

## Species

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# Vertical stratification of the butterfly flight and its variations with forest succession of a tropical forest in Sri Lanka

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## ABSTRACT

We assessed and compared the vertical stratification of butterfly flight in two forest types within the Maragamuwa forest regeneration study site (FRSS), Matale, Sri Lanka. Maragamuwa FRSS has two forest patches of different age categories, one is Early Secondary Forest (ESF) and the other is Late Secondary Forest (LSF). Butterfly flying heights recorded in both forest areas. The flight divided into three groups: Low level (0- 1m), mid-level (1- 3m), and high level (>3m). A negative correlation ( $r$ ) between butterfly abundance and flying height was observed by performing the Pearson correlation analysis (ESF  $r=-0.677$ , LSF  $r=-0.766$ ;  $p<0.05$ ). In LSF, the highest species richness recorded at the mid-level (DMg = 9.94), which has a good understory, while the species richness was higher in the low level (DMg = 7.61) of the ESF, which has a good ground vegetation. The species richness was lowest at the high level in both forest types (ESF DMg =4.18, LSF DMg = 5.71). Butterflies of the family Papilionidae preferred to fly at high levels, and family Lycaenidae butterflies were more abundant at low levels, which proves a positive correlation between flying height and wingspan. Flying height increased with the wingspan ( $r = 0.576$ ;  $p<0.05$ ). The main findings of this study highlight the variation of the butterfly assemblage and flying heights with the forest succession and resource availability.

**Keywords:** Vertical stratification, Butterfly flight, Forest succession, Resource availability

## 1. INTRODUCTION

### Diversity and Distribution of Butterflies

Butterflies (Order Lepidoptera) are a cosmopolitan distributed insect group with about 18,000 species recorded under seven families (Sarjan et al., 2014). Papilionidae, Pieridae, Lycaenidae, Nymphalidae, Riodinidae, Libytheidae, and Hesperidae are the recorded seven butterfly families. Nymphalidae is the largest family with over 7,000 species worldwide, followed by Lycaenidae (Heppner, 2008). The neotropical region records more butterfly species than in the tropical regions, with a species richness of about 7,700 (Marchiori and Romanowski, 2006). There are over 3,000

butterfly species that are yet to be identified mostly from tropical regions (Heppner, 2008).

Sri Lanka is a tropical island which located close to the southern India, in the main land of South Asia. Based on the rainfall and temperature, three main climatic zones had identified in Sri Lanka. Wet zone, Intermediate zone, and Dry zone are those main climatic zones. About 70% of the total area of the country belongs to the dry zone. Dry zone is in the northern, eastern, southern and north-west parts of the country. Wet zone located in the south-west part and the central highlands of the country. This area receives high rainfall and has a low annual mean temperature. The intermediate zone lies in between the wet zone and the dry zone.

However, high biodiversity confined to the wet zone of the island. Sri Lanka records 245 butterfly species in six families. However, no butterfly species from Family Libytheidae recorded from the country. There are 26 endemic butterfly species and 86 subspecies in the country (Van-der-Poorten, 2012). Most of the endemic and restricted butterflies recorded from the wet zone. However, widely distributed butterflies are common in the intermediate and dry zones. Also, it has unique habitats for some rare butterflies. Therefore, every climatic zone is important for the high butterfly diversity in the country.

### Stratification of Butterfly flight

The butterfly flight is stratified. Availability of nectar sources, larval feeding plants, and mating opportunities determine this stratification, as well as the flight distance and time. Except for exceptional circumstances such as migration and pre-copulation flight, butterflies always fly below the canopy. However, the butterfly diversity at the canopy level is more complex. Spitzer et al., (1993) recorded a more diverse and heterogeneous butterfly assemblage at the canopy level compared to the understory level. While searching the food, they locate the best source by flying from one to another. Females stay close to nectar resources while males spend more time on flight to find a good source.

