Diversity and Habitat Preferences of Moths (Insecta: Lepidoptera) in Indikadamukalana, a Lowland Wet Zone Forest in Sri Lanka

P. Gunathunga[1], C. D. Dangalle[1*] and N. Pallewatta[1]

[1]Department of Zoology and Environment Sciences, Faculty of Science, University of Colombo, Sri Lanka

Date Received: July 31, 2022 Date Accepted: October 28, 2022

Abstract

The moths (Insecta, Lepidoptera) of Sri Lanka have not been well studied and no comprehensive scientific study on their diversity has been carried out over the past 100 years. Thus, establishing species richness and diversity of moths in different habitats of the island is important. The present study was carried out to investigate moth species diversity and habitat factors which can affect moths in Indikadamukalana Forest Reserve situated in the wet zone of Sri Lanka. Moth diversity of the forest was investigated for a period of approximately seven months in 2018, where two habitat types as forest edge and within forest were studied. Transect line count method was used to sample diurnal moths and light traps were used to study nocturnal moths. Aerial nets and fruit-baited traps were used to improve the sampling efficiency. Weather parameters of the two habitat types were estimated using a potable weather station. A total of 138 moth species of 19 families were recorded, with forest edge habitat recording 18 families (91 species) and within the forest habitat recording 15 families (47 species). Crambidae and Erebidae were the most prominent families of moths found in both habitats of the forest. Gelechiidae was recorded only from within the forest habitat while Sphingidae, Hepialidae, Tortricidae and Bombycidae were recorded only from the forest edge habitat. Weather parameters between the two habitats did not depict a significant difference. Maintenance of Sri Lanka's biodiversity hotspot status lies within the wet zone of the country. Thus, long term studies of moth communities of the wet zone are of vital importance.

Keywords: Moths, Indikadamukalana forest, forest habitats, species richness, Sri Lanka

1. Introduction

Lepidoptera is the second largest order of class Insecta and is found in all countries of the world except in the poles. It includes the micro-moths, which embraces the most primitive lineages of the Lepidoptera; the macro-moths, which are the predominantly night-flying members of the order; and the butterflies and skippers (Kristensen et al., 2007). There are 255,000 species of Lepidoptera in the world belonging to 125 families. Of these, 231,500 species are moths representing 119 families while only 23,500 species are butterflies and skippers (Capinera, 2008). However, it has been reported that the sampling and identification of moths, especially in the tropical regions has so far been inadequate (Kristensen et al., 2007), and this situation is unlikely to have changed even today. Phytophagous insects, whose presence and abundance depends on particular plant species, thrive in tropical rainforests and high proportions of endemic and rare species have often been recorded (Fiedler and Schulze, 2004). Tropical rainforests are believed to house a tremendous diversity of moths due to habitat heterogeneity and presence of a wide range of niches (Jaroensutasinee et al., 2011), and certain studies have documented the moth species in tropical rain forests from different countries (Brehm and Fiedler, 1999; Beck et al., 2002; Beck et al., 2006; Akite et al., 2015; Nino et al., 2019). When considering the countries of tropical Asia, moth species have been recorded from selected areas of the

Correspondence: cddangalle@zoology.cmb.ac.lk
ISSN 2235-9362 Online ©2022 University of Sri Jayewardenepura

Indian subcontinent, Bhutan, Pakistan and Philippines (Mathew and Rahamathulla, 1995; Irungbam et al., 2016; Faiz et al., 2019; Sebua and Nuňeza, 2020).

However, most of these studies have focused on only certain families of moths such as Pyralidae, Crambidae, Erebidae, Geometridae, Arctiidae, Saturnidae, and Sphingidae, considering their economic importance, high species richness and large body size. However, Mathew and Rahamathulla (1995), who recorded the moth fauna in the lowland evergreen forests of Silent Valley, Western Ghats, disclosed the close resemblance between the moth fauna of India and Sri Lanka, and their origin from the countries from the Oriental region.

In Sri Lanka, a wide variety of moths representing 52 families that includes around 1911 species have been recorded (Wijesekara and Wijesinghe, 2003; Kocak and Kemal, 2012). However, despite their wide variety, moths have been poorly studied in Sri Lanka, a fact that is pertinent to other countries of Asia as well.

In Sri Lanka the last comprehensive scientific study on moths was done by G. F. Hampson between 1892 – 1896 as a part of the “Fauna of British India” series, with four volumes on moth taxonomy and diversity. The studies conducted since then have mainly focused on species of economic importance such as pest species, with studies on diversity and abundance of a few selected groups (Jayaneththi, 2016). The recent invasions by the Fall Armyworm, *Spodoptera frugiperda*, on maize cultivations in the dry zone of Sri Lanka, initiated several investigations on the life history characteristics and management of this moth (Kasige et al., 2022a, 2022b). A few studies have focused on using moth larvae as hosts for rearing parasitoids and other biological control approaches (Karunarathne et al., 2020; Sammani et al., 2020; Singhamuni et al., 2021). The moth diversity of the University of Vavuniya premises and associated host plants have been recorded by Wijerathna et al., (2021). However, though the nomenclature of moths has been updated, the local moth faunal lists have not been updated accordingly. Current studies on moth fauna of Sri Lanka is therefore obstructed by the lack of knowledge (Aluthwattha, 2013).

Moths have been identified as a forest-dependent insect group that has experienced significant declines in species richness and abundance in the last 20 – 40 years, and in need of repeated biodiversity monitoring even within protected and relatively intact forests (Akite et al., 2015). The red lists developed by the International Union for Conservation of Nature (IUCN) is highly biased towards larger and better-studied taxa such as vertebrates, in view of the fact that data on the conservation status of insects are scarce (Koh, 2007). Majority of red lists for moth species have been developed for the countries of Europe (Fox et al., 2019; Duffus and Morimoto, 2022), and rarely for the countries of Asia. In Sri Lanka, eventhough a butterfly conservation action plan (2014) has been developed for the taxonomy, distribution, legal and institutional aspects, and threats faced by butterflies, such action plans or lists for the conservation status of moths are unavailable. However, due to the highly dynamic nature of moth populations, driven by short lifecycles and sensitivity to environmental factors and thus susceptibility to extinction, it is imperative that data on their biology, distribution and habitat preferences be investigated.

