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Article

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ARTICLE

Butterfly diversity in human-modified ecosystems of southern Sikkim, the eastern Himalaya, India

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Abstract: Understanding wild biodiversity of agroecosystems and other human dominated landscapes are crucial for the management and conservation of biological resources. Here, we studied the diversity, abundance, similarity and functionality of butterflies in different human modified ecosystems in southern Sikkim, the Eastern Himalaya. The study was conducted from January 2015 to May 2015 by covering three habitat types namely, farm-based agroforestry, large cardamom-based agroforestry and adjacent natural forest ecosystem. We followed point count method along the transect to collect data on butterflies in the study area. A total of 911 individual butterflies representing six families and 44 species were recorded during the present study in southern Sikkim. Species richness and abundances of butterflies were significantly different among the systems. While diversity and abundance were higher in forest patches, each system harbored unique species assemblages with low similarity between habitats. The information on larval host plants were available for 41 butterfly species which depended on 128 plant species belonging to 27 families. The butterfly community was dominated by oligophagous II (19 species) followed by polyphagous (11 species), monophagous (8 species) and oligophagous I (3 species). Similarly, generalist feeders had higher species and abundance compared to specialist feeders. Specialist species were confined to forest habitat, whereas generalist species were mostly restricted to cultivated systems. The findings of the study highlighted the need for conservation of traditionally managed agroecosystems in order to conserve butterflies and other associated biodiversity.

Keywords: Agroecosystems, butterfly, conservation, eastern Himalaya; host plants.

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Author Contribution: Study designed by BKA, PKC, KS; data collected by PKC, KS; analyzed the data by KS, PKC, SD, BKA and PKC, KS, SD, BKA wrote the manuscript.

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INTRODUCTION

Increased rates of deforestation and forest degradation over the past century have resulted in significant biological attrition globally (Barlow et al. 2007; Primack 2014). Due to ever-increasing human population and subsequent conversion of primary forests for agricultural expansion, many species have lost their potential habitat leading to local extirpation. For example, a large percentage of red-listed species has been threatened by agricultural intensification (Norris 2008). The increasing pressures on the environment by humans necessitate preservation of natural areas crucial for the persistence of biological diversity.

There is a growing concern that, loss of biodiversity will result in declining ecosystem services (Kunte 2000; Kremen et al. 2002; Hooper et al. 2005; Tscharntke et al. 2005). In agroecosystems, natural biodiversity provides a variety of ecosystem services such as pollination, recycling of nutrients, regulation of microclimate and local hydrological processes, suppression of pests and detoxification of noxious chemicals, securing crop protection and soil fertility, etc. (Altieri 1999; Lal 2004; Montagnini & Nair 2004). Most species, which primarily inhabit forests, also interact with agroecosystems and a large proportion of the total species of the region are likely to be encountered in agroecosystems (Pimentel et al. 1992). The management of these agricultural systems can dramatically affect overall levels of biodiversity, as well as the sustenance of particular species. Additionally, understanding biodiversity of agroecosystems and other human dominated landscapes is crucial for the management and conservation of biological resources. In the eastern Himalaya, it has been suggested to formulate planning for land use based on butterfly-forest type associations, by considering forest sub-types as units of conservation (Singh 2017).

Butterfly has been used as an indicator taxa to assess the health of different land use systems (Schulze et al. 2004b). Many studies have recorded higher diversity of butterflies in agroecosystems, e.g. in USA (Meehan et al. 2012), Vietnam (Lien & Yuan 2003), Costa Rica (Horner-Devine et al. 2003) and Japan (Kitahara 2004; Kitahara et al. 2008). Butterfly community is significantly affected by habitat loss and modification, and anthropogenic disturbances (Perfecto et al. 2003; Bobo et al. 2006; Posa & Sodhi 2006). In central Sulawesi, Schulze et al. (2004a) found a steady decline in butterfly species diversity from natural forest, to old secondary forest, secondary forests, agroforestry systems and maize field sites but no significant difference between natural and old secondary forests sites. In Cameroon, however, Bobo et al. (2006) reported a significant decline of butterfly richness and abundance from secondary forests and agroforestry sites towards near primary forests and annual crop sites and high species turn over along the gradient of land conversion but with loss of range-restricted and forest species. The studies in tropical regions have reported decline in butterfly species richness with increasing management intensity (Mas & Dietsch 2003; Francesconi et al. 2013). Schulze et al. (2010) highlighted the importance of human-modified habitats for conservation of overall biodiversity across all major tropical regions. Along a gradient from open to forest habitats, species' habitat preferences significantly relates to population trends; drastic decline of open-habitat species and moderate increase of forest species (Herrando et al. 2016). Endemicity and larval host plant specificity have been reported as significant predictors of vulnerability to habitat disturbance for butterflies (Posa & Sodhi 2006).

Studies on butterfly communities in India have focused mostly on protected areas or forest ecosystems (Uniyal & Mathur 1998; Uniyal 2004, 2007; Barua 2007; Barua et al. 2010; Singh 2010, 2017; Sengupta & Ghorai 2013; Sethy et al. 2014; Acharya & Vijayan 2015; Chettri 2015; Sondhi & Kunte 2016). A few ecological studies have reported the butterfly communities in agroecosystems in India, mostly from the Western Ghats region (Kunte 1997; Kunte et al. 1999; Shahabuddin & Ali 2001; Dolia et al. 2008; Mone et al. 2014). The natural vegetation types harbor greater diversity than human-modified habitats but home gardens and agricultural fields display distinct species composition (Kunte et al. 1999). Distance to protected area and percentage canopy cover influenced abundance and richness of butterflies in the Western Ghats (Dolia et al. 2008). High butterfly diversity including legally protected species has been reported in agri-horticultural ecosystems (Das et al. 2016) and also in tea and coffee plantations (Bora & Meitei 2014; Mone et al. 2014).

Generally, the efforts to preserve biodiversity have focused on establishment of protected area network (PAN) that constitute about 13% of terrestrial lands globally and amounts to one-third of the agricultural lands (38% land cover globally) (Venter et al. 2014; World Bank 2017). Protected areas around the world not only conserve and safeguard biodiversity but also provide essential benefit to local people such as protecting water supplies, food, medicines as well as traditional values, landscape and sustenance for livelihoods. But the establishment of protected area in human-modified landscape is not feasible which necessitates the preservation of existing wild biodiversity in the agricultural systems and surrounding forest patches with the involvement of local communities. The PAN in the Himalayan region is mostly confined to the high elevation areas and there is poor coverage of PAN at low to mid elevations although these areas are rich in biodiversity (Chettri et al. 2008; Shrestha et al. 2010; Acharya et al. 2011; Bhardwaj et al. 2012; Acharya & Sharma 2013). The low to mid elevation areas are represented by mosaic landscape of cultivated systems and forests. The management of these cultivated systems in Sikkim are both traditional (Sharma 2009; Sharma & Acharya 2013) and organic (Bhutia 2015).

