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43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641035, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

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Cover: Whale Shark *Rhincodon typus* and Reef - made with poster colours. © P. Kritika.

INTRODUCTION

Butterflies (Lepidoptera: Rhopalocera) are a vital component of our natural ecosystems due to their important pollination services, high specificity of habitat utilization and complex interactions in food webs (Rusman et al. 2016). The status of butterfly diversity and richness in a given area reveals information on the ecosystem health and its functioning (Andrew et al. 2011). Butterflies are useful model organisms in predicting the impact of climate change on biodiversity (Warren et al. 2001; Davies 2019), and are an excellent indicator taxon for monitoring changes in ecological parameters such as environmental health, land use, habitat quality, levels of biodiversity, and conservation status (Bonebrake et al. 2010; Sharma et al. 2020; An & Choi 2021). They respond quickly to changes in local vegetation, climatic conditions, land use types, and disturbances (Bergerot et al. 2011; Chettri et al. 2018; Sharma et al. 2020; Verma & Arya 2021). Several anthropogenic drivers of defaunation have resulted in a global decline of about 35% in butterfly abundance over the last 40 years (Dirzo et al. 2014), and due to unscientific management, many species are on the verge of extinction (Wallenius et al. 2010; Wagner 2020). The Indian subcontinent is represented by about 1,501 butterfly species (Kehimkar 2016), and the hilly state of Uttarakhand in the western Himalaya hosts around 508 species of butterflies (Sondhi & Kunte 2018).

The Nandhour landscape located in the eastern part of Uttarakhand, is a representative part of the vast conservation geographic division called Terai Arc Landscape (TAL). The TAL is an eco-fragile Terai-Bhabar region on the outer slopes of the Shiwalik Himalaya to the foothill areas and Gangetic flood plains (Semwal 2005; Chanchani et al. 2014). The entire region of the Nandhour due to its unique topography, geology, and climate is well known for pristine ecological conditions, spatial heterogeneity and rich biodiversity (WII 2019). The central part of the landscape was designated as a Nandhour Wildlife Sanctuary (covering a total geographical area of 269.95 km²) in 2012, and recently an eco-sensitive zone (covering a total geographical area of 540.26 km²) has been established around the periphery of the sanctuary for proper management and propagation of wildlife (Anonymous 2020). However, human activities such as habitat fragmentation, over-exploitation, and poaching have posed serious threats to the rich biodiversity of the region (Mehra 2015).

Published data on butterfly fauna is currently lacking from the protected landscape of Nandhour. The

landscape has not been surveyed well since the British colonial era. The Nandhour Landscape provides a crucial corridor for wildlife movement across the eastern forests of TAL, such as Brahmadev & Sukhlaphata Wildlife Reserve of Nepal, and the western forests of Corbett & Terai Central Forest Division in India (Verma 2011; WII 2019). In the recent past, few empirical studies have been conducted in protected and unprotected forest ecosystems of Kumaon and Garhwal regions of Uttarakhand (Singh & Bhandari 2003, 2006; Joshi 2007; Joshi & Arya 2007; Singh 2009; Bhardwaj & Uniyal 2011; Smetacek 2012; Bhardwaj et al. 2012; Singh & Sondhi 2016; Arya et al. 2020a,b; Samraj & Agnihotri 2021; Verma & Arya 2021). However, the butterfly diversity and richness of Nandhour Landscape received less attention and was not comprehensively reported from the protected sanctuary. Earlier, Arya & Dayakrishna (2017) recorded 35 butterfly species from the Nandhour Wildlife Sanctuary. There are also few reports on recent rediscoveries and new records of butterfly species to Uttarakhand from the Nandhour Wildlife Sanctuary (Sondhi 2017; Kumar et al. 2020).

Studies on butterflies are important from the standpoint of their diversity, conservation, behavioral, and ecological functional roles as well as to assess the impact of land use changes on them (Bonebrake et al. 2010; Chettri et al. 2018). At present, there are no comprehensive studies that understand the systematic composition of butterflies in this region. Hence, this research primarily aims to record butterfly diversity and richness patterns across different habitats in and around the Nandhour Wildlife Sanctuary of biodiversity rich TAL. The study also intends to investigate the anthropogenic factors affecting butterfly diversity, and to provide guidelines for effective and proper butterfly conservation.