Therefore, in this study we investigate the moth diversity of Indikadamukalana lowland wet zone forest of Sri Lanka in order to record the moth diversity in two habitat types (forest edge and within the forest) of the forest and to study the relationship between species diversity and selected habitat parameters.

2. Methodology

2.1 Study area

The study was conducted in Indikadamukalana forest reserve situated in the wet zone of Sri Lanka. The forest lies adjacent to the Seethawaka Wet Zone Botanic Gardens and is important in providing seeds to the arboretum (Ranwala et al., 2017). It harbours a high species diversity of butterflies, rich in endemic species (Peiris et al., 2020). Two habitat types with different habitat structures were selected: within the forest habitat of Indikadamukalana forest ($6^0$90'19"N; $80^0$16'88"E) and the edge habitat of Indikadamukalana forest (6^0 90'17"N; $80^0$17'01"E) (Figure 01). In selecting the two habitat types different vegetational types representing micro-habitats such as grasses, shrubs, understory and canopy cover were all considered as within forest habitats, while the boundary of the forest with associated home gardens were considered as the forest edge habitat.

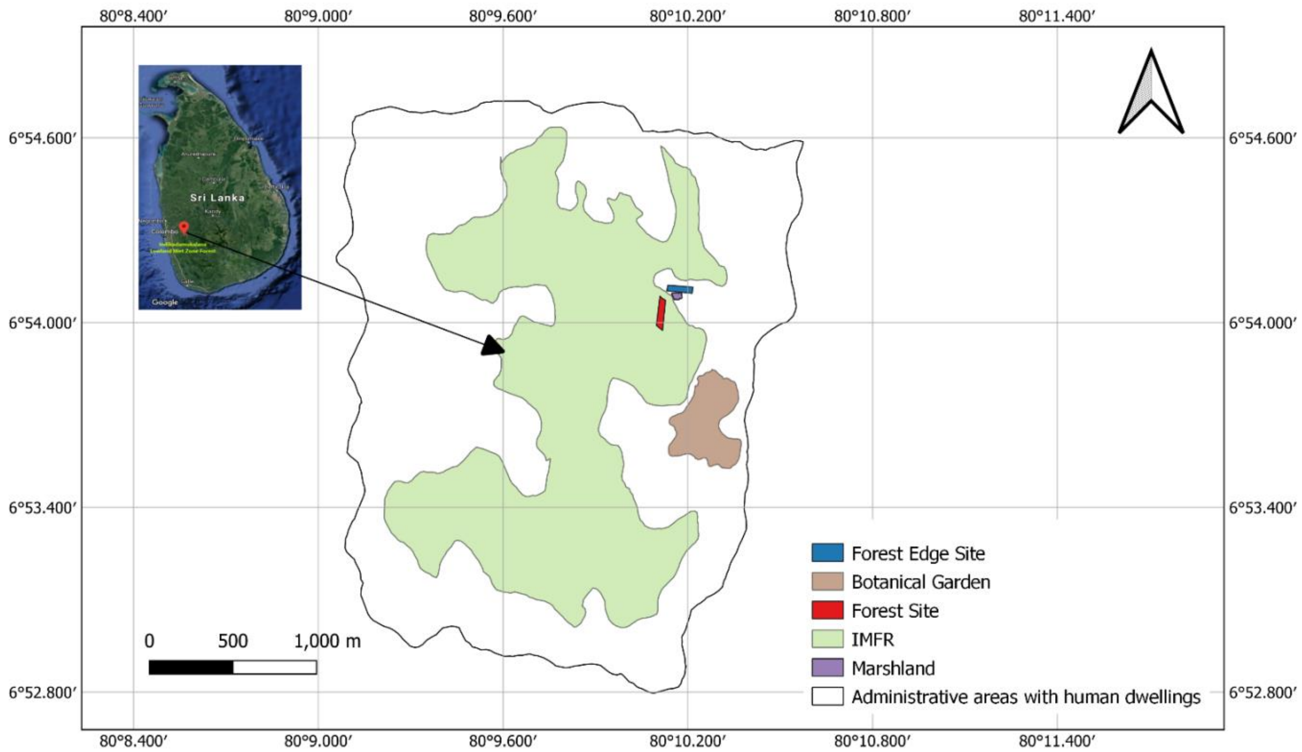

Figure 01: Location of Indikadamukalana forest reserve and study sites.
The two study sites (forest edge site and forest site) are indicated as transects where sampling was conducted. IMFR – Indikadamukalana Forest Reserve

2.2 Field sampling methods

Sampling was conducted in two habitat types of the forest from 24 February 2018 to 15 September 2018 for a period of approximately seven months. In each habitat two 100 m line transects covering the vegetation communities were established where each transect covered an area of 100 m × 40 m. Sampling was carried out for two consecutive days including a single night in the last week of each month so that both diurnal and nocturnal moths were sampled. Thus, sampling was carried out for a total of 16 days, from 8.00 am to 11.00 am and 3.00 pm to 6.00 pm for diurnal moths and from 6.00 pm to 10.00 pm and 4.00 am to 6.00 am for nocturnal moths. Moth species were identified using available field guides (Jayawardana and Jayasinghe, 2016) and unidentified moth species were collected using standard techniques for subsequent identification in the laboratory using taxonomic keys.

For nocturnal moth sampling, light traps were made using 22 W UV light bulbs powered with 12 V batteries (Choi et al., 2009; Choi and An, 2013) and a white reflective sheet of 2.5 m x 2 m hung at a height of 3m. Two light traps were placed along each transect with a 40 m distance in between the light traps (Schmidt and Roland, 2006). At the same time nocturnal moths found inside the houses situated in the edge habitat falling in to the area covered by the transects were sampled using insect nets. For diurnal moth sampling a line transect survey was carried out where insect nets were used where necessary to collect unidentified moth species for further investigation.

