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COMMUNICATION

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Aditya Pradhan & Sarala Khaling

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COMMUNICATION

Butterfly diversity in an organic tea estate of Darjeeling Hills, eastern Himalaya, India

Aditya Pradhan [1] & **Sarala Khaling** [2]

[1,2] Ashoka Trust for Research in Ecology and the Environment, Regional Office Eastern Himalaya-Northeast India, NH 10 Tadong, Gangtok, Sikkim 737101, India.
[1] aditya.pradhan@atree.org (corresponding author), [2] sarala.khaling@atree.org

Abstract: The study was undertaken from March–May 2019 to explore the butterflies in the human-modified tea dominated landscape of Darjeeling Hills and understanding the diversity, community structure, habitat specialization, and conservation status of butterflies in an organic tea estate. Sampling was done in the two representative ecosystems of tea plantation and secondary forest within the study area. Altogether 71 species and sub-species across 43 genera belonging to five families were recorded during this study, of which seven are protected under the Wildlife (Protection) Act of India, 1972.

Keywords: Lepidoptera, secondary forest, species richness, tea plantation.

Abbreviations: TP—Tea Plantation, SF—Secondary Forest, FI—Forest Interior, FE—Forest Edge, OL—Open Land.

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Author details: Aditya Pradhan is currently involved as a Senior Project Fellow with Ashoka Trust for Research in Ecology and the Environment, Regional Office Eastern Himalaya-Northeast India. He has keen interest in biodiversity of Darjeeling-Sikkim Himalaya, and is currently working on the assessment of ecosystem services in the socio-ecological landscape of Darjeeling-Sikkim Himalaya. Sarala Khaling is the Regional Director at Ashoka Trust for Research in Ecology and the Environment, Regional Office Eastern Himalaya-Northeast India. Trained as a wildlife biologist/ecologist Dr. Sarala Khaling, has worked for the past 15+ years in biodiversity conservation and ecosystem services. Her research interests are looking at drivers of change in human-modified landscapes and its impacts on biodiversity and ecosystem services in Northeast India and North Bengal.

Author contribution: Funding for the study was acquired by SK. The study was conceptualized and designed by AP and SK. Data was collected and analyzed by AP. The manuscript was prepared and finalized by AP and SK.

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INTRODUCTION

Tea plantation is one of the important agro-ecosystems based on agroforestry practices in tropical landscapes (Tscharntke et al. 2008). Tea estates in Darjeeling practice shade tea cultivation which includes diverse shade trees of native species (Chettri et al. 2018a). This with surrounding forest patches have a high potential of maintaining biodiversity (Lin et al. 2012; Sreekar et al. 2013; Ahmed & Dey 2014) than monoculture tea plantations (Soh et al. 2006) or abandoned tea plantations (Subasinghe & Sumanapala 2014). Some studies conducted in monoculture tea plantations have shown that tea plantations have lower potential to maintain biodiversity when compared to forests (Ahmed & Dey 2014) and other agroforestry ecosystems such as home gardens (Yashmita-Ulman et al. 2016) but higher than Eucalyptus plantation monocultures (Kottawa-Arachchi & Gamage 2015) and agro-silviculture systems (Yashmita-Ulman et al. 2016).

In Darjeeling, tea plantation started in 1841 (Darjeeling Tea 2020). The first tea garden was established in 1856 by the Kurseong and Darjeeling Tea Company. Currently, there are 87 tea estates covering an area of 17,542 hectares of land (Datta 2010) or 20% of the land of Darjeeling Hills; 51 of the 87 tea estates in Darjeeling have been certified organic (data collected from Tea Research Association, Darjeeling). While a few studies have been undertaken to explore the diversity of birds in the tea landscapes of the region (Ahmad & Yahya 2010; Chettri et al. 2018a), no studies on butterflies has been undertaken till date.

