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Moths (Lepidoptera: Heterocera) collected with light attractant in Serra de Itabaiana National Park, Sergipe, Brazil

José Oliveira Dantas[1], Arivania Santos Pereira[2], Leandro Sousa Souto[2] & Ana Paula Coelho Marques[3]

1. Instituto Federal de Sergipe, São Cristóvão, SE, Brazil. 2. Universidade Federal de Sergipe, São Cristóvão, SE, Brazil. 3. Devry Brasil-Faculdade Martha Falcão, Manaus, AM, Brazil.

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Abstract. Lepidoptera includes the butterflies and moths, being considered the second largest order of Insecta, with about 16% of all of the known species in this class. Few lists of Lepidoptera exist for the Northeast of Brazil, a poorly inventoried geographical area. This work had as main objective to accomplish a preliminary study of the moths collected with attractive light at the Parque Nacional Serra de Itabaina, Sergipe, Brazil, verifying the taxonomic diversity and abundance in the study area and analyzing some ecological aspects of the group. A total of 1,450 samples was collected, of which 447 were identified in 19 families. The remaining of the material consisted of 794 microlepidopterous and another 209 not identified specimens. The richness and abundance of lepidopterous did not vary significantly among the dry and rainy seasons (p> 0.05). However, the composition analysis (NMDS) separated the species in two distinct assemblages, but the similarity analysis indicated that this arrangement does not differ significantly (ANOSIM; p = 0.09; R = 0.22), indicating that the nocturnal lepidopterofauna of Serra de Itabaiana stays constant along the year. The time which has a larger number of collected lepidopterous, was from 18:00 to 21:00h. This is a preliminary study, but that serves as reference for other studies with Lepidoptera in Sergipe.

Keywords: Atlantic Forest; diversity; species composition.

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Corresponding author:

José Oliveira Dantas
josedantas336@gmail.com

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Entomological collections emerge as a means of understanding and preserving insects, as it is undeniable that they play a key role in ecosystems, as they are involved in various ecological processes and interactions (Grimaldi & Engel 2005; Casagrande & Duarte 2021). The order Lepidoptera, which includes butterflies and moths, is today considered the second largest among insects, in terms of number of species, making up around 16% of all living insect species (Casagrande & Duarte 2021; Mitter *et al.* 2017). In Brazil, Lepidoptera are represented by around 3,487 described species (Mitter *et al.* 2017), currently grouped into seven families (Hesperiidae, Lycaenidae, Nymphalidae, Papilionidae, Pieridae, Riodinidae and Hedylidae) (Kristensen *et al.* 2007), making the group therefore ideal for environmental studies on biodiversity (Bogiani *et al.* 2012; Henriques *et al.* 2019).

Although Brazil is considered one of the megadiverse countries, housing around 9.5% of all species in the world, it is still in the discovery and characterization phase for most faunal groups, including Lepidoptera (Casagrande & Duarte 2021).

There are few lists of Lepidoptera species for Northeast Brazil, a geographic region in which this order is poorly inventoried and considered a priority for studies of this nature (Carneiro *et al.* 2008; Melo *et al.* 2019). According to Zacca *et al.* (2011), there are lists of lepidopteran species for the Brazilian Northeast, referring to the States of Maranhão (Bates 1867; Garcia *et al.* 1990), Ceará (Rocha 1936; Silva 1967), Paraíba, Rio Grande do Norte, Pernambuco (Carvalho & Freitas 1939; D'Ameida 1935; Nobre *et al.* 2008), Alagoas (Cardoso 1949; Kesselring & Ebert 1979), Bahia (Zacca *et al.* 2011), and despite recent updates, such as Silva *et al.* (2023), studies remain incipient. For the State of Sergipe, there are no known inventories of Lepidoptera. Therefore, this work aimed to carry out a survey of moths (Lepidoptera: Heterocera) in the Serra de Itabaiana National Park, Sergipe, Brazil, verifying the abundance and richness of these insects in the study area.

MATERIAL AND METHODS

The material was collected in the "Serra de Itabaiana" National Park, located between coordinates -10.66667 and -37.41667, with a maximum altitude of approximately 670 m, covering an area of 1,966 ha and 45 km from Aracaju (Dantas & Ribeiro 2010).