MATERIALS AND METHODS

Study area

Nandhour Wildlife Sanctuary stretched between 28°56'29.35"–29°16'39.79" N & 79°33'03.82"–80°10'00.03" E, is a sub landscape of the Shiwalik-Bhabar Tract in the central sector of the eastern part of TAL (Figure 1). This sub landscape of Nandhour (core zone) along with its adjoining buffer area (eco-sensitive zone) falls under three protected and managed territorial forest divisions of Uttarakhand i.e. Haldwani Forest Division (HFD in the north-west), Terai East Forest Division (TEFD in the south-east), and Champawat

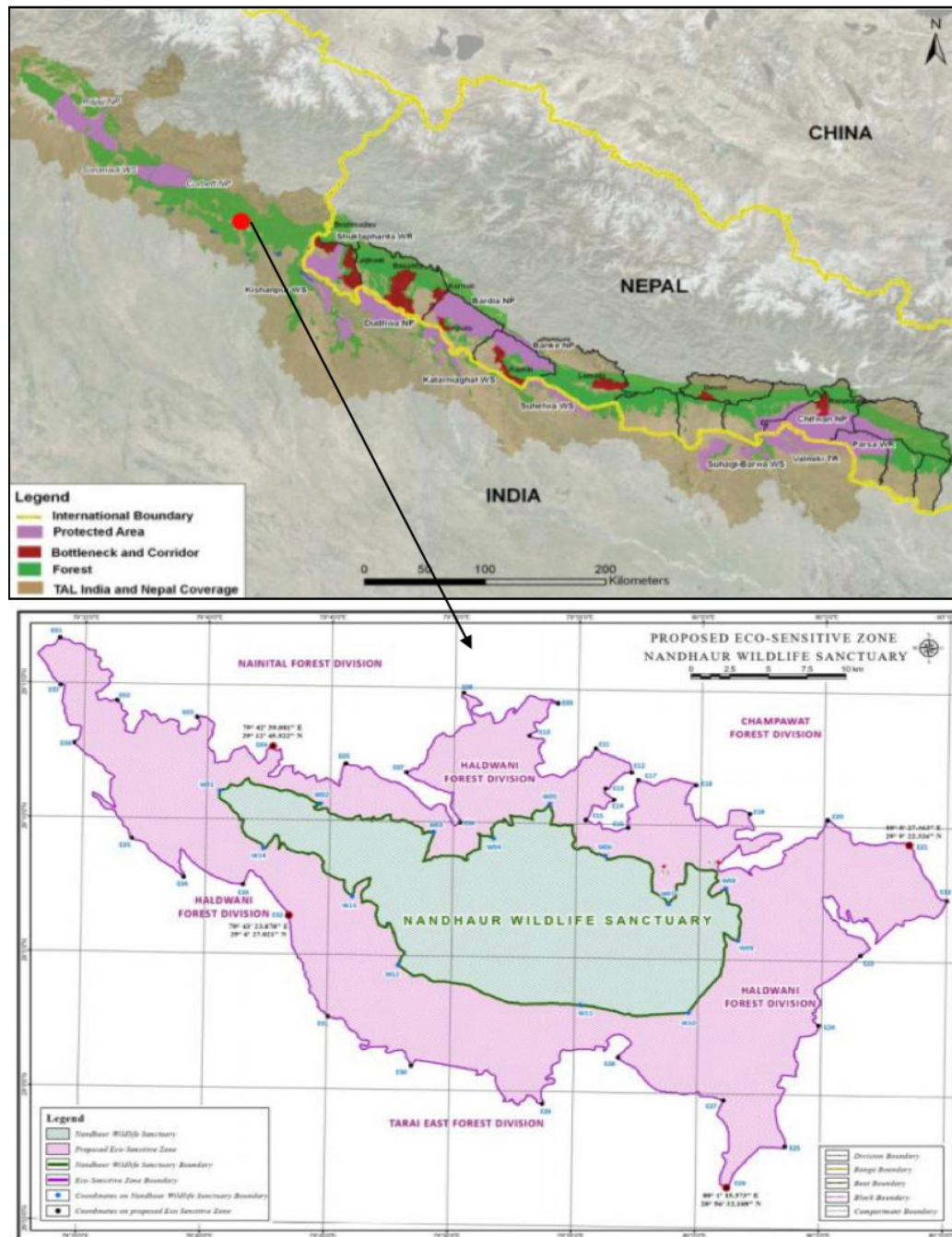


Figure 1. Geographical position of protected Nandhour Landscape in TAL (Terai Arc Landscape) of India (Map data Chanchani et al. 2014; Anonymous 2020).

