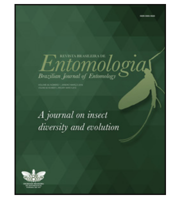
Revista Brasileira de Entomologia xxx (2016) xxx–xxx

SOCIEDADE BRASILEIRA DE ENTOMOLOGIA
FUNDADA EM 1937

REVISTA BRASILEIRA DE
Entomologia
A Journal on Insect Diversity and Evolution
www.rbentomologia.com



Biology, Ecology and Diversity

Streetlights attract a broad array of beetle species

Bruno Augusto Souza de Medeiros[a,*], Alessandro Barghini[b], Sergio Antonio Vanin[c]

[a] Harvard University, Museum of Comparative Zoology, Cambridge, USA
[b] Universidade de São Paulo, Museu de Arqueologia e Etnologia, São Paulo, Brazil
[c] Universidade de São Paulo, Instituto de Biociências, São Paulo, Brazil

ARTICLE INFO

Article history:
Received 8 August 2016
Accepted 30 November 2016
Available online xxx
Associate Editor: Rodrigo Kruger

Keywords:
Lighting
Coleoptera
Light pollution
Insects
Ultraviolet

ABSTRACT

Light pollution on ecosystems is a growing concern, and knowledge about the effects of outdoor lighting on organisms is crucial to understand and mitigate impacts. Here we build up on a previous study to characterize the diversity of all beetles attracted to different commonly used streetlight set ups. We find that lights attract beetles from a broad taxonomic and ecological spectrum. Lights that attract a large number of insect individuals draw a commensurate number of insect species. While there is some evidence for heterogeneity in the preference of beetle species to different kinds of light, all species are more attracted to some light radiating ultraviolet. The functional basis of this heterogeneity, however, is not clear. Our results highlight that control of ultraviolet radiation in public lighting is important to reduce the number and diversity of insects attracted to lights.

Introduction

The effect of light pollution on ecosystems is a growing concern (Gaston et al., 2012; Longcore and Rich, 2004). Knowledge on how light affects the biota – and especially on organismal response to its various properties – can inform the development of environmentally friendly lighting (Gaston et al., 2012). Insects, in particular, are widely known to be attracted to lights, and knowledge on insect response to lights is generally used by collectors and in pest management (Shimoda and Honda, 2013), and it is also important in the control of vector-borne diseases (Barghini and de Medeiros, 2010). Except for a handful of species with economic or health importance, little is known about how different species respond to lights in natural ecosystems or even how this attraction affects populations (Eisenbeis, 2006; Fox, 2013). Insects are attracted to streetlights, sometimes in large numbers (Barghini and de Medeiros, 2012; Eisenbeis, 2006; Eisenbeis and Hassel, 2000), and their diversity is affected near lights even during the day (Davies et al., 2012). Street lights could have adverse effects on insect populations by a variety of mechanisms, including directly mortality caused by exhaustion or attraction of predators, or disruption of biological cycles. It is therefore important to understand what properties of street lighting cause insect attraction, and whether it affects only a few or a large array of species, in order to develop measures to minimize both the impact of lights on particular species and the number of species affected.

If compared to humans, insects have very different sensitivity spectra, usually with receptors maximally sensitive on the ultraviolet (UV), blue and green (Briscoe and Chittka, 2003). In spite of UV radiation being invisible to humans, many of the commonly used external light sources (such as high-pressure sodium vapor lamps and high-pressure mercury vapor lamps) radiate UV. These UV-radiating lamps are still widely used around the world, even though they are being steadily replaced by LED-based technologies. Several studies have shown that lamps emitting shorter wavelengths attract more insects (Barghini and de Medeiros, 2012; Eisenbeis, 2006; Eisenbeis and Hassel, 2000; Nowinszky, 2003; van Langevelde et al., 2011), and UV radiation is especially important in triggering the attraction behavior. For example, with the use of UV filters, the number of insects attracted of a blue (Hg vapor) and yellow (Na vapor) lamps are nearly indistinguishable (Barghini and de Medeiros, 2012). While it is not yet entirely clear why insects are especially attracted to UV-radiating lights, this is probably because terrestrial sources of UV interfere with insect navigation while flying (see a thorough discussion in Barghini and de Medeiros, 2010).

Most of those studies were done in temperate environments and few have evaluated the different insect responses at the species level, without previously selecting target species to be studied, or the overall diversity of species attracted to lights. To date, this has been done mainly for moths. The abundance of moths attracted by a lamp correlates with the number of species attracted and larger moths exhibit a stronger preference for light sources

* Corresponding author.
E-mail: souzademedeiros@fas.harvard.edu (B.A. Medeiros).

http://dx.doi.org/10.1016/j.rbe.2016.11.004
0085-5626/

radiating shorter wavelengths (Nowinszky et al., 2013; van Langevelde et al., 2011). In addition to size, there also seems to be differences in behavior according to taxonomy: Noctuidae moths are more attracted to shorter wavelengths, while Geometridae moths exhibit no preference (Somers-Yeates et al., 2013). Even though moths are conspicuous visitors to lights, they are not the most abundant group of insects attracted to lights (Barghini and de Medeiros, 2012; Eisenbeis and Hassel, 2000; Poiani et al., 2014). It is unknown at this point if observations in moths can be generalized to other insect taxa, especially in more diverse tropical environments.