The previous studies on butterflies of Sikkim have been conducted in PAN or forest ecosystems (Haribal 1992; Acharya & Vijayan 2015; Chettri 2015). Rai et al. (2012), however, reported the rediscovery of two very rare species protected under Schedule I of Indian Wildlife (Protection) Act 1972 from human-modified ecosystems of Sikkim. PAN coverage in Sikkim is almost 31 % of the total geographical area of the state comprising one national park and seven wildlife sanctuaries. With the exception of Kitam Bird Sanctuary (geographical area of 6km^2), there is no PAN coverage below 1,500m in the state. Occurrence of high species richness, narrow elevation range of most species and absence of PAs at low to mid-elevation has pointed a way for extension of conservation efforts to these elevation sites (Acharya & Vijayan 2015). Since the areas below 2,000m are almost entirely inhabited by people and the major chunk of forests fall under private holdings, conservation can be achieved only through the involvement of the local community as suggested for mountainous areas (Kollmair et al. 2005). Hence, the present study was undertaken to understand the biodiversity conservation value of agroecosystems in Sikkim by assessing the butterfly diversity in three representative human-modified ecosystems: farm-based agroforestry systems and large cardamom-based agroforestry system along with adjoining natural forest in southern Sikkim, the eastern Himalaya, India.

MATERIALS AND METHODS

Study area

The study was conducted at Ralong Village (27.31^{0}N & 88.33^{0}E) in southern Sikkim located in the eastern Himalaya, India (Fig. 1; Table 1). The village is situated between 1,800m and 2,100m elevation with a total geographical area of around 5km^2. The region has a cool temperate type of climate with a maximum temperature of 17–27^{0}C, minimum temperature of 02–21^{0}C and mean annual rainfall of 162cm. Sikkim is a part of the eastern Himalaya, which fall under one among the 35 global biodiversity hotspots (Conservation International 2017). Despite its small geographical area (7,096km^2), Sikkim is one of the richest Indian states in terms of biodiversity harboring around 43% mammals, 45% birds, 50% butterflies and 11% flowering plants of the Indian subcontinent (Acharya & Sharma 2013). The total forest cover of Sikkim is 3,389km^2, which accounts for 47.46% of the total geographical area of the state.

We selected three representative ecosystem types for the present study (Table 1) which are described below:

Farm-Based Agroforestry System (FAS)

Farm based agroforesty system is important land use practice in hilly terrains. It is primarily an agri-silvicultural system comprising home gardens and livestock rearing (Sharma 2009). A variety of crops such as maize, potato, millet, beans, pulses, peas and cabbage are cultivated in this system. Dominant tree species that occur in the system are *Schima wallichii*, *Alnus nepalensis*, *Albizia* spp., *Terminalia myriocarpa, Acer campbelli*, *Castanopsis hystrix,* etc.

Large Cardamom-based Agroforestry System (LCAS)

Large cardamom-based agroforestry is a traditional farming system basically practiced in mountain areas especially in Nepal, Bhutan, Sikkim and Darjeeling. Large cardamom is an important cash crop grown as an understory perennial crop predominantly under the shade of Himalayan alder *Alnus nepalensis* (Sharma 2009; Sharma et al. 2016). Other shade tree species such as *Albizia* spp., *Terminalia myriocarpa, Acer campbelli*, *Castanopsis* spp., *Echinocarpus dasycarpus, Eurya acuminata, Juglans regia, Quercus lamellosa, Quercus spicata, Rhus insignis, Symplocos theifolia, Viburnum cordifolium, Zanthoxylum* sp. etc also occur in this system.

Natural Forest Systems (NFS)

The cultivated systems are encircled by small patches of natural forests where the local community depends on fuel wood and cattle fodder. The main type of vegetation in Ralong is temperate broad-leaved forests which comprises tree species such as *Michelia* spp., *Pteris villosa, Quercus lamellosa, Rhus insignis, Quercus thomsonii, Quercus spicata, Symplocos theifolia, Zanthoxylum* sp., *Echinocarpus dasycarpus, Elaeocarpus sikkimensis, Albizia procera, Beilschmiedia roxburghiana, Eurya acuminata, Ficus hookeri,* etc.

