Article

Seasonality and movement patterns of butterflies in an intermediate zone regenerating forest habitat in Sri Lanka

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Received 6 June 2021; *Accepted 15 July 2021*; *Published 1 December 2021*

Abstract
The seasonality of butterflies in the intermediate zone of Sri Lanka was assessed by monitoring the abundance, diversity and occurrence of butterflies in Maragamuwa Forest Regeneration Study Site (FRSS), which consists of two forest types: moderately mature forest of 30 years age (refers as Late Secondary Forest-LSF) and much younger forest of 10 years old (refers as Early Secondary Forest-ESF). The highest butterfly abundance in FRSS was recorded in October to December followed by April to June. In ESF butterfly abundance and species richness were high in October to December (n=26) followed by March and April (n=25) which are the rainy seasons. But in LSF butterfly abundance and richness were high in May and June (n=43), which is the dry season. Most of butterflies recorded throughout the year, while some species recorded only in wet season. Two butterfly migratory seasons were identified in October and March. *Appias galane* and *Catopsilia pomona* were the main species migrate in October and *Appias albino* and *Cepora nerissa* migrated in March. The study had concluded that butterfly seasonality was associated with the climate; and the local movement of butterflies within adjoining forest habitats had caused the temporal variation of the community.

Keywords butterfly; abundance; diversity; forest regeneration; intermediate zone; temporal variation.

Arthropods
ISSN 2224-4255
URL: http://www.iaees.org/publications/journals/arthropods/online-version.asp
RSS: http://www.iaees.org/publications/journals/arthropods/rss.xml
E-mail: arthropods@iaees.org
Editor-in-Chief: WenJun Zhang
Publisher: International Academy of Ecology and Environmental Sciences

1 Introduction

Butterflies (Order Lepidoptera) are cosmopolitan distributed insect group with about 18,000 identified species by 2014 in seven families as Hedylidae, Hesperiidae, Lycanidae, Papilionidae, Pieridae, Nymphalidae and Riodinidae (Sarjan et al., 2014; Hasan et al., 2018; Patil et al., 2019; Haroon et al., 2021). Currently Sri Lankan butterfly fauna consists of 248 species in six families with 31 endemic species (Ministry of Mahaweli Development & Environment, 2019). No Hedylidae butterflies were recorded from Sri Lanka.

The variations in rainfall divide Sri Lanka into three climatic zones as wet, dry and intermediate. Wet zone and highlands of the country have an enriched biodiversity compared to the other parts (Gunawardene et al., 2007). Similarly, high butterfly diversity is also recorded in the wet zone and foot hills (Gamage, 2013).

Intermediate zone has a mixed and complex biodiversity, since it intercepts the characters of both wet and dry zones.

Seasonality in butterfly abundance of two adjoining habitats is different from each other. Variation of resource availability of each area could be the reason for this difference. Studies have shown that mature forests have high butterfly diversity in dry season. But the diversity is high in wet monsoon period in disturbed forests (Hamer et al., 2003, Martinez-Sanchez et al., 2020).

Temporal variation of butterfly diversity and abundance is well documented in the closest mainland, India. In North India highest butterfly abundance has been recorded in April to July and a short elevation in September (Qureshi et al., 2014; Sengupta et al., 2014). In Central India, high butterfly abundance was recorded from July to August (Tiple, 2012). In North East part of India butterfly abundance is maximum in August- September (Ruchi et al., 2012) and in Western India the butterfly abundance was high in June to November (Ganvir and Khaparde, 2018). The common character in this seasonality is all high abundances recorded during monsoon periods. But no long term study has been carried out to understand the seasonality in abundance and diversity of butterflies in Sri Lanka.

This study was designed to assess the butterfly community structure and temporal variation in adjoining forest patches undergoing different succession stages in Maragamuwa Forest Regeneration Study Site (FRSS) in Matale district, Sri Lanka located in the intermediate zone ($7^0$41'39.16" N - $80^0$42'31.58" E) of the country.