Fruit-baited traps were placed for both diurnal and nocturnal moths. As fruits, banana (*Musa sp.)*, papaya (*Carica papaya*) and star fruit (*Averrhoa carambola*) were used according to their seasonal availability. The fruit-baited trap was made by placing a cup with cut pieces of ripe fruits (250 g) at the bottom of a net which was made in a cylindrical shape (120 cm long net) leaving a gap for the moths to enter into the net from the bottom. Two traps per habitat were hung on a tree at a height of 5m from the ground in the pre-established line transects in areas where light traps were not placed. The trap was hung for 24 hours and the observations were recorded from 8.00 am to 11.00 am in the morning, 3.00 pm to 6.00 pm in the evening, 6.00 pm to 10.00 pm and 4.00am to 6.00 am in the night at half an hour intervals.

2.3 Identification of moths

Moth identification was done in the laboratory using a dissecting microscope and with the use of standard keys and descriptions provided in Hampson (1892, 1894, 1895, 1896), Bell and Scott (1937) and Borror et al. (1954). Due to high species diversity and the lack of taxonomic keys with the exception of the taxonomic keys to the moths in the South Asian region in “Fauna of British India” most moths were only possible to be identified up to family level.

2.4 Measurement of weather parameters

In this study, the variation of moth diversity with weather parameters in the two habitat types were taken into account. Therefore, weather parameters including ambient temperature, relative humidity, wind speed (Davis Vantage Pro 2 weather station); light intensity (lux meter); rainfall (Meteorological Department, Sri Lanka) were measured. Measurements were taken at the time of moth collection, and four readings per parameter, per month for diurnal moth locations, and two readings per parameter, per month for nocturnal moth locations were recorded.

2.5 Data Analysis

One-way Analysis of Variance (ANOVA) with Tukey’s comparison was performed using Minitab version 17.0 to observe whether there was a significant difference in weather parameters between the two habitats during the seven months of data collection.

3. Results

3.1 Diversity of moths in the habitats of the Indikadamukalana forest

A total of 138 species of moths representing 19 families were identified from Indikadamukalana rainforest. However, some species were not identified up to the species level and only up to the family level. The edge habitat of the Indikadamukalana forest had a higher diversity of moths than the habitat within the forest and 91 species of 18 families were found in different micro-habitats of the forest edge habitat. The habitat within the forest housed 47 species of moths belonging to 15 families. The family composition of moths in the two habitats were closely similar (Table 01, Figure 02, Figure 03).

Table 01: Moths recorded from the habitats of Indikadamukalana Forest Reserve

Family	Species recorded from the edge habitat	Species recorded from within the forest
1. Notodontidae	9 unidentified sp.	2 unidentified species
2. Erebidae	*Eublemma sp.*	-
	Syntamoides imaon	-
	Nepita conferta	*Nepita conferta*
	Syntomeida sp.	-
	Artaxa sp.	-
	Amata passalis	-
	Erebus ephesperis	-
	Mocis undata	-
	7 unidentified sp.	7 unidentified sp.
3. Noctuidae	*Brithys crini*	-
	1 unidentified sp.	2 unidentified sp.
4. Tortricidae	1 unidentified sp.	-
5. Sesiidae	1 unidentified sp.	1 unidentified sp.
6. Hepialidae	1 unidentified sp.	-
7. Tineidae	6 unidentified sp.	1 unidentified sp.
8. Crambidae	*Ancylolomia japonica*	-
	Bocchoris inspersalis	-
	Metoeca foedalis	*Metoeca foedalis*
	Diaphania indica	-
	Tatobotys biannulalis	*Tatobotys biannulalis*
	Pyrausta panopealis	-
	Omiodes diemenalis	-
	Spoladea recurvalis	-
	Cnaphalocrocis bilinealis	-
	-	*Pleuroptya iopasalis*
	18 unidentified sp.	7 unidentified sp.
9. Pyralidae	7 unidentified sp.	6 unidentified sp.
10. Geometridae	*Hypomecis transcissa*	-
	Hemithea sp.	-
	8 unidentified sp.	8 unidentified sp.
11. Uraniidae	*Dysaethria lilacina*	-
	1 unidentified sp.	1 unidentified sp.
12. Lasiocampidae	2 unidentified sp.	1 unidentified sp.
13. Thyrididae	1 unidentified sp.	1 unidentified sp.
14. Sphingidae	*Daphnis nerri*	-
	1 unidentified sp.	-
15. Bombycidae	1 unidentified sp.	-
16. Eupterotidae	1 unidentified sp.	2 unidentified sp.
17. Zygaenidae	1 unidentified sp.	1 unidentified sp.
18. Drepanidae	2 unidentified sp.	2 unidentified sp.

Figure 02: Moth species of selected families recorded from the edge habitat of Indikadamukalana Forest

Figure 03: Moth species of selected families recorded from within the forest habitat of Indikadamukalana Forest

In both habitats – edge and within the forest, the highest species richness of moths were represented by family Crambidae followed by family Erebidae. In the forest edge habitat, family Notodontidae occupied the third position with family Geometridae in the fourth position whereas in the habitat within the forest, family Geometridae occupied the third position followed by family Pyralidae. The percentage abundance of families Crambidae and Erebidae within the forest habitat was lower than in the habitat at the forest edge. However, species richness of family Geometridae is highest within the forest habitat with edge habitat occupying approximately only half of the species of family Geometridae within the forest (Figures 04 and 05). Family Tortricidae and Tineidae were the least abundant moth families observed in edge and within the forest habitats respectively.

According to Figure 06, 14 families of moths were common to both habitats of Indikadamukalana forest. Family Gelechiidae was only recorded from within the forest habitat of Indikadamukalana while families Tortricidae, Bombycidae, Sphingidae and Hepialidae were recorded only from the edge habitat of Indikadamukalana.