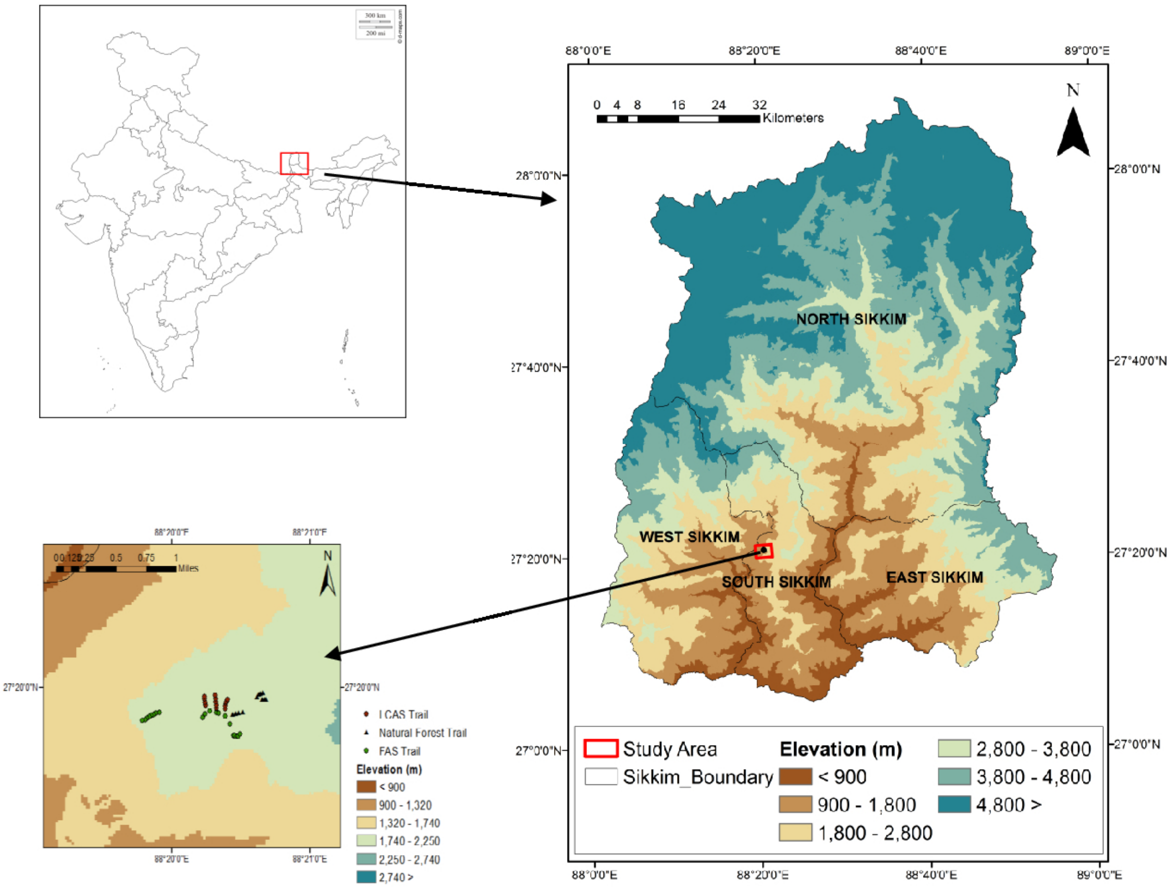

Figure 1. Map showing sampling sites in three different ecosystems located at Ralong, southern Sikkim, eastern Himalaya.

Study design and sampling

The study was designed to cover three representative ecosystem types available in the present study area (FAS, LCAS and NFS). Depending upon the availability of suitable plots and accessibility, we established transect each of 1km length in all the three study systems (Table 1; Fig. 1). Along the transects permanent points were established which were spaced 100m apart making 10 points per transect. We covered equal area (approximately one hectare) in all the three ecosystem types.

We followed point count methods along the transect for sampling butterflies in the study area following Pollard (1977) and Acharya & Vijayan (2015). We conducted five minutes count within 5m radius in each point recording the identity and abundances of butterflies. The sampling of butterflies was done by uniformly covering all the points from January to May 2015. Sampling was done on clear sunny days in the morning from 10:00 hrs to 13:00 hrs when the activity of butterflies remains at its highest. The butterflies were identified at the wing based on photographic plates given in Haribal (1992), Kehimkar (2008) and Sondhi et al. (2013). In cases where instant identification was not possible, photographs were taken and identified using various resources including ifoundbutterflies.org (Kunte et al. 2017). We completed a total of 27 transect visit (nine in each of the study system) totaling 270 point counts. No collection of butterfly specimens was done during this study in Sikkim.

Data Analysis

Community parameters such as species richness, abundance, Shannon-Weiner diversity index and evenness were calculated for total samples as well as each habitat type following Magurran & McGill (2011). Species richness was considered as the total number of species observed and species abundance as number of individual butterflies counted during the sampling. The diversity was analyzed using Shannon-Wiener diversity index (H') = – Σ pilnpi; where pi = proportion of total sample belonging to i^{th} species, ln= natural logarithm (Shannon & Weaver 1949). Similarly, evenness was calculated using the formula: Evenness (J) = H'/H_{max} where H_{max}= lnS, S = number of species, H' = Shannon–Wiener Diversity (Pielou 1969). Based on the observation, we also estimated non-parametric species richness estimators using the software EstimateS version

Table 1. Details of transects established for sampling butterflies in farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, southern Sikkim, eastern Himalaya.

Habitat type	Farm-based agroforestry system	Large cardamom-based agroforesary system	Natural forest system
Dominant vegetation	*Schima wallichii, Alnus nepalensis, Albizia* spp., *Terminalia myriocarpa, Acer campbelli, Castanopsis hystrix*	*Alnus nepalensis, Albizia* spp., *Terminalia myriocarpa, Acer campbelli, Castanopsis hystrix*	*Michelia* spp., *Pteris villosa, Quercus lamellosa, Rhus insignis, Quercus thomsonii, Quercus spicata, Symplocos theifolia.*
Elevation (m)	1700–1900	1700–2100	1700–2100
Latitude	27.3449^{0}N	27.3315^{0}N	27.3348^{0}N
Longitude	88.3405^{0}E	88.3366^{0}E	88.3372^{0}E
Sampling effort (No. of points covered)	90	90	90
Time devoted for sampling (in days)	9	9	9

9.1.0 (Colwell 2013). Using the various estimators and observed richness, species accumulation curves were generated for all the three systems. Among the non-parametric estimators Chao1, Jackknife 1 and Jackknife 2 were preferred because the data was represented by many rare species (singletons and doubletons); these estimators are less sensitive to the patchiness of the species distribution and variability in the probability of encountering species (Colwell & Coddington 1994). To understand the species similarity among the systems, Morisita-Horn similarity index were calculated using EstimateS version 9.1.0 (Colwell 2013).

Variation in species richness and abundances of butterflies among systems was tested using one way ANOVA. Pair wise multiple comparisons based on Tukey's HSD was also conducted to assess the significant difference in the species and abundance of butterflies per point among the three systems. In order to understand the species-abundance pattern of butterfly community, we tested the four distribution model (geometric, log series, truncated log-normal and MacArthur's broken stick) to describe the species–abundance distribution pattern of ecological community (see Magurran & McGill 2011).

We computed relative percentages of butterflies (both species richness and abundance) in each category (butterfly family, habitat specialization and larval host plant specificity). We also assessed the number of larval host plants (family and species) for all the six butterfly family, and butterfly species: host plant species ratio.

Information on habitat specialization for each of the species observed in the study area was obtained from Wynter-Blyth (1957), Haribal (1992), Kunte (2000) and Kehimkar (2008). Each butterfly species was then classified into five habitat specialization classes (Forest interior only, Forest interior + Forest edge, Forest edge only, Openland+forest edge and Openland only) following Kitahara (2004).

Information on larval host plant for each of the species observed in the present study was obtained from different standard references (Haribal 1992; Kunte 2000; Kehimkar 2008; Tiple 2012; Sengupta et al. 2014; Kunte et al. 2017) and field observations. The larval host specificity of butterfly community was assessed by classifying them into monophagous (one species of larval host plant), oligophagous I (>1 species of larval host plant within only one genus in a family), oligophagous II (larval host plant in >1 genus but within a single family) and polyphagous (multiple species of larval host plant in several plant families) following standard methods (Steffan-Dewenter & Tscharntke 1997; Kitahara 2004; Kitahara et al. 2008).

RESULTS

Species richness, diversity and abundance

We observed 911 individual butterflies representing 44 species and six families during this study in southern Sikkim. Species richness, abundance, diversity and evenness of butterflies differed among the three systems (Table 2). Species richness was highest in NFS (32 species, 72.7%), followed by FAS (24 species, 54.5%) and least in LCAS (20 species, 45.5%). Out of the total abundance of butterflies, about 52% were observed in FAS and the rest (48%) in other two systems. But species per point was significantly higher in the FAS compared to other two systems (One way ANOVA: $F_{2, 267} = 65.432$; $P \leq 0.01$) (Table 2; Fig. 2a). Similarly, there was a significant variation in abundance per point of butterflies among the three systems (One way ANOVA: $F_{2, 267} = 85.917$; $P \leq 0.01$) with highest value in FAS (5.2±2.0) and the lowest in LCAS

(Table 2; Fig. 2b). The pair-wise multiple comparisons based on Tukey's HSD test showed significant difference in species per point and abundance per point among all the system pairs (Table 3). Both evenness and Shannon-Weiner diversity index was highest in the forest system compared to other systems (Table 2).