Therefore, females spent less time on flight during feeding compared to males (Kingsolver, 1983). And they encounter more host plants while males find more mating opportunities (Beccaloni, 1997). Vertical stratification of butterfly flight had documented in previous studies. This stratification is sub-family specific in the Family Nymphalidae (De-Vries, 1988; De-Vries et al., 1997; De-Vries et al., 1999; De-Vries et al., 2010). Butterflies of the sub-family Charaxinae and Nymphalinae are dominant at the canopy level. And species of the sub-family Morphinae and Styrinae frequently recorded at the understory level. The occurrence of understory-dominating butterflies decreased with the vegetation height.

Further, a correlation between flight height with wing patterns and wing size in butterflies of the family Nymphalidae had recorded. Understory dwellers carry eyespot patterns in their wings, while canopy-preferring butterflies bear uniformly patterned wings (De-Vries, 1988; De-Vries et al., 1997; De-Vries et al., 1999; De-Vries et al., 2010; Houlihan et al., 2013). The composition and behaviour in a butterfly community depend on the habitat characters such as vegetation structure. Therefore, studying butterfly communities is a proxy to assess the quality of a habitat, especially in forest succession (Weerakoon and Ranawana, 2021). The current study conducted to determine the patterns in butterfly flight in different succession stages in a tropical forest and identify the vertical stratification of the butterfly flight.

## 2. MATERIALS AND METHODS

### Study Area

The study is conducted at the Maragamuwa Forest Regeneration Study Site (FRSS) (70 41' 39.16" N - 800 42' 31.58" E), which located near Maragamuwa village in Matale district, Sri Lanka. Maragamuwa FRSS is in the intermediate zone at 369 m above sea level. The mean annual rainfall was between 1750 mm and 2250 mm, and the mean yearly temperature was 27°C. The FRSS established in a 60-ha block of harvested *Eucalyptus* plantation, managed until 2005 by the Ceylon Tobacco Company (CTC). The west side of the FRSS borders the Kumaragala conservation forest and rest is surrounded by home gardens and cultivation lands. During the establishment of the plantation in late 1980, the natural forest tree seedlings established along the *Eucalyptus* plantation-natural forest edge.

As the forest seedlings grow well on the edge and the shading of the large trees in the natural forest, the *Eucalyptus* trees at the edge have thinned out, which has provided an ideal situation for natural forest tree species succession along the edge of the eucalyptus plantation. This *Eucalyptus*-natural forest edge had selected as a late secondary forest (LSF) for the study. After the timber harvest in 2005, the area has undergone a natural forest regeneration. Currently, the area has a rich understory layer with a good ground cover. Few tree species emerge through the understory and take part in spreading canopy. This forest block had selected as early secondary forest (ESF) for the study.

### Data Collection

The line transect method used to record butterfly abundance data. A total of ten transects established in two habitats; five transects in the ESF and five transects in the LSF. The length of the transect was 100 meters. 20 minutes spent in each transect to observe butterflies and the abundance and flight height of each butterfly recorded. They were identified to the species level by using standard guides (D'Abbrera, 1998). Morning hours spent monitoring butterflies when they were primarily active (Marchiori and Romanowski, 2006). Data was collected weekly for 24 months, from June 2013 to May 2015.

### Data analysis

Flight height data of each species used to identify the flying height range. Whiskers box plots prepared using these data. The flying height range of each species in ESF and LSF compared. Pearson correlation analysis conducted to check the relationship between the flying height and wing span. Butterfly wing span records collected from the literature (Gamage, 2013). Recorded butterfly flight heights divided into three groups: low height (0-1m), mid height (1-3m), and high height (>3m). Dominating species and families for each height level were identified from the abundance data. The Margalef index had used to calculate and compare the species richness at each level. Pearson correlation analysis performed to assess the relationship between flight height and abundance.