Butterflies play an important role in supporting global food supply as pollinators (Losey & Vaughan 2006; Lindström et al. 2018) and are considered to be good indicators of ecosystem health, as they are very sensitive to small environmental variations and changes in forest structures (Pollard 1977). This taxon is vulnerable due to their response to changing habitat, climatic conditions, land-use patterns, and management intensity (Thomas 2005; Rundolf et al. 2008; Zingg et al. 2018).

Butterflies of Darjeeling-Sikkim Himalaya has attracted eminent naturalists and entomologists since the 19th century. In recent years, systematic studies on butterflies have increased in Sikkim (Acharya & Vijayan 2011, 2015; Chettri 2015; Chettri et al. 2018b; Sharma et al. 2020), however, only a few studies (Roy et al. 2012; Sengupta et al. 2014) have been conducted in Darjeeling hills (including Kalimpong). A total of 689 species have been reported to occur in Darjeeling-Sikkim Himalaya (Haribal 1992), which is 51.76% of total butterfly species recorded in India (Varshney & Smetacek 2015; Kehimkar 2016).

The organic tea estates of Darjeeling are expected to maintain a higher richness of butterflies as lower use of chemical insecticides and weedicides have been reported to have a positive impact on the diversity and abundance of butterflies (Rands & Sotherton 1986; Rundlof et al. 2008; Muratet & Fontaine 2015). Thus, the study aims to explore the conservation potential of butterflies in the human-modified tea dominated landscape by understanding the diversity, community structure, habitat specialization, and conservation status of butterflies in an organic tea estate of Darjeeling Hills. The study makes an effort to compare the species richness of tea plantation with that of the secondary forest, thus providing insights on species assemblages within the two representative ecosystems of a typical tea estate in Darjeeling, West Bengal. The study further adds to the limited existing literature on butterflies of Darjeeling Hills, Eastern Himalaya.

MATERIALS AND METHODS

Study Area

This study was conducted in Makaibari Tea Estate in the Kurseong sub-division of Darjeeling District, West Bengal, India (Figure 1A–C). It has an area of 248 hectares, of which 70% is covered by forest, which acts as a barrier to the scorching winds from the plains of Bengal (Makaibari 2020). The tea estate was established in 1859 and became the first tea estate to be certified organic in 1988 (Makaibari 2020). The entire tea estate located in an elevation range of approximately 400–1,100 m practices organic tea cultivation and is one of the lowest elevation tea estates of Darjeeling hills.

Two representative ecosystem types were selected for the present study (Image 1–6):

Tea Plantation (TP): Tea plantation represents an area where small-leaved Chinese variety of tea, *Camelia sinensis* var. *sinensis* that reaches a height of 0.5–1 m are grown (Datta 2010) with uniformly interspaced shade trees that include *Schima wallichii*, *Cryptomeria japonica*, *Albizia procera*, *Alnus nepalensis*, *Syzygium nervosum*, *Exbucklandia populnea*, *Eurya japonica*, *Ficus religiosa*, and *Ficus benghalensis* (Chettri et al. 2018a).

Secondary Growth Forest (SF): Makaibari Tea Estate has areas covered with a semi evergreen forest where tea is not planted. This forest acts as a barrier/wind break and also has numerous water bodies. Vegetation in these areas is dominated by species consisting of *Acer*