The species accumulation curve almost approached an asymptote in FAS and LCAs but still rising in NFS indicating likelihood of detection of additional species from the study area (Fig. 3). It indicates that there was a probability of encountering few additional species in NFS with the increasing sampling effort.

Family wise distribution

The observed butterflies belonged to six families namely, Hesperiidae, Papilionidae, Lycaenidae, Riodinidae, Pieridae and Nymphalidae. The butterfly families differed among the three systems both in terms of species richness and abundance (Fig. 4). Butterflies belonging to all the six families were observed in LCAS and NFS but species from Hesperiidae and Papilionidae families were absent in FAS. In terms of relative species richness, Nymphalidae was the most dominant family in FAS (50%) with twelve species, followed by Lycaenidae (29.2%) with seven species, Pieridae (16.7%) with four species and Riodinidae (4.2%) with one species. Similarly, Nymphalidae (45%) with nine species, Lycaenidae (25%) with five species, Pieridae (15%) with three species and Papilionidae, Hesperiidae and Riodinidae (5% each) with one species each were observed in LCAS. In the NFS, Nymphalidae (53.1%) with 17 species, Lycaenidae (15.6%) with five species, Pieridae (12.5%) with four species, Riodinidae (9.4%) with three species and Papilionidae (3.1%) with one species and Hesperiidae (6.3%) with two species were observed. In terms of relative abundance (%), however, the most abundant family in all the three systems (FAS, LCAS, NFS) was Pieridae (42.4%, 44.1%, 41.9%), followed by Nymphalidae (35.9%, 26.8%, 29.1%) and Lycaenidae (21.5%, 26.8%, 19.4%). Abundance of Riodinidae was highest in NFS (7.8%) which declined in FAS (0.2%) and LCAS (0.6%).

Species similarity and community structure

Among the 44 species, eight species (18.2%) were common to all the three habitats, whereas 20 species (45.5%) were exclusively observed in a single habitat (10 in NFS, five each in FAS and LCAS) (Table 2). FAS shared 17 species with NFS and 10 species with LCAS. LCAS shared 13 species with NFS. Based on the pair-wise Morisita-Horn similarity index value it is observed that all three systems harbored unique assemblages of species with low similarity between sites (Table 4).

Abundance pattern

Out of the total 911 individuals butterflies, Indian Cabbage White was the most abundant species and constituted 32.5% of the total butterflies followed by Metallic Cerulean (16.8 %) and Indian Tortoiseshell (10.6%).

Among the four models of species-abundance distribution pattern, data on butterflies of the present study showed best fit to truncated log normal model as there was no significant difference between observed and expected number of species in each abundance class (χ^2= 3.61; p = 0.60; df = 5). The abundance distribution pattern showed that community is dominated by a few abundant and many rare species (Fig. 5).

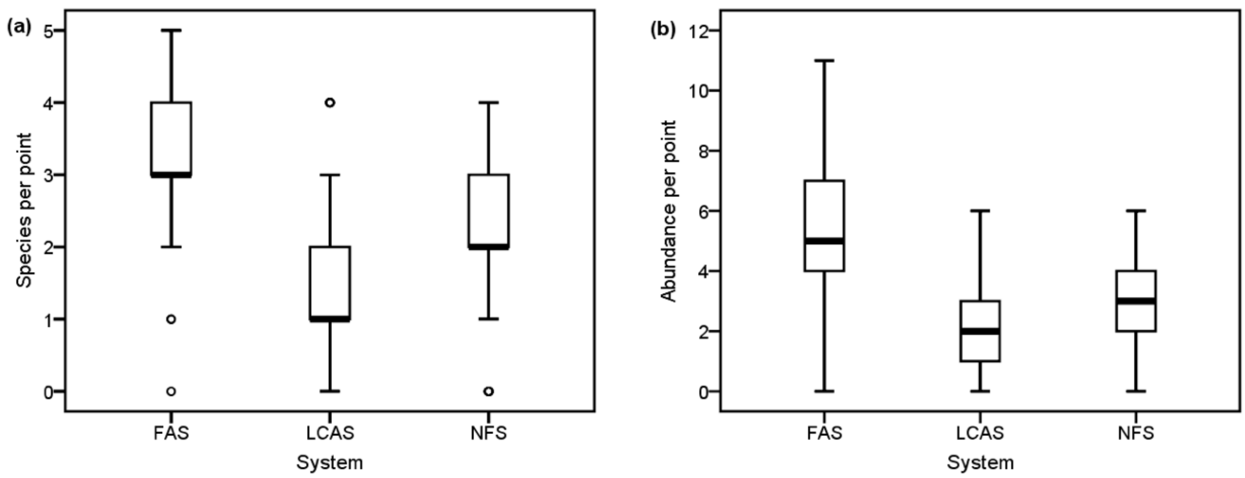

Figure 2. Box-plot showing species per point (a) and abundance per point (b) of butterfly community in farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, southern Sikkim, eastern Himalaya.

Table 2. Species richness, abundance, diversity and evenness of butterfly observed in farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, southern Sikkim, eastern Himalaya.

Parameters	FAS	LCAS	NFS	Total
Species richness	24	20	32	44
Abundance	474	179	258	911
Species per point (Mean± SD)	3.2±1.0	1.4±1.1	2.3±0.9	2.3±1.2
Abundance per point (Mean± SD)	5.2±2.0	2.0±1.7	2.7±1.4	3.3±2.2
Diversity (H')	2.18	2.07	2.59	2.4
Evenness (J)	0.67	0.69	0.74	0.70
Habitat exclusive species	5	5	10	20

Table 3. ANOVA and multiple comparison based on Tukey's HSD for species per point and abundance per point of butterfly community among farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, southern Sikkim, eastern Himalaya. **: significant at p≤0.01.

	$F_{2, 267}$	P	Multiple comparisons	Mean difference	P
Species per point	65.432	0.000**	FAS vs LCAS	1.744	0.000**
			FAS vs NFS	0.911	0.000**
			LCAS vs NFS	-0.833	0.000**
Abundance per point	85.917	0.000**	FAS vs LCAS	3.256	0.000**
			FAS vs NFS	2.522	0.000**
			LCAS vs NFS	-0.733	0.000**

Table 4. Species similarity of butterflies between three systems at Ralong, southern Sikkim, eastern Himalaya. The figures below diagonal represent the pair-wise Morisita-Horn species similarity index and corresponding value above diagonal represents the total species shared by the two systems. FAS - farm-based agroforestry system; LCAS - large cardamom-based agroforestry system; NFS - natural forest system.