2 Materials and Methods

2.1 Location

Maragamuwa FRSS was established in 2005 in a harvested *Eucalyptus* plantation managed by Ceylon Tobacco Company (CTC) from 1980. The elevation of the FRSS is about 369 m above sea level, with mean annual rainfall of 1,750 mm to 2,250 mm, and a mean annual temperature of 27^0C. The western side of the study site is bordered by the natural forest (Kumaragala Forest Reserve, which is a conservation forest managed by the Forest Department of Sri Lanka) while the rest of the plantation is surrounded by the home gardens and slash and burn cultivation lands (Fig. 1). In 2005 CTC has initiated a biodiversity restoration project in Maragamuwa in order to understand the patterns of plant colonization, and factors influencing the development of forest and its associated biodiversity.

The 10 year old forest blocks undergoing natural regeneration was selected as Early Secondary Forest (ESF) to sample butterflies in this study. The vegetation structure of the ESF mainly consists of small trees and shrubs. The 30 year old *Eucalyptus* natural forest edge was selected as Late Secondary Forest (LSF). Vegetation structure of the LSF is more complex than ESF with the highest floral diversity over the mature forest and plantation (Alahakoon et al., 2006).

2.2 Data collection

Line transect method was used to collect butterfly abundance data. A total of ten transects of 100 meters long were established in two forest types, including five transects in each. Butterflies were observed for 20 minutes within each transect. All individuals visible were recorded except behind the recorder. Butterflies were identified in the field using color guide D'Abrera (1998). All field data was recorded in a pre-prepared data sheet. Morning hours were spent to monitor butterflies, as they are mostly active (Marchiori and Romanowski, 2006).

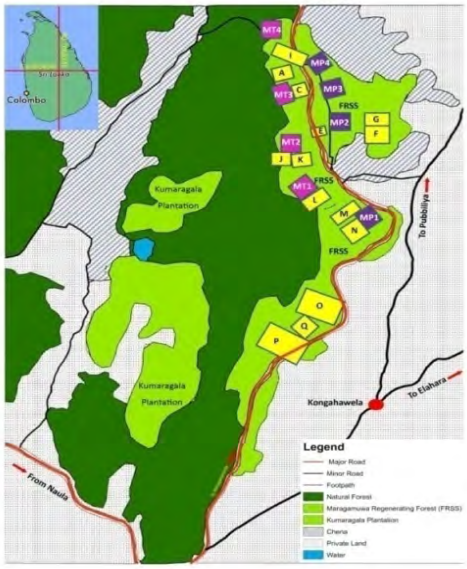

Fig. 1 Location and block map of the study area (Source: Ranawana et al., 2017).

2.3 Data analysis

Temporal variation in butterfly abundance was studied by comparing the monthly average abundance. Mean butterfly abundance was calculated using the following formula:

$$\text{Mean butterfly abundance} = \frac{\text{Total butterfly abundance of the month}}{\text{Number of sampling efforts of the month}}$$

Mean butterfly abundance was used to study the seasonality pattern. Temporal variation patterns of butterfly abundance and butterfly families inthe FRSS were identified and furthermore, patterns in two forest types were compared. The period of highest butterfly richness was identified by evaluating number of species recorded for months. Considering the availability of butterflies, seasonality of butterflies was identified. Furthermore, these periods were compared with the seasonality of rainfall. Component species for migratory seasons were assessed from the abundance data.

3 Results

During the study 53 sampling efforts were carried out for 24 months from June 2013. The survey resulted in recording a total of 5,438 butterflies belonging to 100 species in six families. Early Secondary Forest (ESF) had high butterfly abundance recording 2,963 individuals in 70 species in six families. Late Secondary Forest (LSF) also had high butterfly species richness (76 species) in six families with 2,475 individuals.

Highest butterfly abundance in FRSS was recorded in November followed by June, and the lowest butterfly abundance was recorded in August. Early of the wet season (October-December) and early dry season (May-June) had high butterfly abundance compared to the end of the dry season (August-September) (Fig. 2).