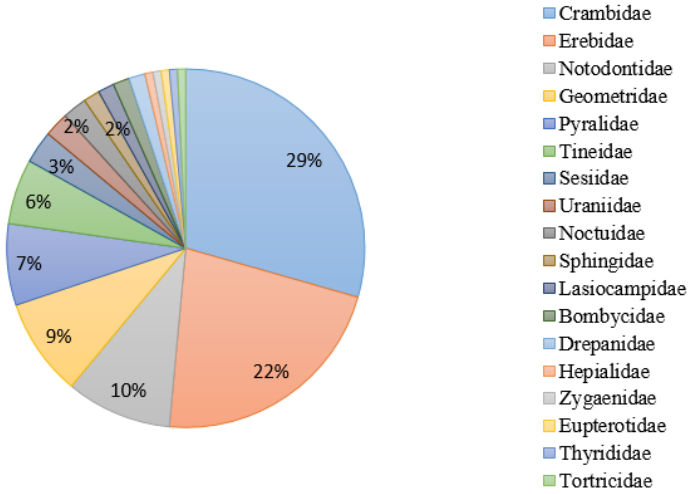

Figure 04: Species richness of moth families in the edge habitat of Indikadamukalana forest

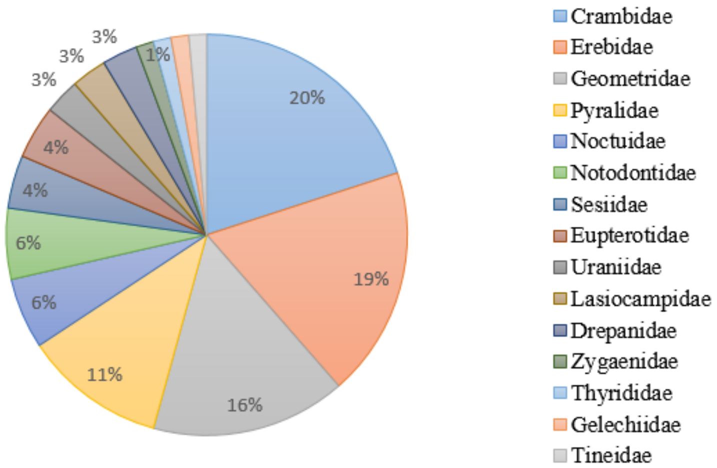

Figure 5: Species richness of moth families in the habitat within Indikadamukalana forest

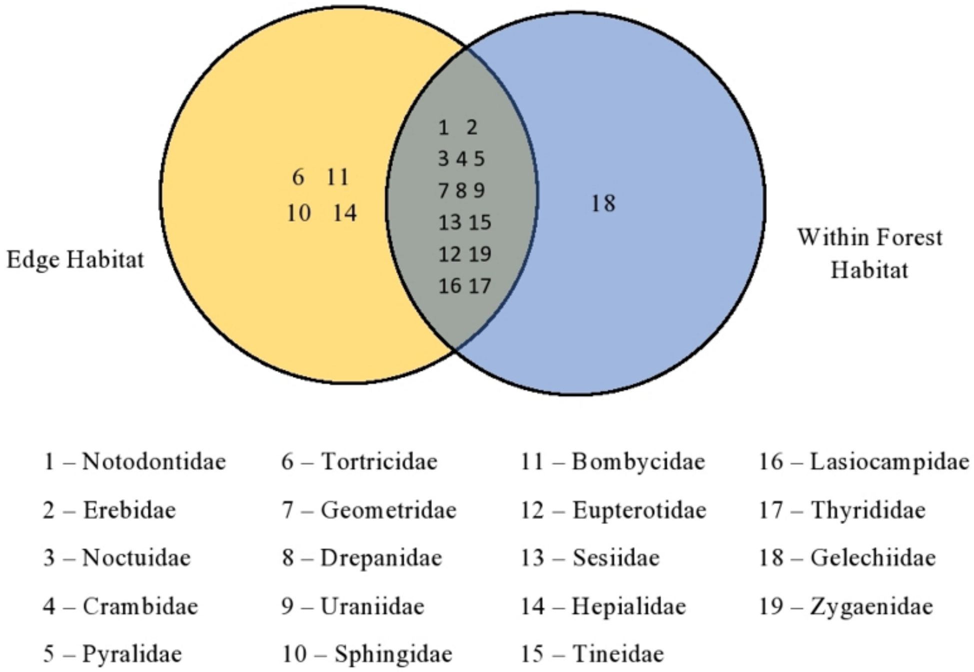

Figure 6: Degree of overlap in the occurrence of moth families in the two habitats at Indikadamukalana Forest

3.2 Vegetation in the habitats of the Indikadamukalana forest

Plant diversity and heterogeneity was high in the edge habitat when compared with the habitat within the forest. The edge habitat consisted of large and small trees such as Godapara (*Dillenia retusa*), Jak (*Artocarpus heterophyllus*), Rambutan (*Nephelium lappaceum*), Papaya (*Carica papaya*), *Albizia*; Shrubs such as Rose apple (*Szygium jambos*), Tea (*Camellia sinensis*), Bovitiya (*Osbeckia octandra*); Herbs such as Bandura wel (*Nepenthes distillatoria*) and aquatic plants such as Blue lotus (*Nymphaea nouchali*). Comparatively the habitat within the forest was dominated and limited to large trees such as Kithul (*Caryota urens*), Mahogany (*Swietenia mahogany*), Ginikuru (*Alstonia macrophylla*), Hal (*Vateria copallifera*) and Wal karabu (*Fagraea fragrans*).

3.3 Effect of weather variables on moth diversity

When considering the climate of the two habitats, significant differences were not evident in any of the parameters diurnally or nocturnally (Table 02). Therefore, differences in moth species diversity in the edge and within forest habitats may not have been influenced by variations of the climate.