Forest Division (CFD in the north-east). Majority of the landscape lies in the HFD of district Nainital (Mehra 2015). The Nandhour Landscape is intersected by the river Nandhour in the north, and bounded by river Gola and river Ladhiya in the west, and by the river Sharda in the east towards Nepal (Verma 2011). Geologically, the landscape consists mostly of alluvial plains (Bhabar), and loose conglomerates & hard sandstones of the Shiwalik

Himalaya (Mehra 2015). The topography of Nandhour is represented by steep mountains, high denudational hills, broad & narrow valleys, flat & rugged slopes, and flood plains. Due to the close proximity to the Himalayan mountain range, the region experiences sub-tropical to temperate type of climate, and the maximum average temperature varies from 28°C in January–37°C in May (Mehra 2015). With an annual precipitation of over

1,400 mm, the region receives most rainfall from the southwest monsoon that breaks in mid June and lasts until the end of September–October (Mehra 2015).

The landscape harbors diverse and complex ecosystems of tropical moist forests and dry deciduous forests. The dominant vegetation includes *Shorea robusta*, *Tectona grandis*, *Dalbergia sisso*, *Syzygium cumini*, *Terminalia arjuna*, *Terminalia alata*, *Terminalia bellerica*, *Mallotus philippensis*, *Mallotus repandus*, *Anogeissus latifolia*, *Butea monosperma*, *Calotropis procera*, *Murraya koenigii*, *Clerodendrum infortunatum*, *Justicia adhatoda*, and *Woodfordia fruticosa* (Verma 2011). These natural forest and riverine habitats are home to about 32 mammalian species, including several endangered and flagship species such as the Royal Bengal Tiger *Panthera tigris* and Asian Elephant *Elephas maximus* (Mann et al. 2013), 250 species of resident and migratory birds, 15 reptilian species, and 20 fish species (Verma 2011). The landscape is also represented by plantation forests, wetlands, barren lands, human settlements, and cultivated lands.

Appraisal surveys on butterflies were conducted in different forest ranges by covering a variety of habitats in and around the sanctuary. Butterflies were sampled in eight habitat types (sites): human habitation & agricultural land (S1 in Nandhour Range of HFD), Butterfly Conservation Zone (S2 in Nandhour Range of HFD), dense moist riverine forest (S3 in Nandhour Range of HFD), moist Bhabar sal (*S. robusta*) forest (S4 in Chakata Range of HFD), open dry riverine forest (S5 in Jaulasal Range of HFD), subtropical Chir Pine *Pinus roxburgii* forest (S6 in Chakata Range of HFD), moist Shiwalik Sal forest (S7 in Dogadi Range of CFD) and moist mixed deciduous forest (S8 in Sharda Range of HFD). Of these S1, S2, S3, S5, S6, and S7 were located in the core zone, while S4 & S8 were located in the buffer area of the sanctuary. For the purpose of the present study, an area of one hectare was selected in each site (Image 1 & Table 1). The sites in the study area were selected on the basis of different land use and forest types to reflect the importance of a mosaic of habitats in sustaining butterfly diversity. Management practices and anthropogenic threats within each site were noted during the study period.

Sampling protocols and data collection

Every month, from March 2018–February 2020, butterflies were sampled for eight consecutive sampling days. Sampling was conducted along three permanent linear transects (each measuring 300 m), spaced about 300–500 m apart from each other, in each of the eight

habitat types (sites) selected in the study area. Modified Pollard Walk Method was adopted for the presence–absence and abundance data of adult butterfly species in each site (Pollard 1977; Pollard & Yates 1993). Diurnal butterflies were counted mostly during optimal conditions of maximum activity, around an imaginary space of 5 m × 5 m × 5 m while walking slowly and uniformly covering each of the three transects of a site between 07.00–13.00 h of a day. A minimum of 1.5 h was spent on butterfly sampling in a permanent transect. The same survey method was employed in each site on consecutive sampling days. The preferred host plants of butterflies available in the sites were also noted through primary observations and secondary information (Wynter-Blyth 1957; Kunte 2000, 2006; Robinson et al. 2010; Sengupta et al. 2014; Nitin et al. 2018; Sondhi & Kunte 2018).

Most of the butterfly species were identified visually with the help of available field guides (Kumar 2008; Kehimkar 2016; Singh 2017; Sondhi & Kunte 2018), photographed by using lens of power 18–15 mm in DSLRs Nikon D3500 and Canon 750D. Species which were difficult to identify superficially were collected by a butterfly net, placed in a clear glass bottle, and identified using morphological keys outlined in the literature (Evans 1932; Wynter-Blyth 1957; Haribal 1992). Each collected individual was released immediately after identification at the site of its capture, and no specimen was harmed or killed during the field visits. Plant species were identified using published information (Verma 2011; Mehra 2015), and by the help of experts and taxonomists at G.B. Pant National Institute of Himalayan Environment and Sustainable Development.