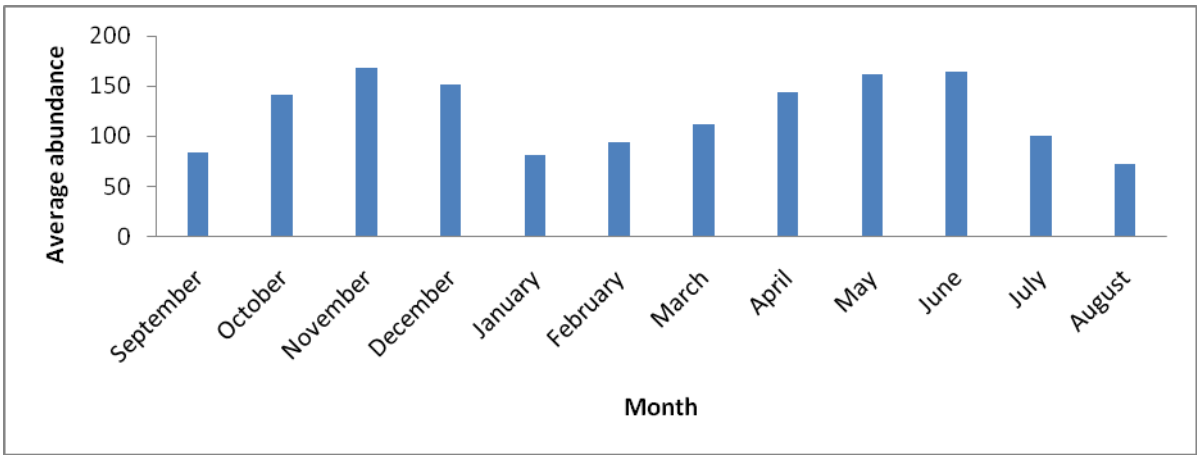

Fig. 2 Temporal variation of cumulative butterfly abundance of Maragamuwa FRSS.

Seasonality of butterflies was different in two forest areas. Highest butterfly abundance in ESF was recorded during November-December. These months are late months of the 2nd inter monsoon and the early months of north east monsoon. Second highest abundance was recorded during March-April period which is the 1st inter monsoon season. In LSF the highest butterfly abundance was recorded in June which is the dry season to the area (Fig. 3).