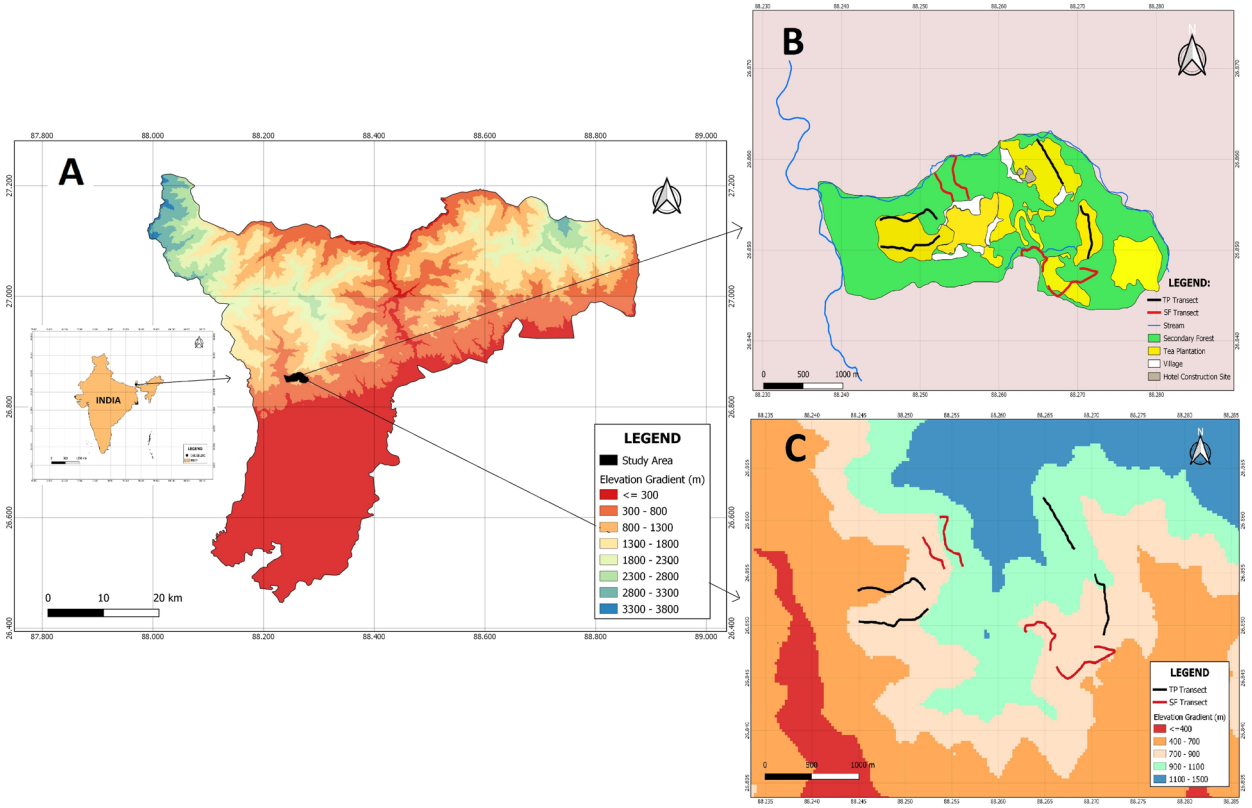

Figure 1. A—the location of Darjeeling and the study area within, along an elevation gradient | B—the study area showing Secondary Forest (SF), Tea Plantation (TP), SF Transects, TP Transects, Streams, and Villages of Makaibari Tea Estate, Darjeeling Hills, Eastern Himalaya, India | C—the study area showing SF Transects, TP Transects along an elevation gradient.

oblongum, Schima walichi, Shorea robusta, Terminalia myriocarpa, Eriobotrya bengalensis, Magnolia pterocarpa, Acer campbelli, Tetrameles nudiflora, Prunus nepalensis, Bombax ceiba, and mixed bamboo groves.

Study Design and Sampling

Eight trails were selected as transects (four each) in two representative ecosystem types (Figure 1B–C). The transects were approximately 1km in length and approximately 3m in width. Sampling was carried out twice in each transect during the pre-monsoon season from March to May 2019 on clear sunny days mostly between 09:00–15:00 h when butterfly activity is at its highest. Butterflies were sampled using the transect walk method (Pollard 1977; Acharya & Vijayan 2015) along the selected transects.