Here we study the diversity of Coleoptera, the most diverse insect order, attracted to different light sources. In a previous study, he have found that UV radiation, even in small amounts, is extremely important to trigger insect attraction to lights, but we have not studied the response of individual species (Barghini and de Medeiros, 2012). Coleoptera was one of the most abundant orders collected in our traps, and beetles represent the most species-rich order of insects, comprising over 380,000 described species (Slipiński et al., 2011), and encompassing also a wide ecological diversity (McKenna et al., 2015). To better understand the heterogeneity in insect attraction to lights in a natural setting and the diversity of insects attracted by each kind of lamp, in this study we have sorted and identified all species of Coleoptera attracted to lights in a subset of our previous sampling. We aim to understand whether commonly used street lamps that attract a larger number of individuals also attract more species in a natural setting, and also to characterize the heterogeneity in responses to lights among beetle species.

Material and methods

Collection

Here we used the material collected in the same set of experiments performed by Barghini and de Medeiros (2012), and details on the methods can be found on that paper. The test was conducted in a street surrounded by trees and isolated from urban lighting on the main campus of the University of Sa˜o Paulo in the city of São Paulo. Static insect collecting traps similar to those used by Eisenbeis and Hassel (2000) were set up below lamps installed on seven-meter-tall lampposts, filled with 70% ethanol as killing agent. Each treatment utilized a full cut-off lighting fixture as follows: Hg: mercury vapor bulb protected with tempered glass; Na: high-pressure sodium vapor bulb with tempered glass; Na_F: sodium vapor bulb with tempered glass and a UV filter (Polycarbonate Lexan© 2 mm); and Control: trap without lamp. Hg is a white lamp radiating UV and shorter wavelengths. Na is a yellow lamp that radiates longer wavelengths, but also some UV. Radiation spectra for the lamps used can be found in Barghini and de Medeiros (2012).

Collections were performed in two separate campaigns. The first comprised 24 collections between March and June 2005; the second an additional 13 collections between October and December 2005. On each collection date, traps were set up before twilight and taken down in the following morning. The Coleoptera were sorted into morpho-species and identified to the family or subfamily level using various sources (Arnett et al., 2002; Arnett and Thomas, 2000; Lawrence et al., 1999). After initial identification, the classification was updated to match that used in the most recent beetle phylogeny (McKenna et al., 2015). All the material was deposited in the Museu de Zoologia of the Universidade de São Paulo (MZSP).

Correlations between abundance and diversity

All statistical analyses were done in R Version 3.2.3 (R Core Team, 2015), and the data and scripts used to run the analyses and generate graphs and tables can be found in the first author's github repository (https://github.com/brunoasm/Medeiros_RBE_2016). To test whether the diversity of Coleoptera attracted to lamps is correlated with number of individuals, we used Spearman's rank correlation test considering each trap in each day as a data point. We used species richness and phylogenetic diversity (Faith, 1992) as diversity indexes, and we also tested the correlation between the two of them in the same way. To generate a phylogenetic tree to calculate phylogenetic diversity, we used the subfamily-level beetle tree from McKenna et al. (2015) as a backbone tree. Species found in this study were added by attaching a branch to a random position within the clade defined by the most recent common ancestor of the family or subfamily. Finally, species present in the backbone tree but not in this study were pruned. For the calculation of phylogenetic diversity, the age of the tree root was rescaled to 1, so that species richness and phylogenetic diversity are calculated in the same scale. We repeated the procedure to generate a total of 100 random trees to test sensitivity of the results. All manipulations used functions the R packages phytools v. 0.5-20 (Revell, 2012) and ape v. 3.4 (Paradis et al., 2004). Q2

Effect of lamps on diversity and abundance of Coleoptera attracted

We used generalized linear mixed models to test for differences in the abundance, species richness and phylogenetic diversity of beetles collected in each treatment. In all models, the kind of lamp was considered a fixed effect and date of collection a random effect. We used a generalized linear model with Poisson error distribution and log link function for the count response variables (abundance and species richness) and a normal linear model for continuous response variables (phylogenetic diversity). In all cases, model fit was assessed graphically by generating quantile–quantile plots and predictor–residuals plots. The significance of trap as a predictor was tested with a Wald chi-square test. All calculations were done in R package lme4 v. 1.1-11 (Bates et al., 2015). To further test whether differences in diversity attracted to lights are simply a consequence of differences in abundance, we generated rarefaction curves for each lamp using functions in the R package picante v. 1.6-2 (Kembel et al., 2010).

Heterogeneity in Coleoptera preference to lights

To test for heterogeneity in the response of species to lights, we used two approaches. First, we tested whether some lamps consistently attract only a subset of beetle diversity. If that were the case, the diversity attracted to these lamps would result to be phylogenetically clustered with respect to our overall sampling. For each lamp, we calculated the mean pairwise phylogenetic distance (MPD) (Webb et al., 2002) of all species collected throughout the study, averaged over the 100 random trees. We calculated MPD both weighted and unweighted by abundance. To test whether the MPD in each lamp indicated phylogenetic clustering, we randomized the species × lamp matrix by using the trial-swap algorithm (Miklós and Podani, 2004), and drawing a new random phylogenetic tree (from the 100 trees we generated) in each replicate. We have done 10,000 replicates, with 100,000 iterations of the trial-swap algorithm per replicate. These analyses used functions in the R package picante v. 1.6-2 (Kembel et al., 2010).

We also modeled beetle behavior by using latent Dirichlet allocation (LDA) (Blei et al., 2012). The formal definitions of the model can be found in Blei et al. (2012), with a verbal explanation provided by Riddell (2014). This model is normally used in machine