Habitats	FAS	LCAS	NFS
FAS	-	10	17
LCAS	0.49	-	13
NFS	0.642	0.362	-

Habitat specialization

Butterflies under different habitat specialization classes showed distinct pattern in the three ecosystems (Fig. 6). As expected, forest interior species, both in terms of species richness (4.2-25%) and abundance (0.4-12.0%), were highest in NFS which declined slightly in LCAS but sharply in FAS. Forest interior + forest edge species were absent in FAS and LCAS and recorded only in NFS with low species richness (1.2%) and abundance (6.3%).

The species richness of forest edge only species were highest in NFS which declined by about 25% in LCAS and 50% in FAS. Similarly, their abundance was also highest in NFS which declined by about 50% in LCAS and four times in FAS. Species richness of openland + forest edge species declined from FAS towards NFS through LCAS and their relative abundance was highest in FAS and least in LCAS. Species richness of open land only was least in NFS and increased about four and five times, respectively in LCAS and FAS. Their abundances were also least in NFS which increased around two times in FAS and LCAS.

Larval host plant specificity

Out of 44 species observed in the present study, information on larval host plant could be obtained only for 41 species representing 897 individuals. These 41 species depended on 128 plant species (belonging to 27 families) as larval host plant (Appendix I; Table 5). The butterfly community was dominated by oligophagous II (19 species; 46.3%) followed by polyphagous (11 species; 26.8%) and monophagous (8 species; 19.5%) and least for oligophagous I (3 species; 7.3%) (Figure 7). In terms of abundance oligophagous II (57.9%) showed the highest value followed by polyphagous (25.2%), oligophagous I (12.5%) and minimum for monophagous (4.55%).

Butterflies considered as generalist feeder (Polyphagous + Oligophagous II) showed high richness (30 species; 73.2%) compared to specialist feeder (monophagous + oligophagous I) (11 species; 26.8%). Similar trend was observed in terms of butterfly populations. Monophagous and oligopahgous species

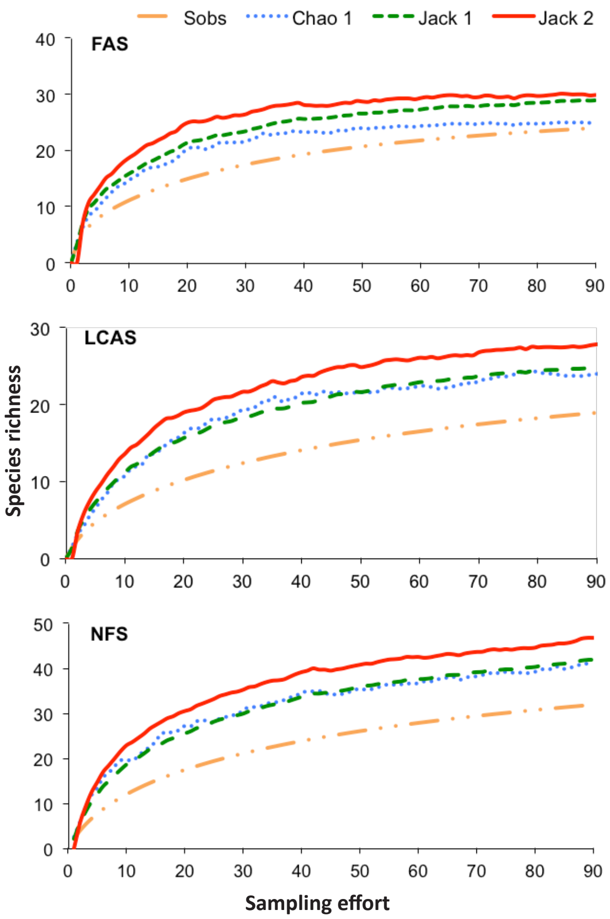

Figure 3. Species accumulation curve of butterflies based on observed species (Sobs) and non-parametric estimators (Chao 1, Jack 1 and Jack 2) in farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, southern Sikkim, the eastern Himalaya.

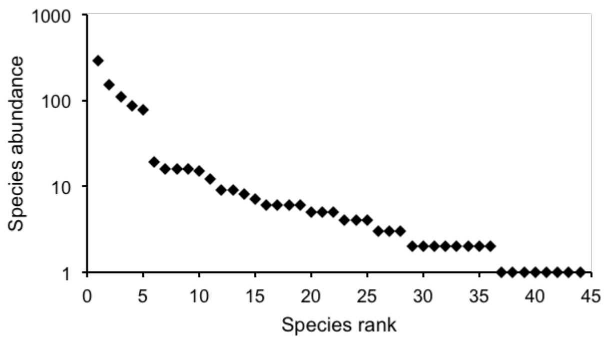

Figure 5. Whittaket Plot (rank-abundance distribution) for total sample of butterflies in Ralong, southern Sikkim, eastern Himalaya.

were restricted to NFS, whereas oligophagous II and polyphagous were mostly confined to cultivated systems (Fig. 7).

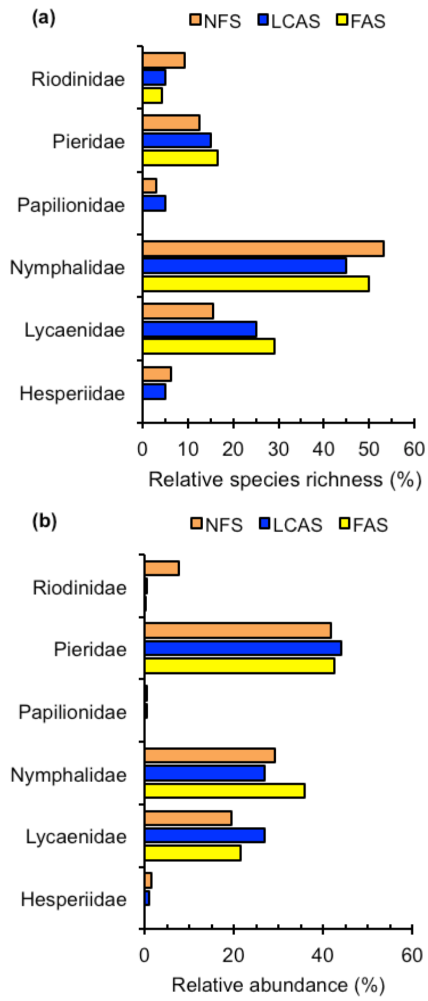

Figure 4. Bar diagram showing the relative species richness (a) and abundance (b) of different families of butterflies in farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, southern Sikkim, eastern Himalaya.

