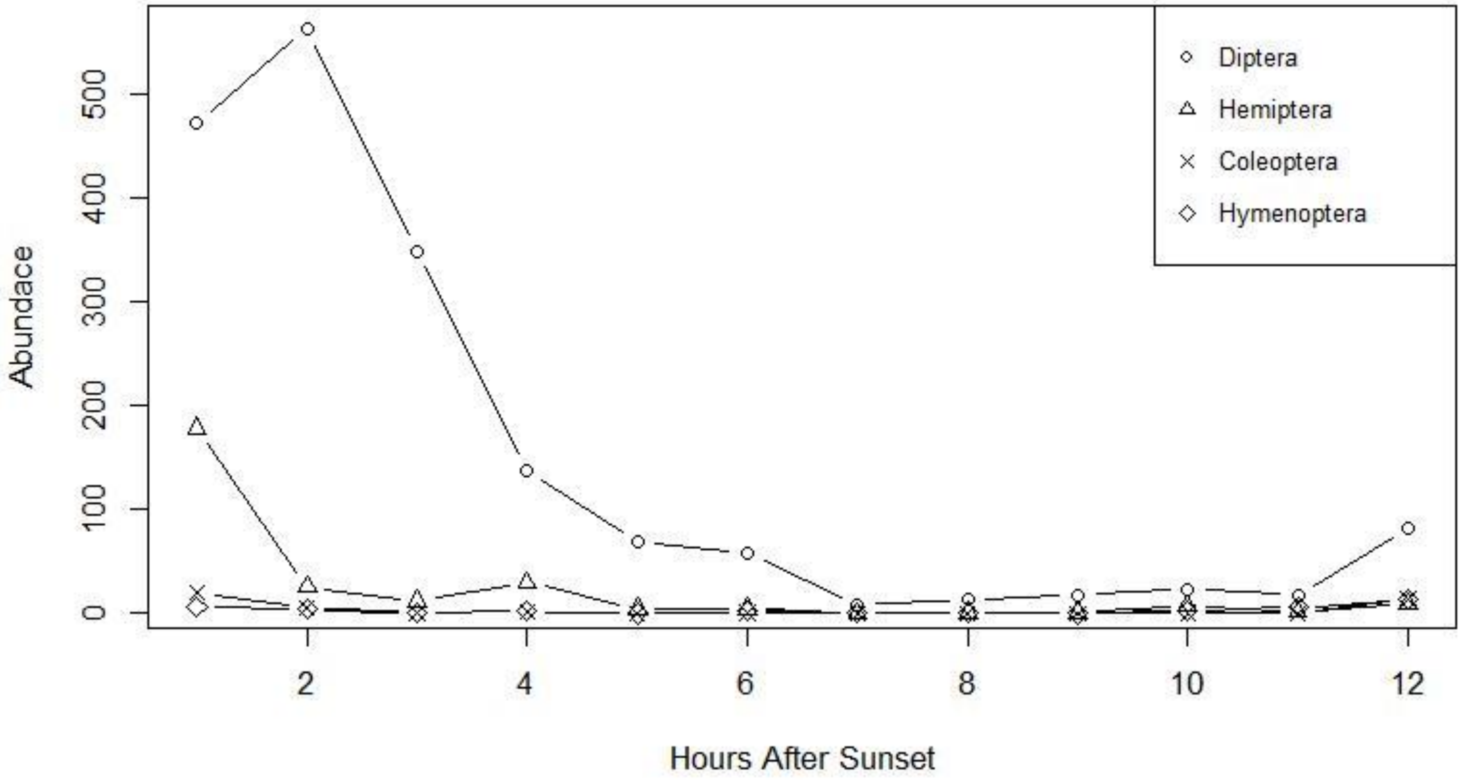

Figure S14: Line graph showing the abundance of the individuals of arthropods orders throughout the night (hours after sunset) in **lit sites**. Circles = Diptera order, Triangle = Hemiptera order, X = Coleoptera order and Rhombus = Hymenoptera.