Data analysis

Monsoon affects the diversity and distribution of butterfly community at a temporal scale across India (Wynter-Blyth 1957), and several species are strictly seasonal (Kunte 1997; Harisha & Hosetti 2021). Therefore, an annual survey period was categorized into three main seasons—summer (March–June), rainy (July–October), and winter (November–February) to determine the seasonality pattern of butterflies in the study area. The taxonomic classification of butterflies was adopted from Kehimkar (2016), Sondhi & Kunte (2018). The total number of counted individuals of each species across habitat types was pooled to obtain the relative abundance following Verma & Arya (2021) expressed as a percentage based on total individual counts of butterfly fauna in the study area. A rank abundance curve to depict the distribution pattern of different

Table 1. Descriptions of sites (habitat types) selected for butterfly samplings in the protected landscape of Nandhour.

Site code	Site name	Geographical coordinates		Elevation (m)	Habitat type	Major vegetation	Management practices and disturbances
		Latitudes (N)	Longitudes (E)				
S1	Nandhour village	29.122	79.701	315	Human habitation and agricultural land	<i>Mangifera indica</i> , <i>Syzygium cumini</i> , <i>Azadirachta indica</i> , <i>Tectona grandis</i> , <i>Cassia fistula</i> , <i>Citrus spp.</i> , <i>Carica papaya</i> , <i>Musa paradisiaca</i> , <i>Ageratum conyzoides</i> , <i>Urena lobata</i> , many cultivated crops and vegetables	Cultivation practices, use of pesticides and fertilizers, transportation
S2	Butterfly zone	29.132	79.704	332	Butterfly Conservation Zone	<i>Tectona grandis</i> , <i>Shorea robusta</i> , <i>Syzygium cumini</i> , <i>Ficus racemosa</i> , <i>Cassia fistula</i> , <i>Lagerstroemia speciosa</i> , <i>Asclepias curassavica</i> , <i>Ageratum conyzoides</i> , <i>Bidens pilosa</i> , <i>Solanum nigrum</i> , <i>Vallisneria spiralis</i> , <i>Bauhinia vahlii</i> , <i>Tinospora cordifolia</i> , <i>Dendrocalamus strictus</i> , <i>Thysanolaena latifolia</i>	Plantation, ecotourism
S3	Machhli van	29.133	79.705	353	Dense moist riverine forest	<i>Syzygium cumini</i> , <i>Mallotus repandus</i> , <i>Ficus semicordata</i> , <i>Ficus virens</i> , <i>Dalbergia sissoo</i> , <i>Bischofia javanica</i> , <i>Pterospermum acerifolium</i> , <i>Kydia calycina</i> , <i>Bauhinia variegata</i> , <i>Albizia procera</i> , <i>Falconeria insignis</i> , <i>Lannea coromandelica</i> , <i>Leucaena leucocephala</i> , <i>Salix tetrasperma</i> , <i>Artemisia nilagirica</i> , <i>Rhus parviflora</i> , <i>Toddalia asiatica</i> , <i>Eclipta prostrata</i> , <i>Youngia japonica</i> , <i>Lantana camara</i> , <i>Argemone mexicana</i> , <i>Ageratina adenophora</i>	Forest patrolling, camping, trekking
S4	Suryadevi temple	29.231	79.638	419	Moist Bhabar sal forest	<i>Shorea robusta</i> , <i>Careya arborea</i> , <i>Terminalia alata</i> , <i>Aegle marmelos</i> , <i>Tectona grandis</i> , <i>Mallotus philippensis</i> , <i>Dalbergia sissoo</i> , <i>Cassia fistula</i> , <i>Carissa spinarum</i> , <i>Calotropis procera</i> , <i>Murraya koenigii</i> , <i>Ziziphus xylopyrus</i> , <i>Clerodendrum infortunatum</i> , <i>Capparis zeylanica</i>	Sacred grove, religious activities, grazing, collection of fuelwood and fodder
S5	Jaulasal	29.069	79.821	245	Open dry riverine forest	<i>Holoptelea integrifolia</i> , <i>Dalbergia sissoo</i> , <i>Ficus racemosa</i> , <i>Accacia catechu</i> , <i>Cordia dichotoma</i> , <i>Persea gambelii</i> , <i>Haldina cordifolia</i> , <i>Engelhardtia spicata</i> , <i>Kydia calycina</i> , <i>Ricinus communis</i> , <i>Ardisia solanacea</i> , <i>Datura stramonium</i> , <i>Lantana camara</i> , <i>Youngia japonica</i> , <i>Rungia pectinata</i> , <i>Ichnocarpus frutescens</i> , <i>Argemone mexicana</i>	Forest patrolling, illicit felling, grazing
S6	Patrani village	29.219	79.692	1044	Subtropical chir pine forest	<i>Pinus roxburghii</i> , <i>Quercus leucotrichophora</i> , <i>Ougeinia oojensis</i> , <i>Grewia optiva</i> , <i>Anogeissus latifolia</i> , <i>Myrica esculenta</i> , <i>Boehmeria rugulosa</i> , <i>Cinnamomum tamala</i> , <i>Berberis asiatica</i> , <i>Rubus ellipticus</i> , <i>Pyracantha crenulata</i> , <i>Urtica dioica</i> , <i>Achyranthes aspera</i> , <i>Bidens biternata</i> , <i>Cannabis sativa</i> , <i>Woodfordia fruticosa</i> , <i>Cirsium wallichii</i> , <i>Flemingia strobilifera</i>	Forest fires, grazing, collection of fuelwood, fodder and forest products
S7	Dogadi range	29.070	80.018	350	Moist Shiwalik sal forest	<i>Shorea robusta</i> , <i>Anogeissus latifolia</i> , <i>Adina cordifolia</i> , <i>Diploknema butyracea</i> , <i>Mallotus philippensis</i> , <i>Tectona grandis</i> , <i>Lagerstroemia parviflora</i> , <i>Terminalia alata</i> , <i>Ailanthus excelsa</i> , <i>Murraya koenigii</i> , <i>Clerodendrum infortunatum</i> , <i>Flemingia strobilifera</i> , <i>Smilax aspera</i>	Silvicultural activities
S8	Sharda range	29.080	80.092	280	Moist mixed deciduous forest	<i>Shorea robusta</i> , <i>Adina cordifolia</i> , <i>Tectona grandis</i> , <i>Toona ciliata</i> , <i>Dalbergia sissoo</i> , <i>Mitragyna parviflora</i> , <i>Mallotus philippensis</i> , <i>Terminalia arjuna</i> , <i>Terminalia alata</i> , <i>Ehretia laevis</i> , <i>Aegle marmelos</i> , <i>Bauhinia racemosa</i> , <i>Ficus benghalensis</i> , <i>Ficus religiosa</i> , <i>Phyllanthus emblica</i> , <i>Schleichera oleosa</i> , <i>Madhuca indica</i> , <i>Cassia fistula</i> , <i>Diospyros melanoxylon</i> , <i>Crateva religiosa</i> , <i>Bombax ceiba</i> , <i>Murraya koenigii</i> , <i>Ziziphus xylopyrus</i> , <i>Clerodendrum infortunatum</i> , <i>Ageratina adenophora</i> , <i>Lantana camara</i>	Logging, transportation