DISCUSSION

During this study a total of 44 species belonging to six families of butterflies were recorded from three ecosystems in southern Sikkim, the eastern Himalaya. These species comprise 6.38% species of the butterflies reported from Sikkim (Haribal 1992). The total species observed during this study was low which may be because of number of reasons, e.g., the study was conducted in a small geographical area and for a short time span (five months; winter and pre-monsoon season) 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). Nonetheless, this study explored the potentiality of cultivated systems in harboring butterflies in an important part of global

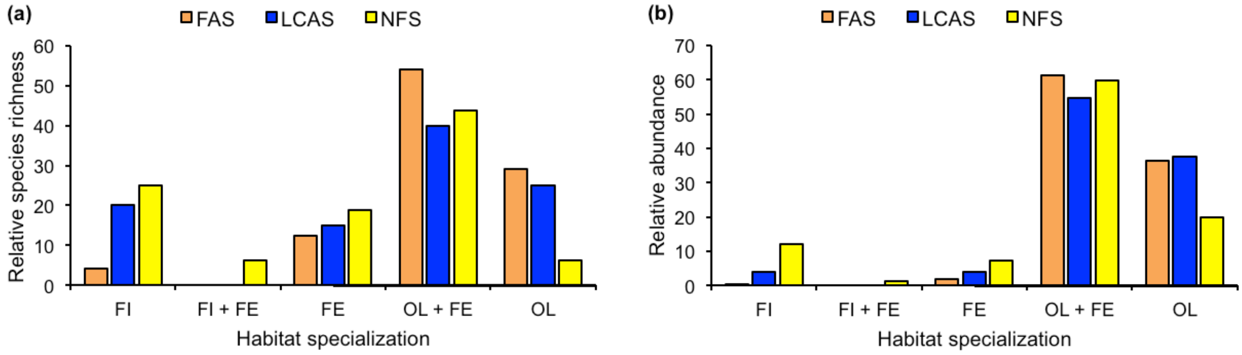

Figure 6. Habitat specialization of the butterfly communities in terms of (a) relative species richness (%) and (b) relative abundance (%) in farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, South Sikkim, eastern Himalaya. FI (Forest interior only), FI+FE (Forest interior + Forest edge), FE (Forest edge only), FE + OL (Forest edge + Openland), OL (Openland only).

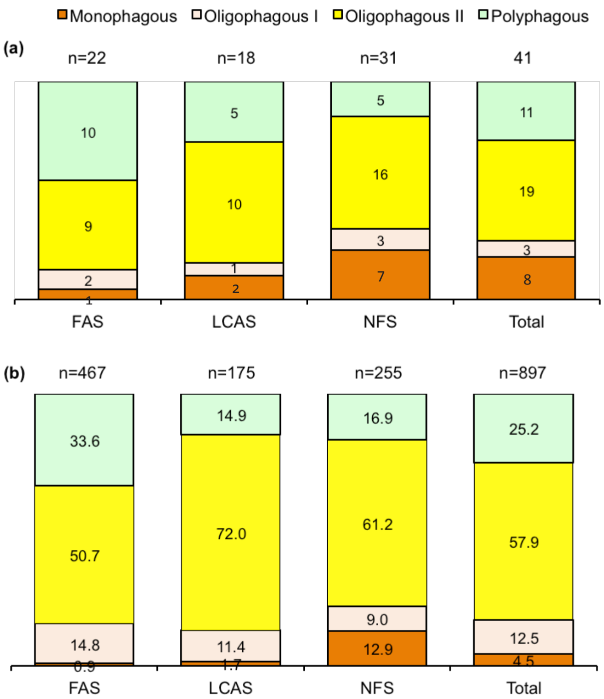

Figure 7. Larval host specificity of butterfly communities in terms of (a) relative species richness and (b) relative abundance in farm-based agroforestry system (FAS), large cardamom-based agroforestry system (LCAS) and natural forest system (NFS) of Ralong, southern Sikkim, eastern Himalaya.

biodiversity hotspot of the Himalaya.

Species richness and diversity of butterfly were high in the forest system as compared to other systems. It is expected because forests system comprised undisturbed patch of vegetation with tall trees and abundant flowering plants which provide favorable habitat to the butterflies. Butterfly community is significantly affected by habitat loss and modification (Perfecto et al. 2003; Bobo et al. 2006; Chettri 2010). Land use change and agricultural intensification leads to homogenization of butterfly community (Ekroos et al. 2010) with species assemblage shifting from specialist to generalist (Börschig et al. 2013). Some studies reported poor representation of butterflies in farmland habitats (Schulze et al. 2004b; Fitzherbert et al. 2006; Vu 2009); however, many studies have found higher diversity of butterflies in agro-ecosystems (Horner-Devine et al. 2003; Lien & Yuan 2003; Bobo et al. 2006; Dolia et al. 2008; Kitahara et al. 2008).

Nymphalidae was the most dominant family in terms of species richness. Similar pattern of dominance of Nymphalidae in the butterfly communities have been reported in other studies conducted in forests and human-modified ecosystems (Uniyal 2007; Vu 2013; Acharya & Vijayan, 2015; Chettri 2015; Nandakumar et al. 2015; Das et al. 2016; Singh 2017).

The butterfly communities in all the three habitats showed distinct species assemblage with very low similarity and high turnover rate between them. It indicates the importance of cultivated systems in conservation of unique butterfly assemblages. The low similarity among systems reflect the uniqueness of each habitat in terms of quality, resource availability and their distribution pattern specific to the preference of butterflies (Blair & Launer 1997).

Species abundance distribution pattern of butterfly fitted to truncated lognormal distribution showing no significant difference in observed and expected number of species in each abundance classes. This is an indication of the rather stabilized ecological community (Magurran & McGill 2011).

Forest habitat harbored large number of specialist species (monophagous and forest interior), whereas cultivated systems mostly harbored open habitat and generalist species (open land and polyphagous).

Table 5. Analysis of the larval host plants of the butterflies observed in Ralong, southern Sikkim, eastern Himalaya

Butterfly family	Butterfly species	Host plant family	Host plant species	Ratio (butterfly species: host plant species)
Hesperiidae	2	2	3	0.67
Lycaenidae	6	6	19	0.32
Nymphalidae	25	20	75	0.33
Papiliondae	1	1	4	0.25
Pieridae	4	4	22	0.18
Riodinidae	3	1	3	1.00
Total	41*	27	128	0.32

*Data for larval host plant were not available for three species (two for Lycaenidae and one for Nymphalidae family)

Similar trend was reported in the Himalaya (Bhardwaj et al. 2012), Western Ghats (Kunte et al. 1999; Dolia et al. 2008) and elsewhere (Francesconi et al. 2013; Herrando et al. 2016). Specialist and rare species are mostly encountered in forests and metric decreases with increasing forest habitat disturbance levels (Mayfield et al. 2005; Vu 2013). Conversely, common species increase with growing forest habitat disturbance levels. Butterfly community is mostly determined by the larval host plants (Kitahara 2004; Barua 2007; Kitahara et al. 2008; Sengupta et al. 2014), nectar plants (Barua 2007; Sengupta & Ghorai 2013), plant species richness, herb and shrub density (Bhardwaj et al. 2012), tree species richness and density (Chettri 2010; Acharya & Vijayan 2015). Habitat specialist species confined to NFS were mostly from Papilionidae and Hesperiidae families. Papilionids have been reported as very sensitive to loss of primary forest habitat and land use change (Barua et al. 2010).