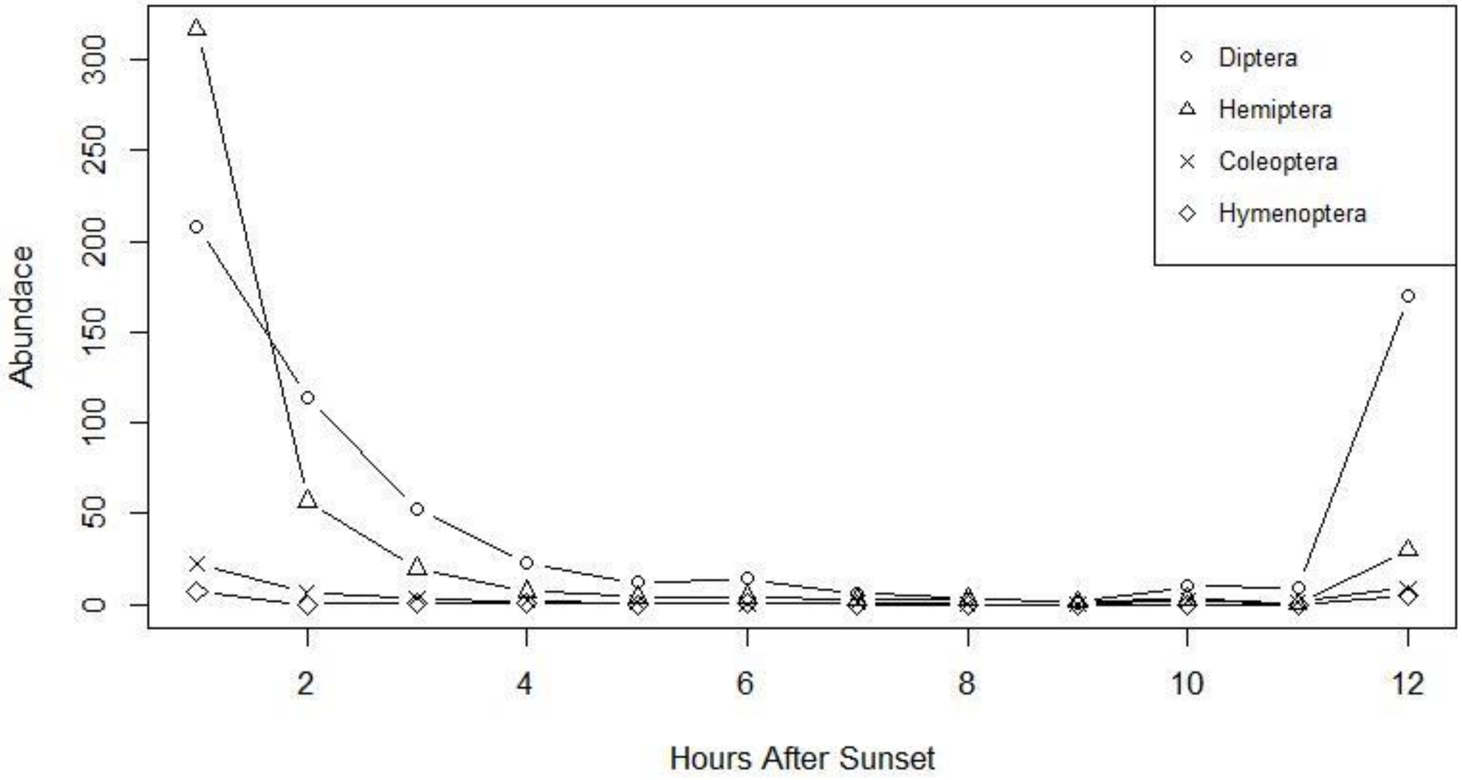

Figure S15: Line graph showing the abundance of the individuals of arthropods orders throughout the night (hours after sunset) in **unlit sites**. Circles = Diptera order, Triangle = Hemiptera order, X = Coleoptera order and Rhombus = Hymenoptera.