## 3. RESULTS

A total of 4,450 butterfly flying heights were recorded and assessed. The total number of butterfly species identified during the study was 100. In ESF, the highest butterfly abundance recorded at a lower level, and the lowest was recorded at a high level. However, in LSF, the highest butterfly abundance and species richness recorded at the mid-level, followed by the lower level. The lowest abundance and richness recorded at a high level (Tables 1 and 2). According to the Pearson correlation analysis, a negative correlation ( $r$ ) observed between butterfly abundance and flying height (ESF  $r=-0.677$ , LSF  $r=-0.766$ ). This decrease was statistically significant in both forest types ( $p<0.05$ ). All butterfly families except Nymphalidae demonstrated a precise vertical distribution in flying height.

The species richness was high in Nymphalid butterflies in all three height levels in both forest types. Butterflies of the family Pieridae dominated the high level in both forest areas, while family Nymphalidae dominated both mid and low levels. In the lower stratum butterfly community, Chestnut bob (*Iambrix salsala*) dominated the Hesperidae family, Tiny grass blue (*Zizula hylax*) was the most frequently recorded Lycaenid butterfly species, and White four-ring (*Ypthima ceylonica*) was the mostly recorded Nymphalid species. In the mid-stratum community, the Common Indian crow (*Euploea core*) was the dominating Nymphalid, while the Common albatross (*Appias albina*) and Lesser albatross (*Appias galene*) were the frequently recorded Pierid butterfly. Lemon emigrant (*Catopsilia pomona*) was the high stratum preferring Pierid species.

In ESF, species richness of all butterfly families except Papilionidae decreased with height. However, a higher Papilionid butterfly species richness was recorded near the canopy and sub-canopy level (at a higher stratum). Also, the abundance of the Pieridae butterflies increased with the height in the ESF (Table 1). However, both species richness and abundance were high in the mid-level in LSF followed by low level. The least abundance and species richness recorded at the high level in LSF (Table 2). Papilionid butterflies were more flight-specific than species of other butterfly families. They prefer to fly at high levels. Also, the height preference of pierid butterflies increases with height.

The spatial preference of butterfly species of the family Hesperidae and Riodinidae has not recorded, however overall, they preferred a low flight (Figure 1). The low level dominated by small butterfly species of the Family Lycaenidae. Nymphalid species are abundant in mid-level, and large Papilionidae species frequently recorded in high canopy. Whiskers box plot prepared to contrast and compare the flying regions of butterflies (Figures 2 and 3). Flying heights of butterflies in both forest types were used to prepare the whiskers box plots. Variations of each flying height recording contributed to the final position of the species in the stratum (Low height, Mid height, High height).