CONCLUSION

This short-term study on butterflies of Ralong, southern Sikkim indicated the significance of cultivated systems and human influenced landscapes for conservation of butterflies and other biodiversity elements. Most of the studies on biodiversity are focused on forests, and areas outside the protected areas are not given due importance from the conservation point of view. This study reflects that although the forest is richer in terms of species, there are many species which occur only in the cultivated systems. Hence, for the conservation of these species cultivated systems should be given due consideration in conservation programs. Original remnant patches of forest and native vegetation among agricultural fields can be retained in consultation with various stakeholders and local communities and managed without further loss of biodiversity. Further studies designed to assess diverse taxa sampled across all the four seasons (winter, pre-monsoon, monsoon and post monsoon) in a long term basis undertaking large geographical area, large elevation range, diverse ecosystems covering the larval and adult stage would provide better insights on the importance of cultivated systems in conservation of biodiversity.

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Appendix I. Butterflies observed in three ecosystems of southern Sikkim, eastern Himalaya including their habitat, larval host specificity and larval host plant. Number represents the abundances of butterflies observed during the study.

	Species	Scientific name	FAS	LCAS	NFS	Total	$^{\$}$Habitat	Larval host specificity	Larval host plants species and family
	Hesperiidae								
1	Common Small Flat	*Sarangesa dasahara* Moore, 1866	-	-	2	2	FI	Monophagous	*Asystasia macrocarpa* (Acanthaceae)
2	Spotted Demon	*Notocrypta feisthamelii* Boisduval, 1832	-	2	2	4	FI	Oligophagous II	*Curcuma aromatica, Hedychium acuminatum* (Zingiberaceae)
	Lycaenidae								
3	Azure Sapphire	*Heliophorus moorei* Hewiston, 1856	5	1	3	9	FE + OL	-	-
4	Common Cerulean	*Jamides celeno* Cramer, 1775	-	6	-	6	OL	Oligophagous II	*Butea monosperma, Crotolaria* spp., *Derris indica, Pongamia pinnata, Xylia xylocarpa* (Fabaceae)
5	Dark Cerulean	*Jamides bochus* Stoll 1782	1	-	3	4	FE + OL	Oligophagous II	*Butea monosperma, Crotalaria albida, Crotalaria ferruginea, Crotalaria mucronata, Pongamia pinnata, Xylia xylocarpa* (Fabaceae)
6	Golden Sapphire	*Heliophorus brahma* Moore 1857	4	-	1	5	FE	Oligophagous II	*Polygonum nepalense, Rumex nepalensis* (Polygonaceae)
7	Malayan	*Megisba malaya* Horsfield, 1828	-	2	-	2	FE	Monophagous	*Allophylus cobbe* (Sapindaceae).
8	Metallic Cerulean	*Jamides alecto* Felder, 1860	76	38	34	148	OL	Oligophagous II	*Boesenbergia rotunda, Elettaria cardamomum* (Zingiberaceae)
9	Pale Grass blue	*Pseudozizeeria maha* Kollar, 1844	7	1	-	8	OL	Polyphagous	*Strobilanthes capitatus, Strobilanthes roseus, Strobilanthes thomsoni* (Acanthaceae)*; Oxalis corniculata* (Oxalidaceae)
10	Pea Blue	*Lampides boeticus* Linnaeus, 1767	7	-	9	16	FE + OL	Oligophagous II	*Butea minor, Crotalaria albida, Crotalaria ferruginea, Crotolaria mucronata* (Fabaceae)
11	White Cerulean	*Jamides pura* Moore, 1886	2	-	-	2	OL	-	-
	Nymphalidae								
12	Banded Treebrown	*Lethe confusa* Aurivillis, 1898	-	-	1	1	FI	Monophagous	*Poa annua* (Poaceae)
13	Blue Tiger	*Tirumala limniace* Cramer, 1775	2	-	1	3	OL + FE	Oligophagous II	*Calotropis gigantea, Calotropis procera, Asclepias curassaviva* (Apocynaceae)
14	Common Bushbrown	*Mycalesis perseus* Fabricius, 1775	2	-	4	6	FI	Oligophagous II	*Apluda mutaca, Elusine coracan, Oryza* sp., *Sorghum* sp.(Poaceae)
15	Common Crow	*Euploea core* Carmer, 1780	1	-	-	1	OL + FE	Polyphagous	*Barleria prionitis* (Acanthaceae); *Nerium odorum* (Apocynaceae); *Ficus benghalensis, Ficus religiosa* (Moraceae)
16	Common Sailer	*Neptis hylas* Linneaus, 1758	4	-	5	9	OL + FE	Polyphagous	*Bombax ceiba* (Malvaceae); *Elaeocarpus lanceifolius* (Elaeocarpaceae); *Dalbergia sissoo, Dalbergia stipulacea* (Fabaceae); *Grewia sapida* (Malvaceae)
17	Common Tiger	*Danaus genutia* Cramer, 1779	-	3	3	6	OL + FE	Oligophagous II	*Asclepias curassavica, Ceropegia lawii, Ceropegia* spp. (Apocynaceae)
18	Dark-brand Bushbrown	*Mycalesis mineus* Linneaus, 1758	-	-	3	3	FE	Oligophagous II	*Lopantherum* spp., *Pogonontherum* spp., *Microstegium* spp. (Poaceae)
19	Glassy Tiger	*Parantica aglea* Stoll, 1782	-	1	-	1	FI	Oligophagous II	*Ceropegia bulbosa, Cryptolepis buchananii, Tylophora carnosa,* (Apocynaceae)
20	Great Evening Brown	*Melanitis zitenius* Herbst, 1796	-	1	-	1	FI	Oligophagous II	*Bambusa arundinacea, Ochlandra* sp. (Poaceae)