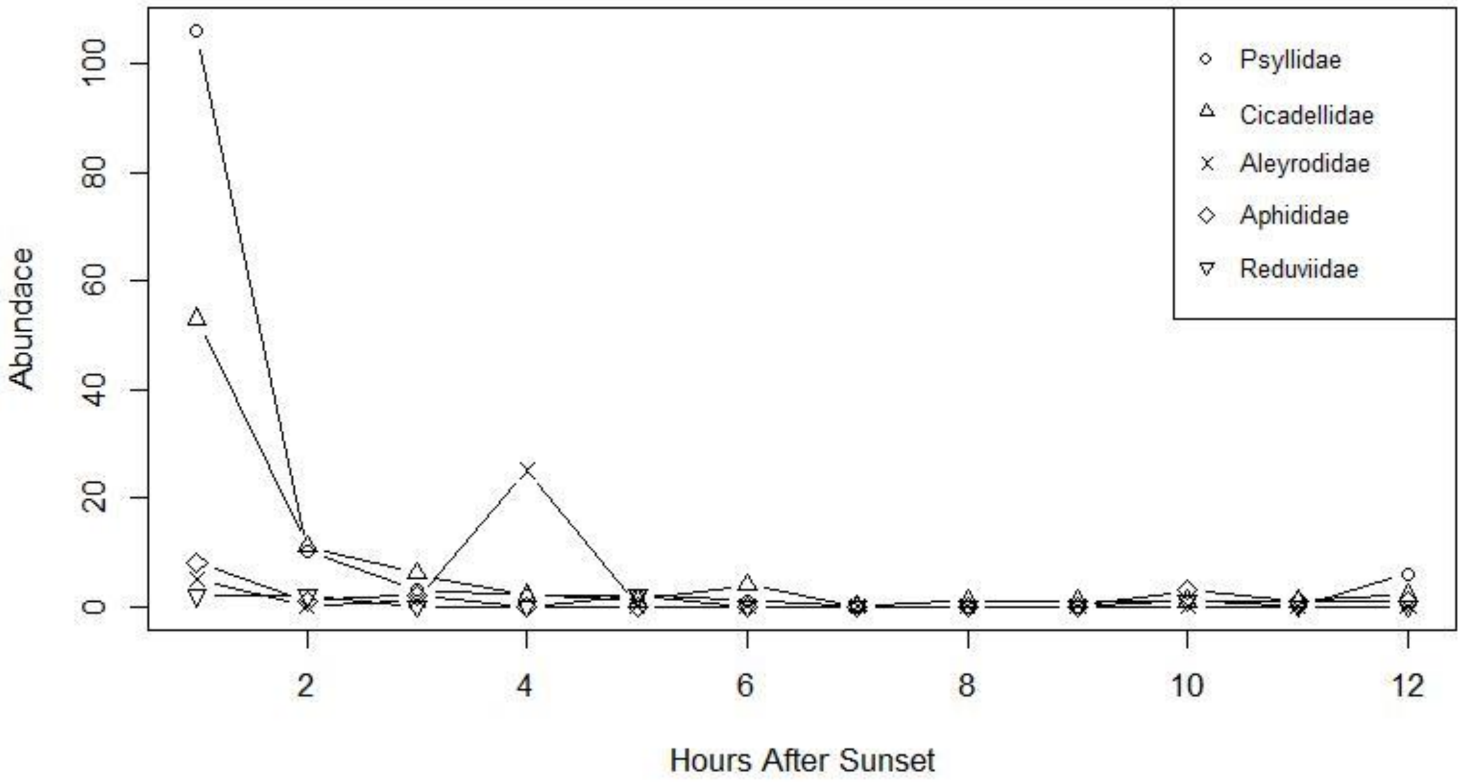

Figure S16: Line graph showing the abundance of the individuals of hemiptera families throughout the night (hours after sunset) in **lit sites**. Circles = Psyllidae, Triangle = Cicadellidae, X = Aleyrodidae, Rhombus = Aphididae and Reverse Triangle = Reduviidae.