species was created by log transforming the individual abundance data following Magurran (2004). Diversity measures were obtained using the Shannon–Weiner diversity index (Shannon & Weaver 1949), Margalef richness index (Margalef 1972), and Pielou evenness

index (Pielou 1969). Individual based rarefaction curves were obtained for each habitat types following Gotelli & Colwell (2001). The analyses of diversity measures and rarefaction curves were done using the software PAST (Hammer et al. 2001). In order to compare the species

richness and abundance of butterflies across seasons and habitat types, one-way analysis of variance (ANOVA) tests at the 5% level of significance were performed using the software SPSS. The Sorensen's similarity index was calculated to determine the extent of assemblage similarity in different habitat types of the study area (Sorensen 1948).

RESULTS

Overall species composition of butterflies

A total of 10,713 individuals belonging to 89 species and six families were recorded during the study period (2018–20) from eight habitat types selected in the Nandhour Landscape (Appendix 1). The butterfly community was more or less evenly distributed in the study area as depicted by a relatively low steep inclination of the plot in the rank abundance curve (Figure 2). Detailed account of each family is given below:

Family Hesperidae: This family comprised of eight species and 4.48% of the total recorded individuals (Images 1–8). Species namely, *Parnara guttatus* (Relative abundance = 1.82) and *Borbo bevani* (1.29) were the most abundant found across all habitats, while the least abundant species *Udaspes folus* (0.13) was found in agricultural land, dry riverine, and chir pine forests, & *Aeromachus stigmata* (0.13) in chir pine forest (Appendix 1).

Family Riodinidae: Riodinidae consisted of three species with 1.90% of the total individuals (Images 9–11). *Dodona durga* (1.39) recorded as the most abundant species in this family was found across all habitats except agricultural land and butterfly zone. *Abisara bifasciata* (0.07) recorded as the least abundant was found in moist riverine and Shiwalik Sal forests (Appendix 1).