Table 2: Climate parameters of the two habitats in Indikadamukalana forest (Mean ± Std. Dev.)

Habitat Parameter	Forest Edge		Within Forest	
	Nocturnal (n = 12)	Diurnal (n = 24)	Nocturnal (n = 12)	Diurnal (n = 24)
Temperature (^{0}C)	26.08 ± 1.84	27.74 ± 1.53	25.90 ± 0.53	27.31 ± 1.88
Relative Humidity %	89.00 ± 0.03	83.38 ± 0.06	90.20 ± 0.01	81.25 ± 0.09
Wind Speed (kmh^{-1})	0.20 ± 0.45	0.89 ± 1.61	0.60 ± 1.34	0.83 ± 1.08
Rainfall (mm)	6.88 ± 7.88		7.95 ± 8.55	
Light intensity (klux)	-	17.19± 26.10	-	5.87 ± 7.73

4. Discussion

Tropical rain forests harbor a large amount of herbivorous insects, particularly comprising of phytophagous Coleoptera, and Lepidoptera such as butterflies and moths (Fiedler and Schulze, 2004). However, habitat loss due to forest destruction and non-sustainable forest use, especially in tropical forests around the equator have resulted in large diversity losses of these insects (Beck et al., 2002). When considering the Lepidoptera, moths maybe more affected by the habitat changes than the butterflies, as they are more ecologically diverse and at least 15 times more taxonomically diverse than butterflies (Wagner et al., 2021). The substantial decline of moths have been reported for countries such as the United Kingdom, United States, Germany, Sweden, India, Netherlands, Siberia and New Zealand (Dar and Jamal, 2021), but vaguely for biodiversity rich tropical islands such as Sri Lanka. In Sri Lanka, regardless of studies concerning the decline in moth diversity, surprisingly, even the diversity of moths have not been investigated for more than a 100 years. In this study we investigated the moth diversity in a tropical wet zone forest of the country with the intention of recording the moth species found in the wet zone forest, species rich families, habitats with high diversity and possible weather parameters of the habitats affecting moth diversity.

One hundred and thirty-eight moth species were recorded from Indikadamukalana forest which represented 7.22% of the 1911 moth species that have been recorded from Sri Lanka. The edge habitats of the forest had a high moth species richness (91 species) when compared with the habitats within the forest (47 species). However, the moth family compositions of the two habitats were more or less similar with 14 families (~74%) being common to both habitats. The Pyraloidea (Geometridae and Pyralidae) species richness was high within the forest, and Gelechiidae were restricted to the forest. Tortricidae, Sphingidae, Bombycidae and Hepaliadae were only found in the edge habitats. Families Crambidae and Erebidae which are large moth families with worldwide distribution, were the prominent families of both the habitats. Weather parameters did not seem to affect moth diversity of the two habitats as significant differences of parameters were not evident between the two habitat types. However, microclimatic conditions such as air and soil temperatures, wind velocity, short-wave radiation, and air and soil moisture are known to be significantly different between forest edges and habitats inside the forest, with high variability of the parameters at the forest edge (Chen et al., 1993). Therefore, further studies including long-term investigations and recordings of soil parameters are suggested.

Previous studies on species richness of moths reveal that some are on par with the current study and some have deviations. Beck et al., 2002, Fiedler and Schulze, 2004 and Sutrisno, 2010, have revealed that moth species richness is high in undisturbed primary forests than disturbed habitats and have suggested possible reasons for this observation. Beck et al. (2002), suggests that old-growth forests have well-developed undergrowth to support a rich diversity of moth species, whereas disturbed secondary forests and farmland sites lack undergrowth vegetation and thus supports a less number of moth species. Fiedler and Schulze (2004) suggest that a plethora of moth species may exist in undisturbed habitats due to the prevalence of host plants and a variety of woody plants. According to Sutrisno (2010), the green canopy of primary forests provide refuge for many moth species. These studies particularly focus on family Geometridae, and affirms that the species diversity tends to decrease at the disturbed edges of forest reserves when compared with the habitats within the forests. A similar outcome was also revealed in the present study, where the edge habitats had a low number of Geometrid species when compared with the habitats within the Indikadamukalana forest.

However, several studies suggest that forest edges support a higher number of moth species by providing habitat heterogeneity, and that moth species richness in such habitats are higher than that of forest sites (Brehm and Fiedler, 1999; Hawes et al., 2009). Brehm and Fiedler (1999) suggests that the high diversity may only be due to the immigration of moth species to disturbed sites from adjacent intact forests, whereas, Hawes et al. (2009) suggests that the alternative land uses such as exotic tree plantations can support a substantial level of moth diversity. Further, Nino et al. (2019) reports that moths at the forest edge are significantly larger than those of the forest interior due to more mobility and better tolerance to desiccating conditions. A greater proportion of the larger moths are females that produce more offspring ensuring species survival (Nino et al., 2019).

Forest edges are transition areas between different habitats in the same ecosystem created for settlements, agriculture, logging or by natural causes (Laurance et al., 2007). Alterations in environmental conditions, vegetation structure and composition and altered biotic interactions such as predation and parasitism in edge habitats cause changes in species diversity and abundance which is termed as the “edge effect” (Zurita et al., 2012). In the present study, species richness of moths were higher at the forest edge compared to the habitats within the forest which may be due to differences in vegetation composition and biotic interactions between the moths and other animals. Thus, plant diversity and heterogeneity may have been high in the edge habitat compared to the habitat within the forest resulting a higher diversity of moth species. However, biotic interactions between moths and other animals were not studied in the present study.