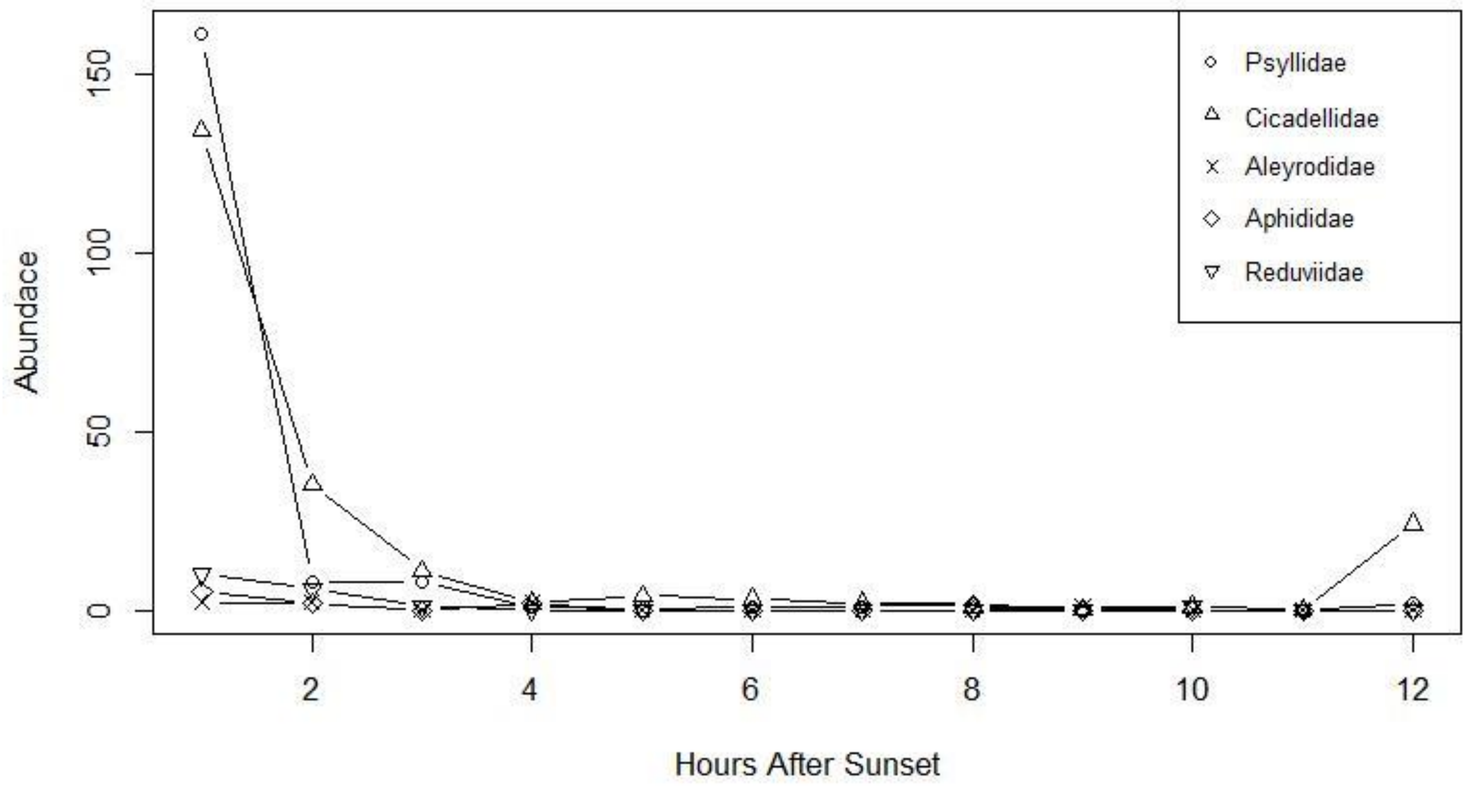

Figure S17: Line graph showing the abundance of the individuals of hemiptera families throughout the night (hours after sunset) in **unlit sites**.

Circles = Psyllidae, Triangle = Cicadellidae, X = Aleyrodidae, Rhombus = Aphididae and Reverse Triangle = Reduviidae.