Family Pieridae: With a total of 37.97% individuals, Pieridae was the most abundant family and comprised of 15 species (Images 12–26). Most of the species were euryoecious in nature. Species such as *Catopsilia pomona* (6.78), *Pieris brassicae* (5.84), *Eurema laeta* (5.05), *Eurema hecabe* (4.48), *Pieris canidia* (3.97), and *Catopsilia pyranthe* (3.85) were recorded as the most abundant and found across all habitats. The least abundant species under this family namely, *Colias erate* (0.35) was found in butterfly zone, moist & dry riverine forests, Chir Pine forest, and mixed deciduous forest, and *Eurema andersonii* (0.45) in moist Bhabar Sal forest, moist & dry riverine forests (Appendix 1).

Family Papilionidae: This family was comprised of

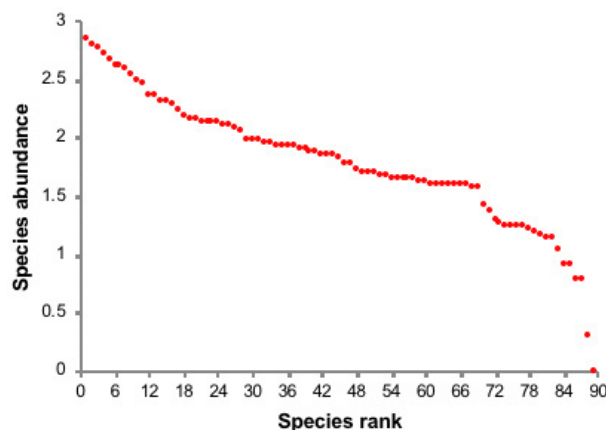


Figure 2. Rank abundance curve of butterfly species in the study area.

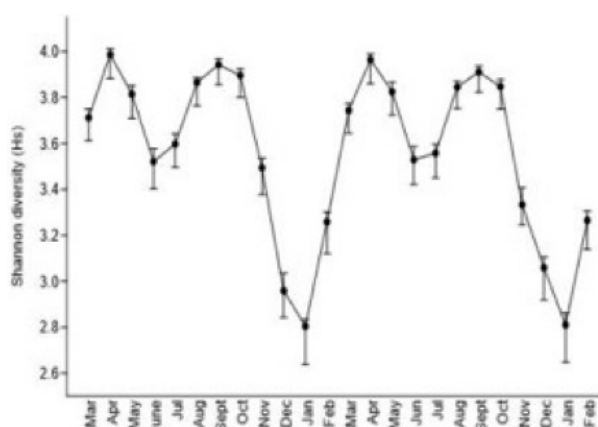


Figure 3. Month-wise Shannon diversity of butterflies recorded from March 2018–February 2020.

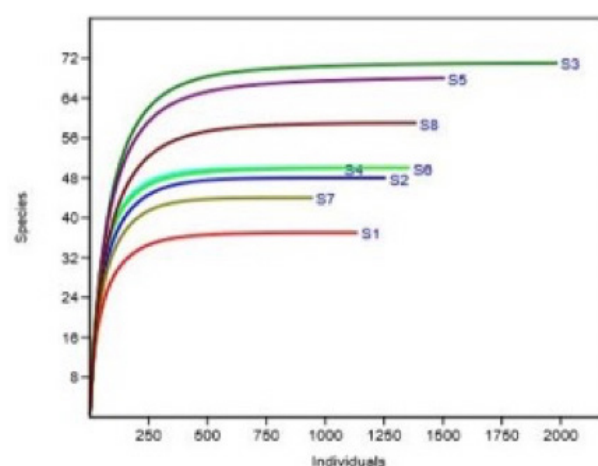


Figure 4. Individual rarefaction curves of butterfly assemblages across eight sites (habitat types) selected in the study area.

seven species and 9.24% of the total recorded individuals (Images 27–33). Swallowtails, namely, *Papilio polytes* (3.70), and *Papilio demoleus* (2.88) were the most abundant found across all habitats, while *Papilio clytia* (0.16) found in moist riverine and mixed deciduous forests, and *Graphium nomius* (0.42) in moist riverine, Bhabar Sal & mixed deciduous forests were the least abundant species under this family (Appendix 1).