	Species	Scientific name	FAS	LCAS	NFS	Total	$Habitat	Larval host specificity	Larval host plants species and family
21	Great Silverstripe	*Argynnis childreni* Gray, 1831	2	-	-	2	OL	Polyphagous	*Mentha longifolia* (Lamiaceae); *Buddleja asiatica* (Buddlejaceae); *Viola diffusa, Viola serpens, Viola tricolor* (Violaceae); *Rubus niveus* (Rosaceae)
22	Green Commodore	*Sumalia daraxa* Doubleday, 1848	-	4	2	6	FE	Oligophagous II	*Populus gamblei, Populus glauca, Salix tetrasperma, Salix salwinensis* (Salicaceae)
23	Himalayan Fivering	*Ypthima sakra* Moore, 1857	4	-	8	12	FE	Monophagous	*Digitaria ciliaris* (Poaceae)
24	Himalayan Jester	*Symbrenthia brabira* Moore, 1872	-	-	1	1	FI	Oligophagous II	*Debregeasia longifolia, Elatostema grande* (Urticaceae)
25	Indian Fritillary	*Argynnis hyperbius* Linnaeus, 1763	4	-	-	4	OL	Polyphagous	*Tagetes patula, Zinnia* sp. (Asteraceae); *Antirrhinum majus* (Plantaginaceae); *Fagopyrum* sp. (Polygonaceae); *Viola diffusa, Viola serpens, Viola tricolor* (Violaceae)
26	Indian Red Admiral	*Vanessa indica* Herbst, 1794	14	2	-	16	OL	Polyphagous	*Digitalis purpurea* (Plantaginaceae); *Urtica dioica, Boehmeria diffusa, Boehmeria glomerulifera, Boehmeria penduliflora, Girardinia diversifolia* (Urticaceae)
27	Indian Tortoiseshell	*Aglais caschmirensis* Kollar, 1844	68	20	17	105	OL	Oligophagous I	*Urtica dioica, Urtica parviflora* (Urticaceae)
28	Large Yeoman	*Cirrochroa aoris* Doubleday, 1847	-	-	1	1	FI	Monophagous	*Hydnocarpus* sp. (Achariaceae)
29	Orange Oakleaf	*Kallima inachus* Doyere, 1840	-	-	1	1	FI+FE	Polyphagous	*Strobilanthes cuspidatus* (Acanthaceae); *Prunus persica* (Rosaceae); *Polygonum orientale* (Polygonaceae); *Girardinia diversifolia* (Urticaceae)
30	Painted Lady	*Vanessa cardui* Linnaeus, 1758	49	13	15	77	OL + FE	Polyphagous	*Artemisia* sp., *Blumea* sp., *Echinops echinatus, Gnaphalium affine, Gnaphalium* sp. (Asteraceae); *Zornia diffusa, Zornia gibbosa* (Fabaceae); *Argemone mexicana* (Papaveraceae); *Boehmeria diffusa, Debregeasia bicolor, Girardinia diversifolia* (Urticaceae)
31	Plain Tiger	*Danaus chrysippus* Linnaeus, 1758	-	-	1	1	OL + FE	Oligophagous II	*Asclepias curassavica, Calotropis gigantea, Cryptolepis buchananii, Ceropegia* sp. (Apocynaceae)
32	Himalayan Queen Fritillary	*Issoria isaeea* Gray, 1846	13	1	5	19	OL + FE	Polyphagous	*Viola diffusa* (Violaceae); *Taraxacum officinale* (Asteraceae)
33	Red Lacewing	*Cethosia biblis* Drury, *1770*	-	-	2	2	FI+FE	Oligophagous I	*Passiflora cochinchinensis*, *Passiflora moluccana*, *Passiflora* sp. (Passifloraceae)
34	Scarce Woodbrown	*Lethe siderea* Marshall, 1880	-	3	-	3	FI	-	-
35	Straight-banded Treebrown	*Lethe verma* Kollar, 1884	-	-	5	5	FI	Monophagous	*Arundinaria aristata* (Poaceae)
36	Yellow Coster	*Acraea issoria* Hubner, 1881	7	-	-	7	OL + FE	Polyphagous	*Boehmeria* sp., *Pouzolzia hirta* (Urticaceae); *Buddleja asiatica* (Buddlejaceae)
	Papilionidae								
37	Common Peacock	*Papilio bianor* Cramer, 1777	-	1	1	2	OL + FE	Oligophagous II	*Zanthoxylum armatum, Zanthoxylum achanthopodium, Clausena* sp., *Citrus* spp. (Rutaceae)

	Species	Scientific name	FAS	LCAS	NFS	Total	$Habitat	Larval host specificity	Larval host plants species and family
	Pieridae								
38	Common Grass Yellow	*Eurema hecabe* Linnaeus, 1758	2	5	9	16	OL + FE	Oligophagous II	*Acacia gageana, Acacia pennata, Albizia procera, Caesalpinia sp., Cassia fistula, Cassia mimosoides, Cassia siamea, Cassia tora, Moullava spicata, Pithelobium dulce* (Fabaceae)
39	Common Jezebel	*Delias eucharis* Drury, 1773	1	-	1	2	OL + FE	Oligophagous II	*Dendrophthoe falcata, Loranthus longiflorus, Loranthus elasticus, Scurrula* sp. and *Viscum* sp. (Loranthaceae)
40	Dark Clouded Yellow	*Colias fieldii* Menetries ,1855	56	9	17	82	OL + FE	Polyphagous	*Trifolium repens, Indigofera* sp. (Fabaceae); *Rubus* sp. (Rosaceae)
41	Indian Cabbage white	*Pieris canidia* Linneaus, 1786	142	65	81	288	OL + FE	Oligophagous II	*Rorippa dubia, Rorippa indica, Brassica juncea, Sisymbrium* sp. (Brassicaceae)
	Riodinidae								
42	Dark Judy	*Abisara fylla* Westwood, 1851	-	-	15	15	FI	Monophagous	*Maesa chisia* (Myrsinaceae)
43	Punchinello	*Zemeros flegyas* Bosiduval, 1836	1	-	4	5	FE	Oligophagous I	*Maesa chisia, Maesia indica,* (Myrsinaceae)
44	Striped Punch	*Dodona adonira* Hewitson, 1866	-	1	1	2	FE	Monophagous	*Maesa chisia* (Myrsinaceae)
	Total species richness		**24**	**20**	**32**	**44**			
	Total abundance		**474**	**179**	**258**	**911**			

$ Habitat specialization: FI (Forest interior only), FI+FE (Forest interior + Forest edge), FE (Forest edge only), FE + OL (Forest edge+ Openland), OL (Openland only).
FAS- farm-based agroforestry system; LCAS- large cardamom-based agroforestry system; NFS- natural forest.
Data source: Haribal 1992; Kunte 2000; Barua 2007; Kunte et al. 2017; Kehimkar 2008; Tiple 2012; Sengupta et al. 2014; and field observations.
Figures indicate the number of individual butterflies observed during the study.

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