The collection method was the use of a luminous attraction on a white sheet, mounted approximately 50 cm from the floor and illuminated with two mercury vapor mixed light lamps, each with 250 W and placed on opposite sides of the sheet, and one 127 W black light bulb, placed on just one side. The lamps were powered using a 1,200 W Buffalo® two-phase gasoline generator, with a break of around 10 min during the night, just to refill it.

Microlepidoptera were collected with the aid of the entomological aspirator, being euthanized in death bottles and transferred to entomological blankets. The larger moths were collected with the aid of an entomological net or "puçá", sacrificed with a lethal injection of ethyl acetate between the thorax and abdomen, and temporarily placed in entomological envelopes. Butterflies, although in small numbers, if collected, were sacrificed with a small compression on the sides of the thorax and also placed in envelopes. Subsequently, all specimens were transported to the Entomology Laboratory of the Federal University of Sergipe, mounted, dried in an oven and labeled, following standard procedures for lepidopterans (Almeida *et al.* 1998). The microlepidoptera were pinned through double mounting, using entomological triangles.

Six monthly collections were carried out, three in the rainy season (May, June and July/2011) and three in the dry season (October, November and December/2011), preferably during the waning/new lunar transition period, when the nights are darker, throughout the year, which enhances the effect of the light attraction (Martins *et al.* 2006; Dantas *et al.* 2008). In addition to the comparison between the different seasons, the richness and abundance of Lepidoptera was compared at different periods of the night: from 18:00 to 21:00, 21:00 to 24:00, 24:00 to 03:00 and from 03:00: 00-06:00h.

Lepidoptera were mounted and morphotyped using a Motic® model K-400 or SMZ140 stereomicroscope. The identification of specimens into families was carried out with the aid of a stereomicroscope, using a dichotomous identification key (Triplehorn & Johnson 2011) and the classification adopted was that of Duarte *et al.* (2012). Some specimens were sent to specialists at the Federal University of Paraná (UFPR), for identification at a specific level, including Mimallonidae, Noctuidae, Notodontidae, Saturniidae and Sphingidae. The microlepidoptera were only analyzed statistically, given the great difficulty in identifying them. The material was deposited in the Entomological Collection of the Universidade Federal de Sergipe (CEUFS/Department of Biology/Center for Biological and Health Sciences).

The data were compared using the following statistical methods: to analyze the composition of the morphotypes in the two seasons of the year, Non-Metric Multidimensional Scaling (NMDS) (Gotelli *et al.* 2011) was performed, followed by similarity analysis (ANOSIM) (Clarke 1993). To test whether abundance and richness varied between seasons, the non-parametric Wilcoxon test ($p < 0.05$) was performed, taking into account the non-normality of the data.

RESULTS AND DISCUSSION

A total of 1,450 individuals were collected, of which 447 were identified in 19 families: Arctiidae, Bombycidae, Cossidae, Erebidae, Geometridae, Hyblaeidae, Immidae, Lymantriidae, Megalopoygidae, Mimallonidae, Noctuidae, Notodontidae, Nymphalidae, Pyralidae, Saturniidae, Sesiidae, Sphingidae, Thyrididae and Tortricidae. Part of the material was not identified, consisting of 794 microlepidoptera and another 209 specimens.

The number of lepidopterans collected was highest in the month of June (second collection of the rainy season), followed by the months of December and October, respectively. The months of July, November and May had a lower abundance of lepidopterans collected (Figure 1).

This study comprises the first survey of lepidopterans in Atlantic Forest remnants in Sergipe. Darrault & Schlindwein (2002) carried out surveys in "Tabuleiro Paraibano", while Duarte-Júnior & Schlindwein (2005) carried out studies in the Atlantic Forest of Pernambuco, using the same sampling method, but with an emphasis on Sphingidae. In these studies, the richness and abundance of moths were greater in the months of May to June in these regions, which partially corroborates the data obtained, as the month of june was the month with the greatest abundance of lepidopterans collected in this study.