Family Lycaenidae: This family was comprised of 13 butterfly species and 17.87% of the total recorded individuals (Images 34–46). Species such as *Pseudozizeeria maha* (5.69), *Heliophorus sena* (3.20), *Zizeeria karsandra* (2.81), and *Lampides boeticus* (1.91) were the most abundant and found in almost all habitats. *Flos asoka* (0.05) found in Shiwalik sal forest, *Tarucus nara* (0.05) in moist and dry riverine forest, and *Arhopala amantes* (0.10) in Shiwalik sal forest were recorded as the least abundant species under this family (Appendix 1).

Family Nymphalidae: Nymphalidae with a total of 43 species was the most species rich and with a total of 28.51% individuals was the second abundant family in the study area (Images 47–89). The most abundant species included *Euploea core* (2.14), *Danaus genutia* (1.91), *Danaus chrysippus* (1.66), *Junonia iphita* (1.48), *Ypthima kasmira* (1.28), and *Parantica aglea* (1.26) which were also found in all habitats. The least abundant species were *Athyma selenophora* (0.01) found in moist riverine forest, *Charaxes agrarius* (0.07), *Lethe confusa* (0.09), and *Ypthima asterope* (0.14) found in dry riverine forest (Appendix 1).

Seasonality of butterflies

Across the seasons, species richness, and abundance showed significant differences when analyzed through one-way ANOVA (Richness: $F = 31.21$, $df = 2, 21$, and $P = 0.00$; Abundance: $F = 21.25$, $df = 2, 21$, and $P = 0.00$). The highest number of species and individuals were recorded during rainy season (82 species and 50.46% of the total individuals), followed by summer (78 species and 37.56% of the total individuals) (Table 2). Winter season showed a significantly lower richness and abundance (48 species and 11.97% of the total individuals).

Seasonally, a bi-annual peak in butterfly diversity was observed in the study area (Figure 3). The Shannon diversity (H_s) was at its peak during the dry summers (Mar–May) and the monsoons (Aug–Oct). Diversity was at its minimum during Dec–Jan (winters). Forty-eight species were found across all seasons, 23 species were found during the summer and rainy seasons, 11 species were found during the rainy season, and seven species

Table 2. Number of species and individuals of butterflies recorded in different months and seasons in Nandhour landscape.

Seasons	Months	Month-wise		Season-wise	
		Species	Individuals	Species	Individuals
Summer	March	64	1,396	78	4,024
	April	76	1,328		
	May	66	811		
	June	48	489		
Rainy	July	54	929	82	5,406
	August	67	1,460		
	September	79	1,817		
	October	71	1,200		
Winter	November	44	500	48	1,283
	December	26	213		
	January	20	140		
	February	34	430		

Table 3. Values of diversity indices calculated for butterfly assemblages across sites and study area.

Diversity measures	Study sites								Study area
	S1	S2	S3	S4	S5	S6	S7	S8	
Shannon (H_s)	3.20	3.56	3.97	3.68	3.90	3.69	3.42	3.69	3.93
Margalef (H_m)	5.11	6.58	9.21	7.02	9.15	6.79	6.27	8.01	9.48
Evenness (J)	0.67	0.73	0.75	0.79	0.73	0.80	0.69	0.68	0.57

were found during the summer (Appendix 1).

Diversity and richness patterns of butterflies across habitats

The steeper and asymptotic individual rarefaction curves showed adequate sampling efforts to differentiate assemblages in each site (Figure 4). The overall species richness pattern differed significantly across the selected habitat types (ANOVA: $F = 3.92$, $df = 7, 184$, and $P = 0.00$), while the abundance showed insignificant differences (ANOVA: $F = 0.61$, $df = 7, 184$, and $P = 0.74$). The highest number of species was recorded in S3 (71 species), followed by S5 (68 species), S8 (59 species), S4, S6 (50 species each), S2 (48 species), S7 (44 species), and S1 (37 species).

The calculated diversity measures show high richness patterns in eight habitat types of the study area (Table 3). The maximum species diversity and richness was recorded in the sites represented by riverine forests (S3, S5 with H_s 3.97 & 3.90; H_m 9.21 & 9.15, respectively), while the habitat characterized by human settlements and agricultural land showed the minimum