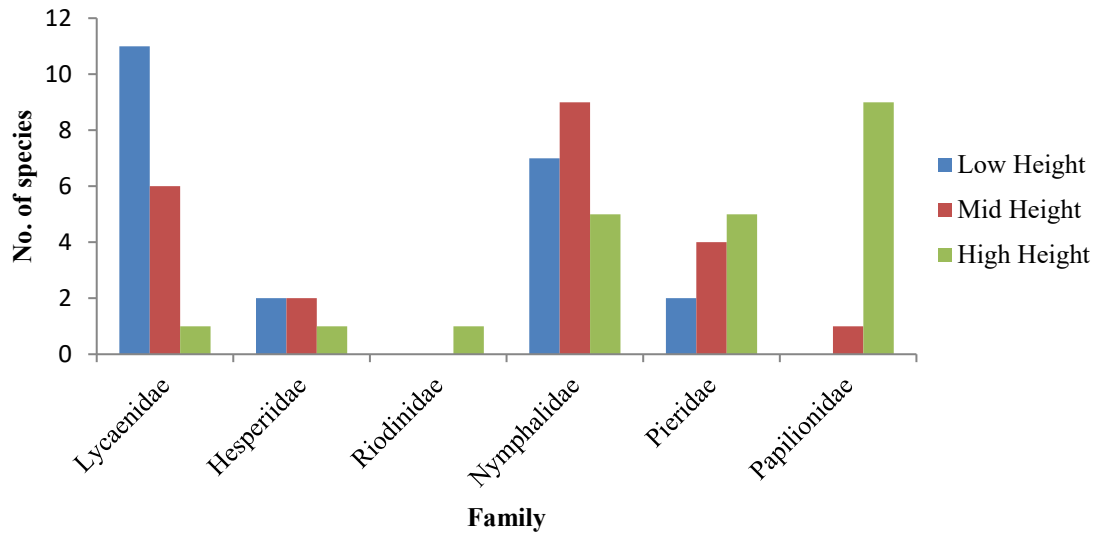


Figure 1 Species separation in between each stratum according to families

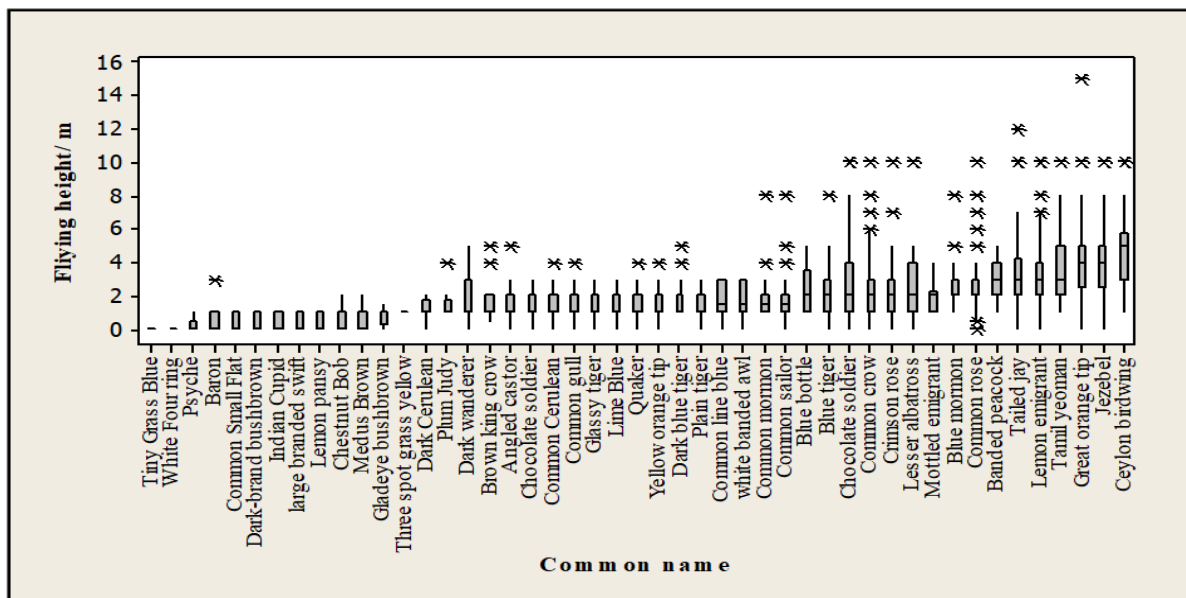
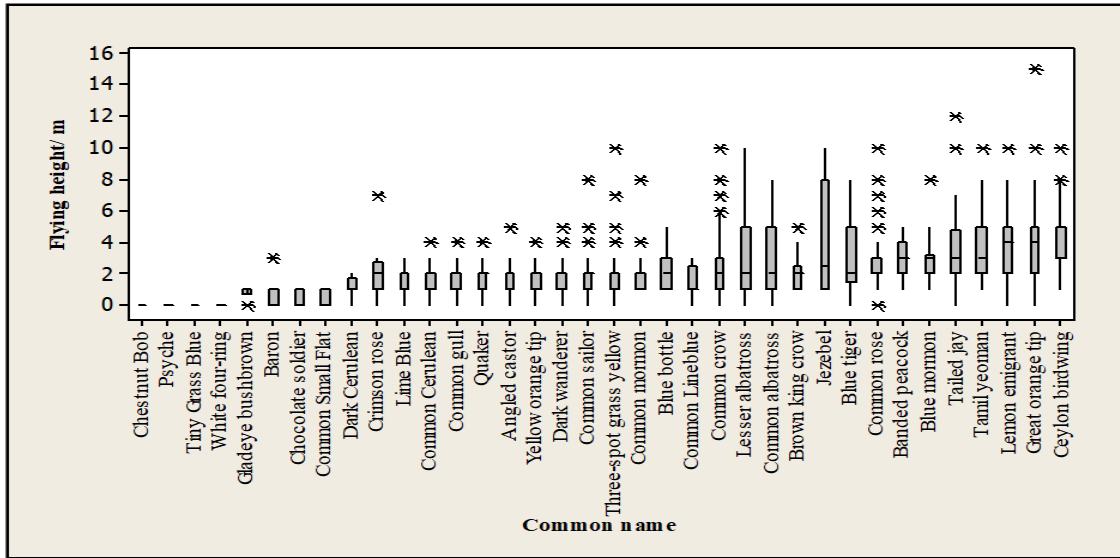