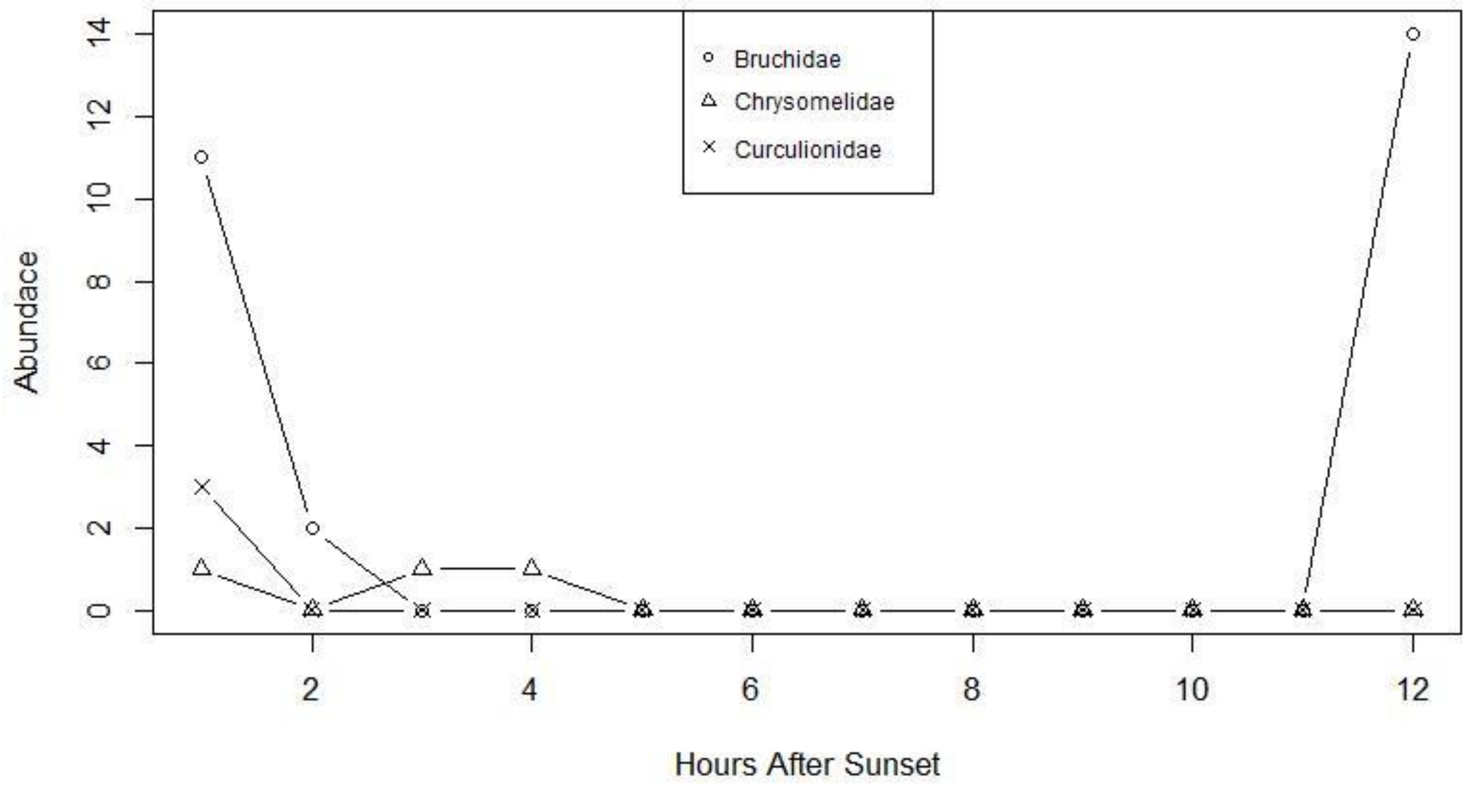

Figure S18: Line graph showing the abundance of the individuals of coleoptera families throughout the night (hours after sunset) in **lit sites**. Circles = Bruchidae, Triangle = Chrysomelidae, X = Curculionidae.