Following Kitahara (2004), points along transects were divided into three habitat classes: Forest Edge (FE), Open land (OL), and Forest Interior (FI). Points with forest on both sides were considered as FI sites, points with forest on one side and open land on the other as FE sites, and a point with open land on both sides as OL sites. Here open land refers to areas which do not have canopy cover in both TP and SF transects, and these represented either tea plantation sites or degraded forest sites.

Butterflies were photographed and identified using standard field guide (Kehimkar 2016), and online web resources (www.ifoundbutterflies.org). Species that could not be identified were photographed and shown to experts for identification. An effort was made to use the latest nomenclature and common names as far as possible as per Varshney & Smetacek (2015), Kehimkar (2016), and website on Indian butterflies (www.ifoundbutterflies.org).

RESULTS

A total of 71 species across 43 genera belonging to five families, were recorded in the Makaibari Tea Estate during this study (Table 1). The observed butterflies belonged to five families (Figure 2) namely, Hesperiidae (five genera, seven species), Papilionidae (three genera, nine species), Lycaenidae (seven genera, eleven species), Pieridae (nine genera, 12 species) and Nymphalidae (20

Image 1. Landscape view of the study area.

Image 2. Non-perennial stream within the secondary forest.

Image 3. Tea plantation site.

Image 4. Tea plantation and surrounding secondary forest.

Image 5. Secondary forest.

Image 6. Tea plantation site with interspersed shade trees.

genera, 32 species). As shown in Table 1, Nymphalidae (40.81%) with 20 species, Lycaenidae (20.40%) with 10 species, Pieridae (12.24%) with six species, Papilionidae (6.12%) with three species, and Hesperiidae (12.24%) with six species were observed in TP. In the SF, Nymphalidae (53.48%) with 23 species, Lycaenidae

(4.65%) with two species, Pieridae (18.60%) with eight species, Papilionidae (20.93%) with nine species and Hesperiidae (2.32%) with one species were observed (Images 7–16).

The species richness was higher in TP area (49 species, 69.01%) than in SF (43 species, 60.56%). Among the 71 species recorded, 21 species were common to both the habitats, while the rest were exclusively observed either in TP or SF (Figure 3). Among the 21 common species, 11 belonged to family Nymphalidae, six to Pieridae, three to Papiloinidae, and one to Lycaenidae.

Based on habitat classification along each transect, butterflies were observed to utilize all the three habitat classes, with the highest diversity recorded in forest edges (44 species), followed by open land (38 species), and forest interior (29 species). A number of recorded species (26 out of 71 species) , however, were observed to utilize more than one habitat class (Table 1).

Out of the 71 species of butterflies observed in the present study, seven (one species under Schedule I, three species under Schedule II, and three species under Schedule IV) species, namely, *Jamides caerulea*, *Lampides boeticus*, *Euploea klugii klugii*, *Euploea mulciber*, *Neptis sankara*, *Melanitis zitenius gokala*, and *Papilio bootes* are protected in India under the Wildlife (Protection) Act, 1972 (Table 1). Two among these were observed in both TP and SF, while the remaining five were observed only in one of the two representative ecosystem types (two each in TP and SF). Among the protected species four species belonged to Nymphalidae, two to Lycaenidae, and one to Papilionidae (Table 1).

Based on the categorization of Kehimkar (2016), four of the 71 species observed in the present study were rare (Table 1).

Himalayan Spotted Flat *Celaenorrhinus munda*

This species was observed in a FE site (26.856°N & 88.254°E) in SF-transect at an elevation of 870m in March. The site is close to human settlements, and the observed individual was seen feeding on the nectar of Azalea flowers. These butterflies are known to prefer forests at elevations of up to 2,000m (Kehimkar 2016).

Scarce Banded Flat *Celaenorrhinus badia*

This species was observed in an OL site (26.851°N & 88.248°E) in TP-transect at an elevation of 790m in May. The observed individual was perched on the underside of a leaf of a shrub within the tea plantation area. These butterflies have been observed in forests of up to 500m (Kehimkar 2016).