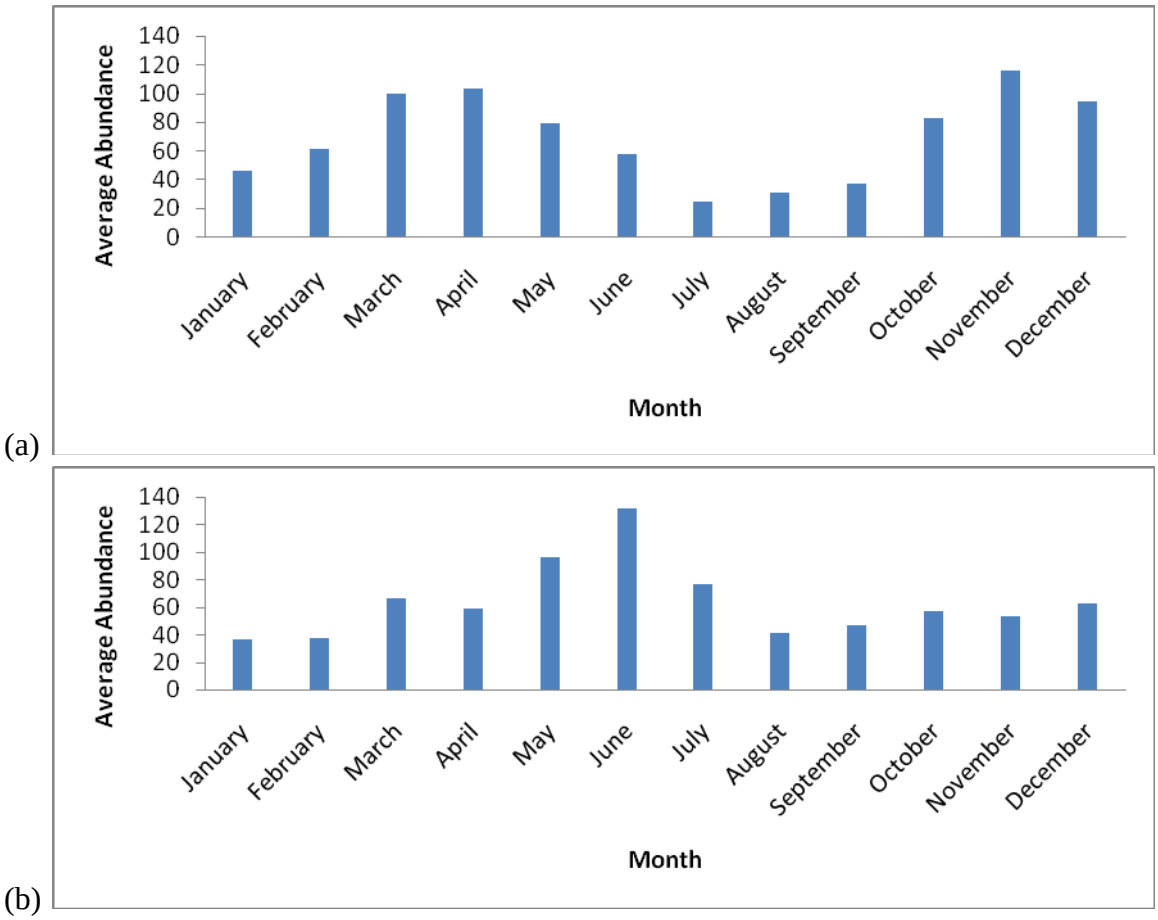

Fig. 3 Temporal variation in butterfly abundance (a) ESF (b) LSF.

In ESF lowest species richness was recorded in August, and the highest in November. Period from June to September had low species richness compared to the other months of the year. In LSF highest species richness was recorded from May and June; and lowest was recorded in December. April to August had high species richness compared to other months of the year (Table 1). During the dry season LSF had high species richness than ESF. But in wet season butterfly species richness was higher in ESF.

Table 1 Butterfly species richness in each month (from 2013 to 2015).

		Number of butterfly species	
Month	Season	ESF	LSF
December	North- East monsoon	27	10
January	(Wet season)	21	26
February		20	12
March	1st Inter monsoon	21	18
April	(Wet + Dry season)	26	31
May		23	43
June	South- West monsoon	17	43
July	(Dry season)	16	29
August		12	26
September		14	15
October	2nd Inter monsoon	25	22
November	(Wet season)	31	26

Most of the butterfly species mate in the wet and early dry seasons (October to May) (Table 2). Few butterfly species such as Plain tiger (*Danaus chrysippus*) mate during the late dry season. Mating season may be affected by the availability of larval host plants.

Table 2 Mating seasons of some butterfly species observed during the study period.

Common name	Mating season					
	Oct-Nov	Dec-Jan	Feb-Mar	Apr-May	Jun-Jul	Aug-Sep
Common crow (*Euploea core*)	+		+			
Plain tiger (*Danaus chrysippus*)	+					+
Angled castor (*Ariadne ariadne*)		+				
White four-ring (*Ypthima ceylonica*)	+			+		
Yellow orange tip (*Ixias pyrene*)				+		
Psyche (*Leptosia nina*)			+			
Lesser albatross (*Appias galane*)	+					
Common gull (*Cepora nerissa*)				+		

Some butterfly species were recorded throughout the year, but some species were present only in few months. Seasonality of occurrence was assessed using presence/absence data. Three main patterns were

identified. Some species were record throughout the year (Y), some species were record during the wet season (W) and some other species were recorded in dry period (D). Most of the species have shown same pattern in both ESF and LSF. But few species had shown a different seasonality. Furthermore, none of the butterfly species were recorded only in dry period at ESF. Also some species were recorded only in dry period at LSF, but they were recorded only in ESF at wet season (Table 3).

Table 3 Periods of occurrence of common butterfly species.

Name	LSF	ESF
Common crow (*Euploea core*)	Y	Y
White four-ring (*Ypthima ceylonica*)	Y	Y
Chocolate soldier (*Junonia iphita*)	Y	Y
Common sailor (*Neptis hylas*)	Y	Y
Common rose (*Pachliopta aristolochiae*)	Y	Y
Common mormon (*Papilio polytes*)	Y	Y
Lemon emigrant (*Catopsilia pomona*)	Y	Y
Lesser albatross (*Appias galane*)	Y	Y
Dark wanderer (*Pareronia ceylanica*)	Y	W
Angled castor (*Ariadne ariadne*)	Y	W
Tamil yeoman (*Cirrochroa thais*)	Y	W
Jezebel (*Delias eucharis*)	W	W
Crimson rose (*Pachliopta hector*)	W	W
Quaker (*Neopithicops zalmora*)	W	W
Brown Awl (*Badamia exclamationis*)	W	W
Psyche (*Leptosia nina*)	D	W
Chestnut Bob (*Iambrix salsala*)	D	W

There was a striking relationship between individual to species ratios and presence of butterfly families. Family Pieridae and Nymphalidae had high Individual: Species ratio (>50), and family Papilionidae, Lycanidae, Riodinidae, Hesperiidae had low individual: species ratio (<50) (Fig. 4). Families with high ratio had more common species with high abundance. But other families had more rare species with low abundance.