In the present study Crambidae and Erebidae were the most speciose families in the forest habitats, a fact which has also been observed in forests elsewhere in the world. Crambidae and Erebidae were the most species rich moth families in the forest ecosystems of Nilgiri Hills, Tamil Nadu, India (Moinudheen and Sivasankaran, 2020), the warm-temperate forests of Hyogo Prefecture, Japan (Funamoto and Sugiura, 2016), and Keoladeo National Park at Bharatpur, India (Trigunayat and Trigunayat, 2021). The variety of different habitats found within the forest and forest edges may have promoted the species richness of the ecologically diverse Crambidae and Erebidae. Further, larvae of many Crambidae are known to be aquatic or semi-aquatic and live in stems or roots, or exposed leaves of aquatic plants (Pabis, 2018). The presence of such habitats in the forest edges of Indikadamukalana may have contributed to the higher numbers of Crambidae in these habitats when compared to habitats within the forest.

The occurrence of moths of families Tortricidae, Sphingidae, Hepialidae and Bombycidae only from the forest edge may be due the host plant interaction of the moths and their evolutionary adaptations. Moths of family Sphingidae are known to be associated with orchid varieties in home gardens (Kitching, 2002), while species of family Tortricidae are usually pests of tea, nuts and fruit varieties (Johnson, 2013; Maniania et al., 2017; Nakai and Lacey, 2017). Family Bombycidae harbours moth species that are pests of jackfruit (Navasero et al., 2013) that are abundant in home gardens and moths of Hepialidae are generalists that feed on a variety of plants (Neilsen et al., 2000). However, their adaptations to disturbed habitats such as forest edges reveal that, certain taxonomic subgroups within these families may react to habitat disturbances differently, a fact which was not considered in the present study. According to Beck et al. (2006), Smerinthinae species of family Sphingidae decreases with habitat disturbance, whereas species of Macroglossinae of the same family thrive in disturbed habitats. However, as a whole the moths of family Sphingidae are considered as an exceptional group of insects where many species are well adapted to survive in a changing environment dominated by cultivated areas and secondary forests (Schulze and Fiedler, 2003).

Finally, the study reports a rich diversity of moth species from the tropical wet zone forest, Indikadamukalana, of Sri Lanka. The edges of the forest had a high species richness of moths than the habitats within the forest, possibly due to habitat heterogeneity and differences in vegetation. The composition of the moth families of the two habitats were closely similar, with the exception of a few groups. However, endemic species of moths were not recorded from the investigated sites of the Indikadamukalana forest as expected. Forest habitats of many countries are known to harbor unique sets of endemic moths such as in the native forests of Azores, Portugal (Borges et al., 2018), Western Himalayan forests of India (Sanyal et al., 2017), and rain forests of Costa Rica (Rabl et al., 2019). The shortfall for the absence of endemic moth species in Indikadamukalana may be due to the inability of identifying many species to the lowest taxonomic level. Nevertheless, it is the first time a detailed investigation has been conducted on the moth fauna of Sri Lanka. Further studies addressing the limitations and drawbacks of the current study will benefit the conservation of moth assemblages and their habitats in the future. Such studies are imperative given the extremely rich insect diversity of the country.

Acknowledgements

We wish to thank the Department of Wildlife Conservation and Forest Department for providing permits necessary for field work. We are grateful to Prof. Siril Wijesundara, National Institute of Fundamental Studies, Kandy, Sri Lanka for his permission and support during the field work in Indikadamukalana Forest Reserve. We thank the University of Colombo, Sri Lanka for financial assistance and the Department of Zoology and Environment Sciences, University of Colombo for provision of laboratory facilities and assistance.

References

Akite, P., Telford, R.J., Waring, P., Akol, A.M., Vandvik, V., 2015. Temporal patterns in Saturnidae (silk moth) and Sphingidae (hawk moth) assemblages in protected forests of central Uganda. *Ecology and Evolution*, 5(8): 1746-1757.

Aluthwattha, S.T., 2013. Family Saturniidae (Insecta: Lepidoptera) of Sri Lanka: An overview. Lepcey – *The Journal of Tropical Asian Entomology*, 2(1): 1-11.

Beck, J., Schulze, C.H., Linsenmair, K.E., Fiedler, K., 2002. From forest to farmland: diversity of geometrid moths along two habitat gradients on Borneo.*Journal of Tropical Ecology*, 18: 33-51.

Beck, J., Kitching, I.J., Linsenmair, K.E., 2006. Effects of habitat disturbance can be subtle yet significant: biodiversity of hawkmoth-assemblages (Lepidoptera: Sphingidae) in Southeast-Asia. *Biodiversity and Conservation,* 15(1): 465-486.

Bell, T.R.D., Scott, F.B., 1937. Sphingidae, in: Blanford, W.T., (Ed.), The Fauna of British India, including Ceylon and Burma Vol. 5. Taylor and Francis, Fleet Street, London, pp.1- 638.

Biodiversity Secretariat , Ministry of Environment & Renewable Energy. 2014. Butterfly Conservation Action Plan of Sri Lanka. Colombo: BDS.

Borges, P.A.V., Santa-Rita, J.V.P., Nunes, R., Danielczak, A., Hochkirch, A., Amorim, I.R., Lamelas-Lopez, L., Karsholt, O., Vieira, V., 2018. Species conservation profile of moths (Insecta, Lepidoptera) from Azores, Portugal. Biodiversity Data Journal. 6.

Borror, D.J., Triplehorn, C.A., Johnson, N.F., 1954. An introduction to the study of insects, sixth ed. Saunders College Publishing, United States.

Brehm, G., Fiedler, K., 2005. Diversity and community structure of geometrid moths of disturbed habitat in a montane area in the Ecuadorian Andes. *Journal of Research on the Lepidoptera*. 38: 1-14.

Capinera, J.L., 2008. Encyclopedia of Entomology, second ed. Heidelberg, Germany.

Chen, J., Franklin, J.F., Spies, T.A., 1993. Contrasting microclimates among clearcut, edge, and interior of old-growth Douglas-fir forest. *Agricultural and Forest Meteorology*. 63(3-4): 219-237.

Choi, S.W., An, J.S., 2013. What we know and do not know about moth diversity from seven-year-monitoring in Mt. Jirisan National Park, South Korea. *Journal of Asia-Pacific Entomology*. 16(4): 401-409.