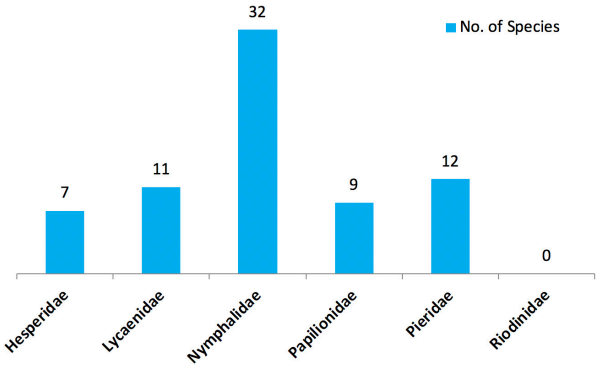

Figure 2. Family-wise distribution and the number of recorded species in Makaibari Tea Estate, Darjeeling Hills.

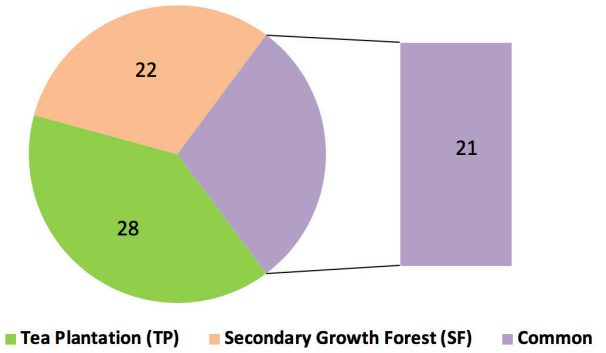

Figure 3. Number of species encountered exclusively in the two ecosystem types (namely, Tea Plantation and Secondary Forest) and the number of species that were common to both the ecosystem types.

Royal Cerulean *Jamides caerulea*

This species was observed in an OL site (26.851°N & 88.246°E) in TP-transect at an elevation of 780m in April. The observed individual was seen feeding on the nectar of a flowering herb within the tea plantation area. These butterflies have been observed in forests of up to 500m (Kehimkar 2016).

Krishna Peacock *Papilio krishna*

This species was observed in a FI site (26.857°N & 88.255°E) in SF-transect at an elevation of 920m in May. The observed individual was seen basking on a leaf within the forest. These butterflies have been observed in forests of up to 900–3,000 m (Kehimkar 2016).

DISCUSSION

During this study, 10.30% of the total butterflies reported from Darjeeling-Sikkim Himalaya (Haribal 1992) were recorded from the two representative

Table 1. Checklist of butterflies recorded in Makaibari Tea Estate.