Figure 2 Whiskers box plot for recorded butterfly flight height at early secondary forest (Note: Graph contains only those species which had more than ten observations)

According to the Pearson correlation analysis, a positive relationship was identified ( $r= 0.576$ ) between flying height and wingspan. Species with short wings often recorded in the lower strata and the species with long wings frequently recorded in the upper stratum near canopy. This relationship is statistically significant ( $p<0.05$ ) (Table 2). In general, small butterflies fly in low height level and large butterflies prefer upper levels. But some species with high wingspans were more abundantly recorded in low flight heights (i.e., Brown king crow, *Euploea klugii*), while some species which had short wings compared to those species found in high flight levels (i.e., Common sailor, (*Neptis hylas*)), Angled castor (*Ariadne ariadne*).



**Figure 3** Whiskers box plot for recorded butterfly flight height at late secondary forest (Note: Graph contains only those species which had more than ten observations)

**Table 1** Vertical stratification of butterfly assemblage in ESF

Family	Low height		Mid height		High height	
	No. of species	No. of individuals	No. of species	No. of individuals	No. of species	No. of individuals
Hesperiidae	4	26	2	3	1	2
Lycanidae	16	289	4	24	1	3
Nymphalidae	20	860	13	318	8	160
Papilionidae	5	38	6	77	8	40
Pieridae	10	159	9	133	8	296
Riodinidae	1	2	0	0	1	1
Total	56	1374	34	555	27	502
(DMg)	7.61		5.22		4.18	

**Table 2** Vertical stratification of butterfly assemblage in LSF

Family	Low height		Mid height		High height	
	No. of species	No. of individuals	No. of species	No. of individuals	No. of species	No. of individuals
Hesperiidae	7	54	9	30	1	2
Lycanidae	11	149	15	155	5	30
Nymphalidae	15	172	23	395	11	109
Papilionidae	3	5	9	95	7	88
Pieridae	10	148	12	350	11	230
Riodinidae	0	0	1	7	0	0
Total	46	528	69	1032	35	459
(DMg)	7.34		9.94		5.71	

#### 4. DISCUSSION

Forest vegetation stratification is a typical character in tropical forests. Tropical forest vegetation stratified to the ground layer, understory, sub-canopy, canopy, and emergent layer. Some animal groups such as insects are highly dependent on the occurrence of plant species. Therefore, their assemblage also could be stratified according to the height. In rainforests, high insect abundance is recorded in the canopy (Hamer et al., 1997). Butterflies is one of a vital insect class in the ecosystem. They search for food and mates by flying from one place to another. Also, flight is important in escape from predators and harsh conditions. Kingsolver, (1983) stated that male butterflies spend more time on flight than females.

They show a more prolonged flight if the ambient temperature is optimal. Also, during mate locating and courtship activities, males spent longer durations on flight (Kingsolver, 1983). Vertical stratification of butterfly communities previously documented in some other regions of the world. In most of those studies, the space was divided into two strata, canopy and understory (De-Vries et al., 1997; De-Vries et al., 1999). However, in the current study butterfly flying space divided into three strata. The volume contained in each stratum differs from one another. The low level has the minimum space, while the high level has the highest. However, the highest butterfly abundance records at the low level.