Choi, S.W., Park, M., Kim, H., 2009. Differences in moth diversity in two types of forest patches in an agricultural landscape in Southern Korea – Effects of habitat heterogeneity. *Journal of Ecology and Environment*. 32(3): 183-189.

Dar, A.A., Jamal, K., 2021. The decline of moths globally: A review of possible causes. *Munis Entomology & Zoology*. 16(1): 317-326.

Duffus, N.E., Morimoto, J., 2022. Current conservation policies in the UK and Ireland overlook endangered insects and are taxonomically biased towards Lepidoptera. *Biological Conservation*. 266.

Faiz, A.U.H., Hassan, M.U., Bagaturov, M.F., Tariq, G., Faiz, L.Z., 2019. Diversity of moths in some selected areas of district Bagh, Azad-Jammu & Kashmir. *Journal of Bioresource Management.* 6(1): 27-35.

Fiedler, K., Schulze, C.H., 2004. Forest modification affects diversity (but not dynamics) of speciose tropical pyraloid moth communities. *Biotropica.* 36(4): 615-627.

Fox, R., Harrower, C.A., Bell, J.R., Shortall, C.R., Middlebrook, I., Wilson, R.J., 2019. Insect population trends and the IUCN Red List process. *Journal of Insect Conservation.* 23: 269-278.

Funamoto, D., Sugiura, S., 2016. Settling moths as potential pollinators of *Uncaria rhynchophylla* (Rubiaceae). *European Journal of Entomology.* 113: 497-501.

Hampson, G.F., 1892. Moths, in: Blanford, W.T., (Ed.), The Fauna of British India, including Ceylon and Burma Vol. 1. Taylor and Francis, Fleet Street, London, pp. 1-527.

Hampson, G.F., 1894. Moths, in: Blanford, W.T., (Ed.), The Fauna of British India, including Ceylon and Burma Vol. 2. Taylor and Francis, Fleet Street, London, pp. 1-609.

Hampson, G.F., 1895. Moths, in: Blanford, W.T., (Ed.), The Fauna of British India, including Ceylon and Burma Vol. 3. Taylor and Francis, Fleet Street, London, pp. 1-546.

Hampson, G.F., 1896. Moths. in: Blanford, W.T., (Ed.), The Fauna of British India, including Ceylon and Burma Vol. 4. Taylor and Francis, Fleet Street, London, pp. 1-594.

Hawes, J., da Silva Motta, C., Overal, W.L., Barlow, J., Gardner, T.A., Peres, C.A., 2009. Diversity and composition of Amazonian moths in primary, secondary and plantation forests. *Journal of Tropical Ecology*. 25(3): 281-300.

Irungbam, J.S., Chib, M.S., Wangdi, K., 2016. Taxonomic review of the superfamily Pyraloidea in Bhutan (Lepidoptera). *Journal of Asia-Pacific Biodiversity*. 9(3): 355-382.

Jaroensutasinee, M., Pheera, W., Ninlaeard, R., Jaroensutasinee, K., Choldumrongkul, S., 2011. Weather affecting macro-moth diversity at Khao Nan National Park, Thailand. Walailak Journal. 8(1): 21-31.

Jayaneththi, H.B., 2016. Note on butterfly-moth *Tetragonus catamitus* Geyer, 1832 (Callidulidae) in wet zone, Sri Lanka. *Naturalist Journal of Ecology and Nature*. 8: 26-28.

Jayawardana, C.N., Jayasinghe, H.D., 2016. Colombo wetland moths. Sri Lanka Butterfly Conservation Society, Malwana, Sri Lanka.

Johnson, J., 2013. Pest control in postharvest nuts, in: Harris, L. (Ed.), Improving the Safety and Quality of Nuts. Woodhead Publishing Series, United States, pp. 56-87.

Karunarathne, E.V.U.P., Dissanayaka, D.M.S.K., Wijayaratne, L.K.W., 2020. Development and evaluation of diets for rearing *Corcyra cephalonica* (Stainton) (Lepidoptera: Pyralidae) using readily-available materials. *Rajarata University Journal.* 5(2): 79-85.

Kasige, R.H., Dangalle, C.D., Pallewatta, N., Perera, M.T.M.D.R., 2022a. Egg cluster characteristics of fall armyworm, *Spodoptera frugiperda* (Lepidoptera: Noctuidea) in Sri Lanka under laboratory conditions. *The Journal of Agricultural Sciences – Sri Lanka*. 17(1): 200-210.

Kasige, R.H., Dangalle, C.D., Pallewatta, N., Perera, M.T.M.D.R., 2022b. Laboratory studies of larval cannibalism in same-age conspecifics of fall armyworm, *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera, Noctuidea) in maize. *Tropical Agricultural Research & Extension.* 25(1): 79-86.

Kitching, I.J., 2002. The phylogenetic relationships of Morgan's Sphinx, *Xanthopan morganii* (Walker), the tribe Acherontiini, and allied long-tongued hawkmoths (Lepidoptera: Sphingidae, Sphingine). *Zoological Journal of the Linnean Society.* 135(4): 471-527.

Kocak, A.O., Kemal, M., 2012. Preliminary list of the Lepidoptera of Sri Lanka. Cesa News. 79: 1-59.

Koh, L.P., 2007. Impacts of land use change on South-east Asian forest butterflies: a review. *Journal of Applied Ecology*. 44: 703-713.

Kritensen, N.P., Scoble, M.J., Karsholt, O., 2007. Lepidoptera phylogeny and systematics: the state of inventorying moth and butterfly diversity. *Zootaxa*. 1668(1): 699-747.

Laurance, W.F., Nascimento, H.E.M., Laurance, H.G., Andrade, A., Ewers, R.M., Harms, K.E., Luizao, R.C.C., Ribeiro, J.E., 2007. Habitat fragmentation, variable edge effects, and the landscape-divergence hypothesis. *PLOS one*. 10: 1-8.