Common name	Scienntific name	Family	*Ecosystem type	#Habitat	Wildlife (Protection) Act, 1972	Status category (Kehimkar 2016)
Chestnut Bob	*Iambrix salsala*	Hesperiidae	TP	FE		Common
Common Red Eye	*Matapa aria*	Hesperiidae	TP	FE		Common
Common Small Flat	*Sarangesa dasahara*	Hesperiidae	TP	FE		Common
Common Spotted Flat	*Celaenorrhinus leucocera*	Hesperiidae	TP	FE		Common
Detached Dart	*Potanthus trachala*	Hesperiidae	TP	FE		Common
Himalayan Spotted Flat	*Celaenorrhinus munda*	Hesperiidae	SF	FE		Rare
Scarce Banded Flat	*Celaenorrhinus badia*	Hesperiidae	TP	OL		Rare
Royal Cerulean	*Jamides caerulea*	Lycaenidae	TP	OL	Schedule II	Rare
Silver Forget-me-not	*Catochrysops panormus*	Lycaenidae	TP	OL		Uncommon
Forget-me-not	*Catochrysops strabo*	Lycaenidae	TP	OL		Common
Purple Sapphire	*Heliophorus epicles*	Lycaenidae	TP, SF	OL + FE + FI		Common
Common Cerulean	*Jamides celeno*	Lycaenidae	TP	FE		Common
Pea Blue	*Lampides boeticus*	Lycaenidae	TP	OL	Schedule II	Common
Bhutya Lineblue	*Prosotas bhutea*	Lycaenidae	SF	OL		Uncommon
Tailless Lineblue	*Prosotas dubiosa*	Lycaenidae	TP	OL		Common
Common Lineblue	*Prosotas nora*	Lycaenidae	TP	OL		Common
Pale Grass Blue	*Pseudozizeeria maha*	Lycaenidae	TP	OL		Common
Dark Grass Blue	*Zizeeria karsandra*	Lycaenidae	TP	OL		Common
Banded Treebrown	*Lethe confusa*	Nymphalidae	SF	FE + FI		Common
Blue King Crow	*Euploea klugii klugii*	Nymphalidae	SF	FI	Schedule IV	Uncommon
Striped Blue Crow	*Euploea mulciber*	Nymphalidae	SF	FI	Schedule IV	Common
Broad-banded Sailer	*Neptis sankara*	Nymphalidae	TP	OL + FE	Schedule I	Uncommon
Brown King Crow	*Euploea klugii kollari*	Nymphalidae	SF	FE + FI		Common
Chestnut Tiger	*Parantica sita*	Nymphalidae	TP, SF	OL + FE + FI		Uncommon
Chocolate Pansy	*Junonia iphita*	Nymphalidae	TP	OL + FE		Common
Chocolate Tiger	*Parantica melaneus*	Nymphalidae	TP, SF	OL + FE + FI		Common
Clear Sailer	*Neptis clinia susruta*	Nymphalidae	TP, SF	FE		Uncommon
Common Crow	*Euploea core*	Nymphalidae	TP, SF	OL + FE + FI		Common
Common Jester	*Symbrenthia lilaea*	Nymphalidae	SF	FE		Common
Common Lascar	*Pantoporia hordonia*	Nymphalidae	SF	FI		Common
Common Sailer	*Neptis hylas*	Nymphalidae	TP, SF	OL + FE + FI		Common
Common Three Rings	*Ypthima asterope*	Nymphalidae	TP, SF	OL + FE + FI		Common
Dark Evening Brown	*Melanitis phedima*	Nymphalidae	TP, SF	FE + FI		Uncommon
Glassy Tiger	*Parantica aglea*	Nymphalidae	TP, SF	OL + FE + FI		Common
Great Evening Brown	*Melanitis zitenius gokala*	Nymphalidae	TP	FE	Schedule II	Uncommon
Himalayan Sailer	*Neptis mahendra*	Nymphalidae	TP, SF	FE		Uncommon
Indian Fritillary	*Argyrnnis hyperbius*	Nymphalidae	TP	OL + FE		Common
Indian Tortoiseshell	*Aglais caschmirensis*	Nymphalidae	TP	OL		Common
Large Yeoman	*Cirrochroa aoris*	Nymphalidae	SF	FI		Common
Lemon Pansy	*Junonia lemonias*	Nymphalidae	TP	OL + FE		Common
Leopard Lacewing	*Cethosia cyane*	Nymphalidae	SF	FI		Common
Autumn Leaf	*Doleschallia bisaltide*	Nymphalidae	TP	FE		Uncommon
Orange Staff Sergeant	*Athyma cama*	Nymphalidae	SF	FI		Uncommon