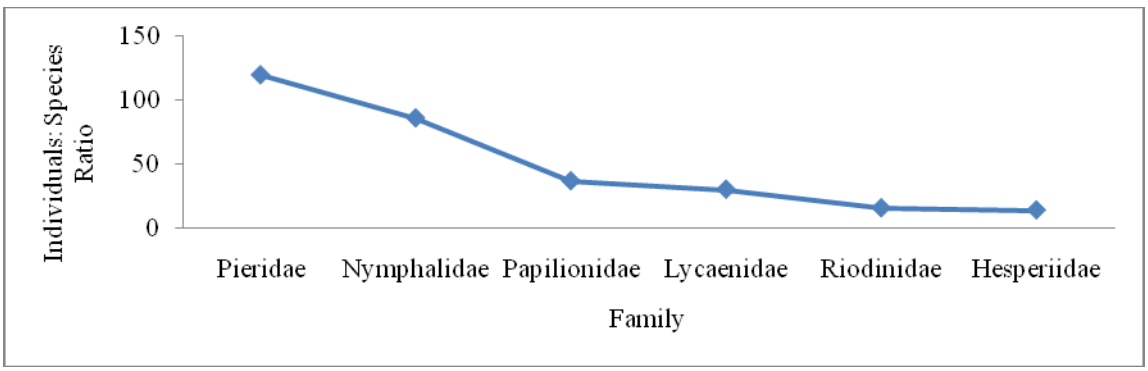

Fig. 4 Variation of Individuals: Species ratio of butterfly families in Maragamuwa FRSS.

Some butterfly species show a seasonal migration referred as 'uphill migration'. During uphill migration, thousands of Pierid butterflies fly from low elevations to high elevations. All migratory periods have been observed during the wet seasons. One migration in the 2nd inter monsoon season (major migration) and the other in the 1st inter monsoon season (minor migration) were observed. Of the recorded four migratory Pieridae butterflies, two species have shown uphill migration during major migration and two species in minor migration (Table 4).

Table 4 Migratory seasons of migrating butterfly species.

Species	Migratory period	
	Major migration (2nd inter monsoon)	Minor migration (1st inter monsoon)
Lesser albatross (*Appias galane*)	*	
Lemon emigrant (*Catopsilia pomona*)	*	
Common albatross (*Appias albino*)		*
Common gull (*Cepora nerissa*)		*

The size of the local population of those migratory species increased during migratory seasons, but reduced back to an average level in non-migratory season (Fig. 5).

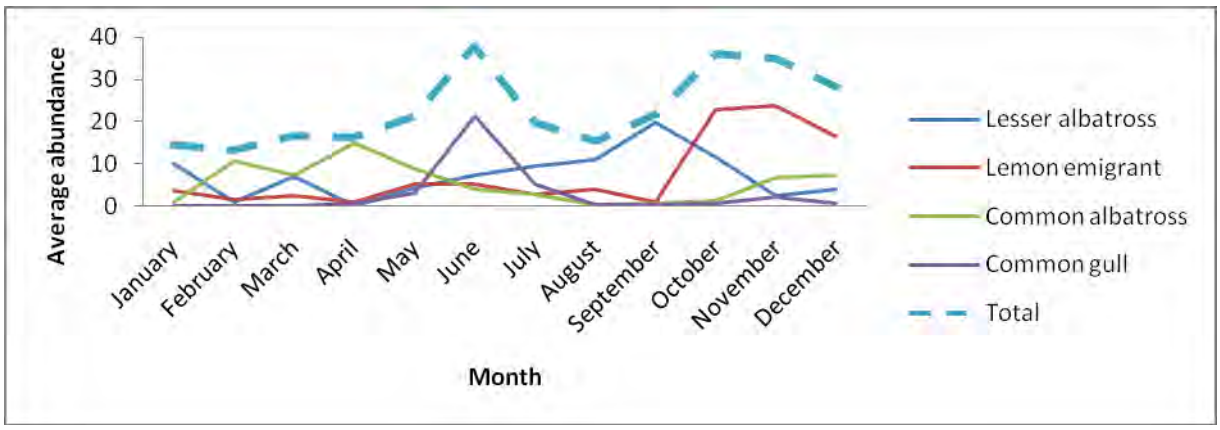

Fig. 5 Temporal variation in abundance of migratory butterfly species.