This observation was proven by the long-term and large-scale study conducted by De-Vries et al., (1997) in a Neotropical rain forest in Ecuador. They recorded lower butterfly abundance in the canopy than in the understory. This abundance variation influenced by the population size. Small butterflies occur in high numbers, which dominate the low level. However, the population size of large butterflies was small. They are the dominating group in the higher levels. Therefore, butterfly abundance decreases towards higher heights. Thus, population size influences the community structure.

Nymphalidae is the global most prominent butterfly family. Nymphalid butterflies show a wide range of spatial stratification. In these species, the body size range is wide. Smaller species are prominent on the ground; larger butterflies fly over the vegetation, while most of the others fly at mid-range. Also, the habitat preferences of these species are different. Some species are more abundant in sunny areas, while some restricted to shady areas. Others have a slow flight at the close canopy, but some species have a fast flight at higher open levels. This high inter-species variation of a single family in a habitat had increased the potential of establishing a healthy community.

Most butterflies fly above the vegetation where their food plants are present. Frequently, they fly at a constant height except when resting and feeding. But during the courtship flight, butterflies show a higher flight than the normal. Butterflies choose nectar plants according to proboscis length and corolla tube length. In general, small butterflies prefer to feed on nectar from small herbs and plants. These are the main vegetation component in the low stratum and also in the ESF. They have very short proboscis length; therefore, they can feed only on flowers with short corolla tubes. However, large butterflies have a wide range of feeding plants. They prefer flowers with long corolla tubes. Shrubs and trees usually found in the mid and high strata and also in LSF have this floral character.

Hence, large butterflies fly at mid and high levels, whereas small butterflies fly at low levels. Wing patterns and wing colors facilitate the survival of butterflies in a particular stratum (De-Vries et al., 1999). Ground-dwelling butterflies have more dull-colored wings. The majority of these butterflies have brownish wings. Most of them bear spots on their wings. Also, butterflies of the Family Lycaenidae have metallic coloration in their wings. These color patterns support butterflies to camouflage in their habitat. But high-level flying butterflies often had colorful wings. They are very noticeable and highly vulnerable to predators such as birds while flying. However, these bright colors resemble that they are unpalatable and poisonous to their predators.

Therefore, the warning message providing by these colors help them to survive during the flight (De-Vries et al., 1999). Stratification in butterfly flight and the correlation with feeding habits and wing coloration are well documented in the Neotropical region. However, there is a gap for these kind of studies in tropical area. The current study will provide information to narrow this gap in Neotropical and Tropical regions. Further, this study highlights how butterfly flight changes with the vegetation structure of a habitat. Therefore, the current study will provide baseline information for more detailed future studies in the tropical region.

#### 5. CONCLUSION

Butterflies show a variation in their flight height. This variation highly correlated with the vegetation characters and the body size. Smaller butterflies fly close to the ground vegetation, is common in the forests at early stages of the succession. However, Larger and medium-sized butterflies were frequent in the understory level at later stages of the forest succession. Regardless of the forest

succession stage, butterflies preferred to fly below the canopy. This study provides evidence for the relationship between butterfly fly height and body size, as well as the fly height and the vegetation structure in tropical forests.

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### Authors Contribution

Buddhika Weerakoon: Research design, Data collection, Data analysis, Manuscript preparation

Kithsiri Ranawana: Research design, Manuscript preparation

### Ethical approval & declaration

In this article, as per the animal regulations followed in Department of Zoology, University of Peradeniya, Peradeniya, Sri Lanka, the authors assessed and compared the vertical stratification of butterfly flight in two forest types within the Maragamuwa forest regeneration study site (FRSS), Matale, Sri Lanka. The Animal ethical guidelines are followed in the study for species observation, identification & experimentation.

### Informed consent

Not applicable.

### Conflicts of interests:

The authors declare that there are no conflicts of interests.

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### Data and materials availability

All data associated with this study are present in the paper.

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