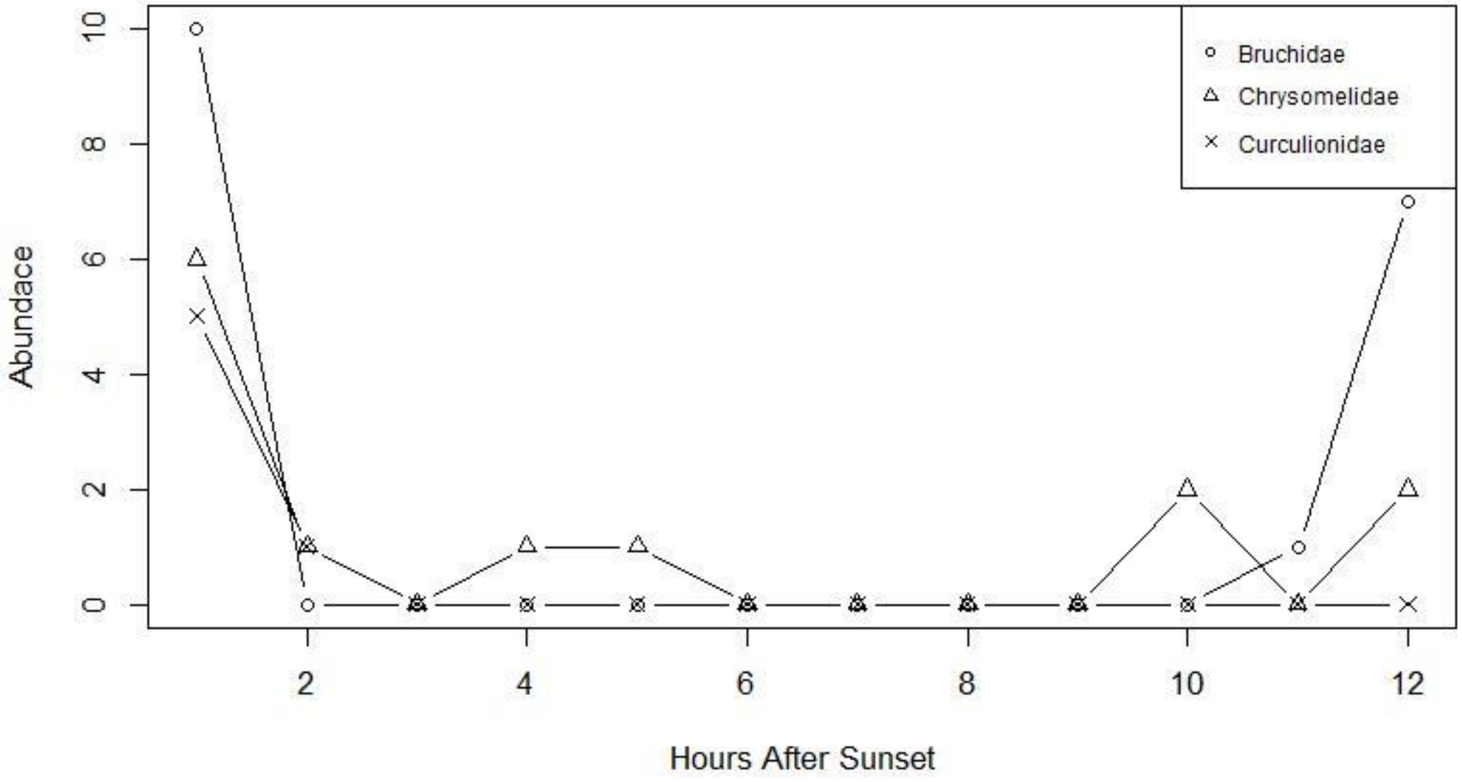

Figure S19: Line graph showing the abundance of the individuals of coleoptera families throughout the night (hours after sunset) in **unlit sites**.

Circles = Bruchidae, Triangle = Chrysomelidae, X = Curculionidae.