Maniania, N.K., Ekesi, S., Dolinski, C., 2017. Entomopathogens routinely used in pest control strategies: Orchards in tropical climate, in: Lacey, L.A. (Ed.), Microbial Control of Insect and Mite Pests. IP Consulting International ,Yakima, United States, pp. 269-278.

Mathew, G., Rahamathulla, V.K., 1995. Biodiversity in the Western Ghats – A study with reference to moths (Lepidoptera: Heterocera) in the Silent Valley National Park, India. *ENTOMON*. 20(2): 25-33.

Moinudheen, N., Sivasankaran, K., 2020. Preliminary study of moth (Insecta: Lepidoptera) in Coonoor forest area from Nilgiri district Tamil Nadu, India. *International Journal of Scientific Research in Biological Sciences*. 7(3): 52-61.

Nakai, M., Lacey, L.A., 2017. Microbial control of insect pests of tea and coffe, in: Lacey, L.A. (Ed.), Microbial Control of Insect and Mite Pests. IP Consulting International, Yakima, United States, pp. 223-231.

Navasero, M.V., Navasero, M.M., de Roxas, M.C.L., Calumpang, S.M.F., 2013. Occurrence of the Moraceae-feeding Bombycid, *Trilocha varians* (Walker) (Bombycidae, Lepidoptera) as pest of Jackfruit and some ornamental species of *Ficus* in the Philippines. *Journl of the International Society for Southeast Asian Agricultural Sciences*. 19(2): 41-48.

Nielson, E.S., Robinson, G.S., Wagner, D.L., 2000. Ghost-moths of the world: a global inventory and bibliography of the Exoporia (Mnesarchaeoidea and Hepialoidea) (Lepidoptera). *Journal of Natural History*. 34(6): 823-878.

Nino, L.M.J., Mortter, R., Brehm, G., 2019. Diversity and trait patterns of moths at the edge of an Amazonian rainforest. *Journal of Insect Conservation*. 23(4): 751-763.

Pabis, K., 2018. What is a moth doing under water? Ecology of aquatic and semi-aquatic Lepidoptera. Knowledge and Management of Aquatic Ecosystems. 419(42).

Peiris, M.U.H., Dangalle, C.D., Pallewatta, N., Wijesundara, S., 2020. Diversity of butterflies in different habitat types of Seethawaka wet zone botanic gardens and Indikadamukalana forest reserve of Sri Lanka. *Ceylon Journal of Science*. 49(1): 49-59.

Rabl, D., Gottsberger, B., Brehm, G., Hofhansl, F., Fiedler, K., 2019. Moth assemblages in Costa Rica rain forest mirror small-scale topographic heterogeneity. Biotropica.

Ranwala, S.M.W., Dilrukshi, I.A.D.N., Wijesundera, D.S.A., Attanayake, A.M.A.S., 2017. The first record on biodiversity of the natural arboretum of Seethawaka wet zone botanic gardens, Sri Lanka. *The Sri Lanka Forester*. 38: 25-45.

Sammani, A.M.P., Dissanayaka, D.M.S.K., Wijayaratne, L.K.W., Morrison III, W.R., 2020. Effect of pheromone blend components, sex ratio, and population size on the mating of *Cadra cautella* (Lepidoptera: Pyralidae). *Journal of Insect Science*. 20(6): 1-7.

Sanyal, A.K., Dey, P., Uniyal, V.P., Chandra, K., Raha, A., 2017. Geometridae Stephens, 1829 from different altitudes in Western Himalayan protected areas of Uttarakhand, India (Lepidoptera: Geometridae). *SHILAP Revista de Lepidopterologia*. 45(177): 143-163.

Schmidt, B.C., Roland, J., 2006. Moth diversity in a fragmented habitat: importance of functional groups and landscape scale in the boreal forest. *Annals of the Entomological Society of America*. 99(6): 1110-1120.

Schulze, C.H., Fiedler, K., 2003. Hawkmoth diversity in Northern Borneo does not reflect the influence of anthropogenic habitat disturbance. *Ecotropica*. 9: 99-102.

Sebua, C.M.D., Nuňeza, O.M., 2020. Species diversity of Lepidoptera in Western Mindanao State University – experimental forest area, Zamboanga City, Philippines. *Entomology and Applied Science Letters*. 7(4): 33-43.

Singhamuni, S.A.A., Hemachandra, K.S., Warnasooriya, P.G.A.S., 2021. Egg parasitoids of cabbage caterpillars in Sri Lanka: A search for biocontrol agents. *The Journal of Agricultural Sciences – Sri Lanka.* 16(1): 174-181.

Sutrisno, H., 2010. The impact of human activities to dynamic of insect communities: a case study in Gunung Salak, West Java. *Hayati Journal of Biosciences.* 17(4): 161-166.

Trigunayat, M.M., Trigunayat, K., 2021. On the diversity of moth fauna of Keoladeo National Park, Bharatpur. *International Journal of Recent Scientific Research.* 12(1): 40515-40518.

Wagner, D.L., Fox, R., Salcido, D.M., Dyer, L.A., 2021. A window to the world of global insect declines: Moth biodiversity trends are complex and heterogenous. *PNAS.* 118(2).

Wijerathna, H.M.P.A., Shama, A.F., Noyalin, M., Wijeyamohan, S., 2021. A preliminary study on the moth diversity (Lepidoptera) of University of Vavuniya, Pampaimadu, Sri Lanka. Vavuniya University International Research Conference 2021. 65-70.

Wijesekara, A., Wijesinghe, D.P., 2003. History of insect collection and a review of insect diversity in Sri Lanka. *Ceylon Journal of Science (Bio. Sci.).* 31: 43-59.

Zurita, G., Pe'er, G., Bellocq, M.I., Hansbauer, M.M., 2012. Edge effects and their influence on habitat suitability calculations: a continuous approach applied to birds of the Atlantic forest. *Journal of Applied Ecology*. 49(2): 503-512.