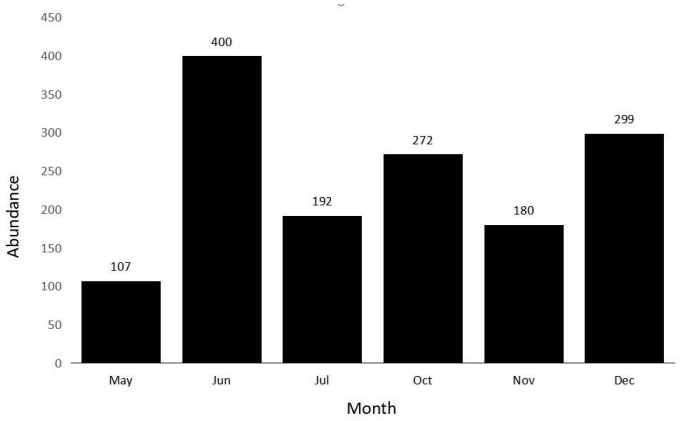

Figure 1. Number of adult Lepidoptera individuals collected during six nocturnal collections using light attractant in Serra de Itabaiana National Park, Sergipe, Brazil.

In the rainy season, 699 individuals were collected (48% of lepidopterans collected) and 751 in the dry season (52% of specimens collected), but the richness ($W = 4$; $p > 0.05$) and abundance ($W = 5$; $p > 0.05$) of lepidopterans did not vary significantly between seasons (Table 1). These results differ from those found by Duarte-Júnior & Schlindwein (2005), who found greater abundance and richness of sphingids in the rainy season (April to June). However, it is important to emphasize that the results obtained in the present study included a greater diversity of Lepidoptera.

Table 1. Richness and abundance of adult Lepidoptera collected during six nocturnal collections using light attractant in Serra de Itabaiana National Park, Sergipe, Brazil. Values indicate mean ± standard error. Equal letters on the same line indicate no significant differences using the Wilcoxon test ($\alpha < 0.05$).

Variable	Dry season	Rainy season
Richness	23.3 ± 3 a	22 ± 2.3 a
Abundance	250 ± 36 a	233 ± 87 a

Although the NMDS analysis presents species ordering in two assemblages with distinct compositions, the similarity analysis indicated that this ordering does not differ significantly (ANOSIM; $p = 0.09$; $R = 0.22$) (Figure 2), indicating that the nocturnal lepidopterofauna of "Serra de Itabaiana" remains constant throughout the year. One of the factors responsible for this divergence (separation into two groups, although not significant) would be the occurrence of the most abundant morphotypes during the two collection seasons. Thus, the majority of morphotypes collected in only one of the seasons were represented by one or two individuals, or occurred in only one collection. Thus, these data were not sufficient to suggest a dissimilarity between the seasons. Future sampling that includes all months of the year or a greater sampling effort will be useful to confirm the trend found in the present study. In general, recent studies show that changes in the composition of Lepidoptera species are more related to climatic variations, altitude and/or habitat fragmentation (Melo *et al.* 2019; Pires *et al.* 2020; Vieira *et al.* 2022).

Regarding the collection time, there was a greater number of lepidoptera collected in the interval from 6:00 pm to 9:00 pm, followed by the shifts from 9:00 pm to midnight, 12:00 pm to 3:00 am, and 3:00 am to 6:00h, respectively (Figure 3).

Species of Mimallonidae, Noctuidae, Notodontidae, Saturniidae and Sphingidae were identified (Table 2).

The species of Sphingidae collected were not the same as those found by Duarte-Júnior & Schlindwein (2005) in the Pernambuco Atlantic Forest. Only *Protambulyx strigilis* (Linnaeus, 1771) (Lepidoptera: Sphingidae) was collected in both States, suggesting that more studies are needed to better understand the diversity of Lepidoptera in the northeast region of Brazil.

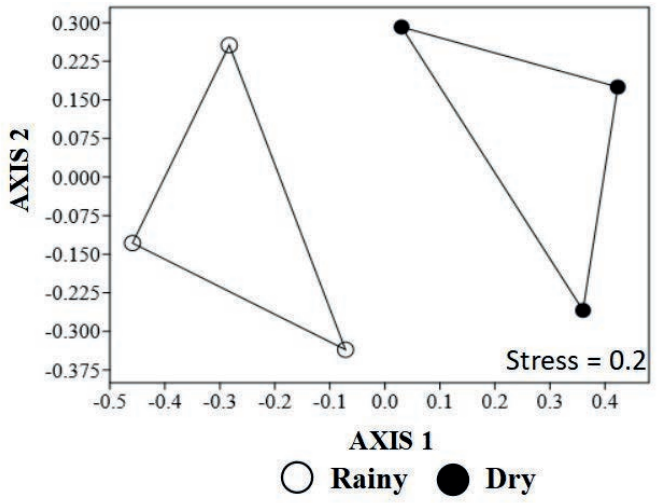

Figure 2. Multivariate analysis (NMDS) of the composition of lepidoptera collected with light attractant in the Serra de Itabaiana National Park, Sergipe, Brazil, in the dry and rainy seasons.