Common name	Scienntific name	Family	*Ecosystem type	#Habitat	Wildlife (Protection) Act, 1972	Status category (Kehimkar 2016)
Plain Tiger	*Danaus chrysippus*	Nymphalidae	SF	FI		Common
Popinjay	*Stibochiona nicea*	Nymphalidae	TP, SF	OL + FE + FI		Common
Powdered Baron	*Euthalia monina*	Nymphalidae	SF	FE		Common
Small Jewel Four-Ring	*Ypthima singala*	Nymphalidae	TP	OL		Uncommon
Straight-banded Treebrown	*Lethe verma*	Nymphalidae	SF	FE		Common
Yellow Coster	*Acraea issoria*	Nymphalidae	TP, SF	OL + FE + FI		Common
Black Prince	*Rohana parisatis*	Nymphalidae	TP	OL		Common
Common Birdwing	*Troides helena*	Papilionoidae	SF	FE		Uncommon
Common Bluebottle	*Graphium sarpedon*	Papilionoidae	SF	OL		Common
Common Mormon	*Papilio polytes*	Papilionoidae	SF	FE		Common
Common Peacock	*Papilio bianor*	Papilionoidae	TP, SF	FE + FI		Uncommon
Krishna Peacock	*Papilio krishna*	Papilionoidae	SF	FI		Rare
Paris Peacock	*Papilio paris*	Papilionoidae	SF	FE		Uncommon
Red Helen	*Papilio helenus*	Papilionoidae	TP, SF	OL + FE		Common
Tailed Redbreast	*Papilio bootes*	Papilionoidae	TP, SF	OL + FE + FI	Schedule II	Uncommon
Yellow Helen	*Papilio nephelus*	Papilionoidae	SF	FI		Uncommon
Chocolate Albatross	*Appias lyncida*	Pieridae	TP, SF	OL + FE + FI		Uncommon
Common Grass Yellow	*Eurema hecabe*	Pieridae	TP	OL		Common
Common Gull	*Cepora nerissa*	Pieridae	TP	OL		Common
Great Orange Tip	*Hebomoia glaucippe*	Pieridae	TP	FE		Common
Indian Cabbage White	*Pieris canidia*	Pieridae	TP, SF	OL + FE + FI		Common
Large Cabbage White	*Pieris brassicae*	Pieridae	TP, SF	OL + FE		Common
Lesser Gull	*Cepora nadina nadina*	Pieridae	TP, SF	OL + FE + FI		Uncommon
Psyche	*Leptosia nina*	Pieridae	TP	OL		Common
Red Base Jezebel	*Delias pasithoe*	Pieridae	SF	FE + FI		Uncommon
White Orange Tip	*Ixias marianne*	Pieridae	TP, SF	OL + FE		Common
Yellow Jezebel	*Delias agostina*	Pieridae	SF	FI		Uncommon
Yellow Orange Tip	*Ixias pyrene*	Pieridae	TP, SF	OL + FE + FI		Common

*Ecosystem type: TP = Tea Plantation; SF = Secondary Forest.
#Habitat specialization: FI (Forest interior only), FI+FE (Forest interior + Forest edge), FE (Forest edge only), FE + OL (Forest edge+ Openland), OL (Openland only), OL + FE + FI (Open Land + Forest interior + Forest edge).

ecosystems in Makaibari Tea Estate, Darjeeling Hills. Moreover, the present study only provides pre-monsoon diversity of butterflies and did not cover the monsoon and post-monsoon seasons when the butterflies are most abundant in India (Kunte et al. 1999; Acharya & Vijayan 2015; Chettri 2015). Thus the total number of butterflies found in the area may be much higher than what is reported in this study.

The highest number of encountered species belonged to Nymphalidae, which is the most dominant family in the tropical region, including the forests and human-modified systems of Darjeeling-Sikkim Himalaya (Acharya & Vijayan 2015; Chettri 2015; Chettri et al. 2018b; Sharma et al. 2020). This suggests that the trend is followed even in tea estates.