4 Discussion

Temporal variation of abundance can be defined as the average deviation of values from a mean value on a proportional scale (Gaston and McArdle, 1994). This is depending on available resources, life history and breeding seasons. Even though butterflies produce large number of eggs; conversion to an adult is low. The average life span of adults is also short due to the high predatory pressure. Thus, butterflies tend to mate once they receive favorable conditions. With the high plant growth rate in the rainy seasons, butterflies get more larval and adult food resources. Caterpillars prefer these fresh leaves over mature leaves (Dannis et al., 2004). Therefore, most of the butterflies mate in early rainy season and adult population increases during rainy season.

Furthermore, many plants start flowering with the rains. These flowers attract local butterflies providing nectar as a gift and get pollinated. *Lantana camera*, *Eupatorium* sp. were some invasive shrubs that were commonly found in ESF. These plants have more flowers than native plants, which can attract more butterflies. Furthermore, petal color of these invasive plants also attracting butterflies. Plants such as *Lantana camera* contain flowers with several bright colors. It is scientifically proven that bright colors such as red, yellow and orange can attract butterflies (Sourakov et al., 2012). As a result of this, elevated butterfly abundance could be recorded in rainy seasons (Qureshi et al., 2014; Ruchi et al., 2012; Sengupta et al., 2014; Tiple, 2012).

Some butterfly species are territorial (Gamage, 2013; Leimar et al., 2003). They do not fly great distances for resources and depend on the available resources in their range. These species remains in the ESF during the dry season also. They are the main components of the butterfly community in ESF during the dry season.

The dominating vegetation of the ESF is understory with shrubs and herbs. The floral count is high in those compared to large trees. Therefore, the vegetation structure of ESF supports to high butterfly abundance during rainy seasons. But with the short life span and less tolerance to harsh conditions, these herbs and shrubs get dried during the dry season, which reduce food resources to local butterfly community. During the dry season those butterflies disperseto nearby LSF, consisting of much mature trees. This finding had proven by different studies across the tropical region stating butterfly diversity was high in undisturbed forests during dry period, but in wet monsoon period diversity was high in disturbed forests (Hamer et al., 2003; Martinez-Sanchez et al., 2020).

Mating frequency and longevity of life span determine the presence of butterflies throughout the year. Butterflies have a life cycle with four main morphological distinct stages as egg, caterpillar, pupa, and adult (Revathy and Mathew, 2014). Duration of each stage differs from species to species, but as an average, complete life span of a butterfly species is two to three months. Therefore, most of butterfly species have several generations for a year. Harsh environmental conditions affect the survival of butterflies as well as the growth rate of larval stages. Several studies have proven that butterfly egg maturation and larval growth is increased with the ambient temperature in cold seasons in temperate region (Gotthard et al., 2000; Berger et al., 2008). But current study showcases the adverse effect of temperature on the butterfly life span in tropical region.

When the environmental conditions are not favorable for the survival of the organisms in the habitat, they disperse to other areas (Kwon et al., 2013). Mass dispersion of organisms for the same direction was known as migration. As other organisms, some species of butterflies also migrate to areas of favorable environmental conditions to safeguard their future populations. Majority of the migratory individuals are males (Mathew and Binoy, 2002). In Sri Lanka butterflies migrate from dry areas to wet and intermediate zones (Van der Poorten, 2012). The butterfly abundance was high in the ESF, which has more nectar resources during these uphill migratory seasons occurring in the wet periods.

5 Conclusion

Butterflies show seasonality on occurrence and diversity. Their abundance and diversity increase with favorable environmental conditions. Rainfall is the main climatic factor affecting the vegetation. Thus, butterflies show a clear seasonality with the rainfall with high abundance and diversity in the wet season. The seasonality of resource availability of different forest types in several succession stages is different. Butterfly community structure changes with this resource availability of the habitat. Some butterfly species show migratory behavior to overcome these harsh conditions of the habitats.

Acknowledgements

Authors would like to acknowledge University of Peradeniya for providing financial support for the study by awarding 'Gate mudliyar A. G. Thilakaratne research fellowship'. The authors have declared that no competing interests exist.

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