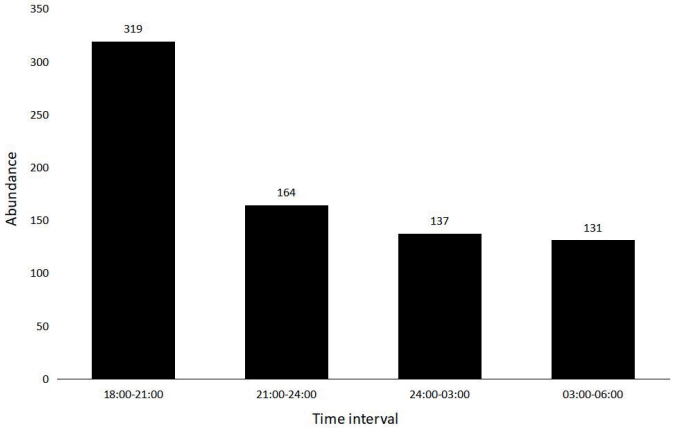

Figure 3. Number of adult Lepidoptera individuals collected with light attractant, at different night times, in a remnant of the Atlantic Forest, in the Serra de Itabaiana National Park.

From the data obtained in the present work, it can be concluded that the "Serra de Itabaiana" National Park, although it is a highly anthropized region, has around 19 families (approximately 15%) of lepidopterans (not including here the majority of butterfly families, due to the collection method used) of the 139 known described families (van Nieukerken *et al.* 2011). The results indicate that the Atlantic Forest of Sergipe has a distinct fauna of lepidopterans (in the case of Sphingidae) and is still little known, also considering the other families of Lepidoptera. Although the effects of environmental changes resulting from the dry and rainy seasons are widely known in the structuring of natural communities, this ecological parameter did not influence the structure of lepidoptera assemblages in the studied ecosystem, since there was no change in any of the evaluated attributes (richness, abundance and species composition). It is suggested that the time of greatest lepidopteran activity is the beginning of twilight, although future studies are needed to confirm this trend. The data obtained allows a better understanding of the Park's lepidoptera, as well as some ecological aspects of the group, as it is a region in which lepidopteran inventories are scarce. The material identified at a specific level could serve as a reference for future studies with moths in Sergipe.

Table 2. Lepidoptera taxa collected with light attraction in the Serra de Itabaiana National Park, Sergipe, Brazil.

Family	Subfamily/Tribe	Genus/Species
Mimallonidae	Mimalloninae	*Cicinnus* sp.
Noctuidae	Catocalinae	*Letis* sp. 1
		Letis sp. 2
		Letis sp. 3
		Letis sp. 4
Notodontidae	Nystaleinae	*Notoplusia* sp.
Saturniidae	Ceratocampinae	*Syssphinx molina* (Cramer, 1780)
	Arsenurinae: Arsenurini	*Titaea tamerlan tamerlan* (Maassen, 1869)
	Hemileucinae: Hemileucini	*Cerodirphia flavosignata* (F. Johnson & Michener, 1948)
	Hemileucinae: Hemileucini	*Gamelia* sp.
	Hemileucinae: Hemileucini	*Lonomia* sp.
Sturniidae	Hemileucinae: Hemileucini	*Pseudautomeris luteata* (Walker, 1865)
Sphingidae	Macroglossinae: Dilophonotini	*Madoryx plutonius* (Hübner, 1819)
	Macroglossinae: Dilophonotini	*Pachylioides resumens* (Walker, 1856)
	Macroglossinae: Dilophonotini	*Perigonia lusca* (Fabricius, 1777)
	Smerinthinae	*Protambulyx strigilis* (Linnaeus, 1771)

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AUTHORS CONTRIBUTIONS

ASP: initial writing, LSS: statistical analysis, JOD- LSS: Final writing and analysis of metadata, APM: Revision and final writing of the article.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

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