The study conducted in the pre-monsoon season showed a rich diversity of butterflies within a small spatial gradient. This was expected as shade-tea cultivation with surrounding forest patches are reported to have the potential to maintain biodiversity (Lin et al. 2012; Sreekar et al. 2013; Ahmed & Dey 2014; Bora & Meitei 2014), as is the case with the present study area. Furthermore, the study area is a certified organic tea estate, uses no chemical pesticides or insecticides (Makaibari 2020), and was thus expected to maintain a higher richness of butterflies owing to its organic farming strategy (Rands & Sotherton 1986; Rundlof et al. 2008; Muratet & Fontaine 2015). Thus the findings of the

study add to the existing literature on retention of high biodiversity, and conservation potential of butterflies in organic agroecosystems of the region (Rundlof et al. 2008; Sharma et al. 2020).

The results showed that the butterfly communities in the two representative ecosystems showed assemblage of different species with low similarity, with approximately 70.42% of the total recorded species (22 in SF and 28 in TP) being recorded exclusively in either of the two systems. This suggests that the two systems are unique from one another in terms of quality and resource availability (Blair & Launer 1997), and are equally important for the conservation of butterflies.

Species richness of butterfly was slightly higher in the tea plantation system than the secondary forest system. It was not expected as forest systems provide favorable habitat to the butterflies (Chettri et al. 2018b). Makaibari Tea Estate, however, practices shade-tea cultivation, along with surrounding forest which covers a major portion (70%) of total area (Makaibari 2020). Thus, tea plantation sites in the study area are enclosed by forests on all sides, allowing easy entry to forest specialist species into the tea plantation system. This was further highlighted by the fact that a number of recorded species (26 out of 71 species) were observed to utilize more than one habitat class. Moreover, it should be noted that tea plantation systems have more open areas, which allow more butterflies to bask around, perch, patrol, and perform mud-puddling.

SF and TP both harbored habitat specialist species (63.38% of all species recorded), of which 28 species were either forest edge or forest interior species (Table 1), suggesting the importance of secondary forest for conservation of butterflies in a tea landscape, which is in line with the findings of other similar studies (Lin et al. 2012; Sreekar et al. 2013; Ahmed & Dey 2014). In India, a similar trend has been reported from other human-modified landscapes in the Himalaya (Chettri et al. 2018b; Sharma et al. 2020) and forests of Western Ghats (Kunte et al. 1999). The number of specialists is inversely proportional to the level of disturbance in forest habitats (Mayfield et al. 2005; Vu 2013; Chettri et al. 2018b), which suggests that the forest habitat in the study area has experienced very less disturbance over the years.

The study also shows that seven of the 71 encountered butterflies are protected under the Wildlife Protection Act of India, 1972, thus Makaibari Tea Estate can be considered to be an important site for the conservation of butterflies.

CONCLUSION

The study highlighted the potential of an organic tea estate surrounded by forest in the conservation of butterflies in Darjeeling Hills, Eastern Himalaya. The study showed that tea plantation systems and secondary forest systems near natural forest area of Darjeeling are equally important in the conservation of butterflies along with natural forest. In the Darjeeling-Sikkim Himalaya, few recent studies have provided information on butterflies from different parts of Sikkim (Acharya & Vijayan 2011, 2015; Kunte 2010; Rai et al. 2012; Chettri et al. 2018b; Dewan et al. 2018; Sharma et al. 2020), however, very few studies have been conducted in Darjeeling (including Kalimpong) Hills (Roy et al. 2012; Sengupta et al. 2014). Thus, the findings of the study add to the limited existing literature on butterflies of Darjeeling Hills, especially in a tea estate area. Further studies are needed to establish baseline data of butterflies in present-day Darjeeling Hills, and our study is an attempt to understand the butterfly diversity in a tea estate of Eastern Himalaya.

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Image 7. Bhutia Lineblue

Image 8. Common Bluebottle

Image 9. Common Jester

Image 10. Common Mormon

Image 11. Glassy Tiger

Image 12. Himalayan Spotted Flat

Image 13. Lemon Pansy

Image 14. Yellow Coster

Image 15. Yellow Orange Tip

Image 16. Purple Sapphire

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