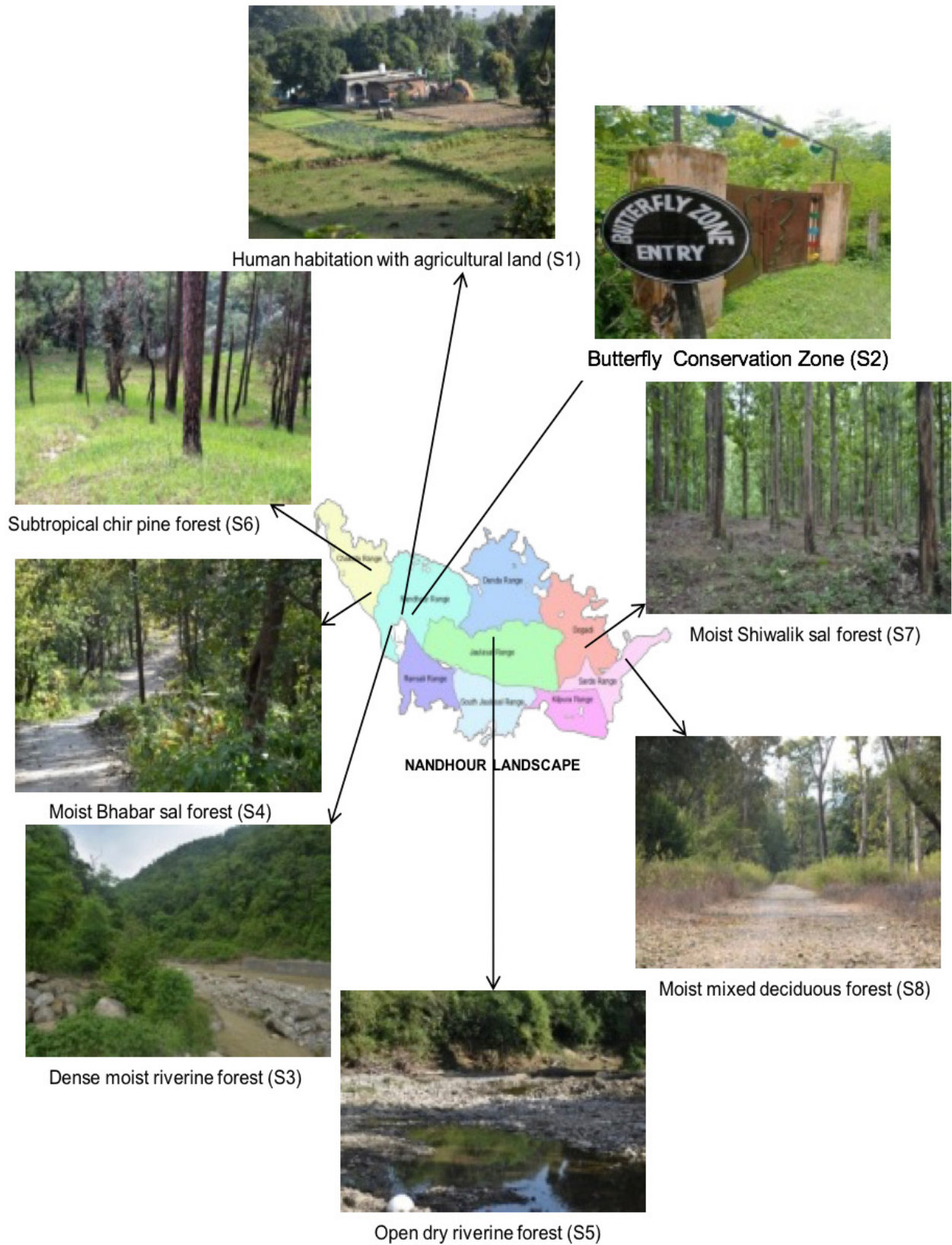


Image 1. Location and view of habitat types (sites) selected for butterfly samplings in the Nandhour Landscape (Map data Verma 2011).

Table 4. Values of Sorensen's similarity index calculated for butterfly assemblages across sites.

	S1	S2	S3	S4	S5	S6	S7	S8
S1	0							
S2	0.82	0						
S3	0.63	0.72	0					
S4	0.69	0.71	0.76	0				
S5	0.67	0.76	0.87	0.68	0			
S6	0.69	0.71	0.68	0.78	0.66	0		
S7	0.76	0.78	0.71	0.64	0.71	0.68	0	
S8	0.67	0.77	0.81	0.72	0.80	0.73	0.75	0

Value ranges between 0 to 1 and higher numbers indicate greater similarity.

diversity, richness, and evenness of the species (S1 with Hs 3.20, Hm 5.11, and J 0.66). Butterfly assemblage in the subtropical Chir Pine forest at S6 was very even in its distribution (J 0.80).

The pair-wise comparisons of Sorensen's similarity index for assemblages in different habitat types depicted that riverine forests (S3 & S5) had high similarity (0.87) and a unique species composition (Table 4). Similarly, man managed habitats (S1 & S2) had a high degree of similarity (0.82), and mixed deciduous forest (S8) had high similarity (0.81 & 0.80) with moist riverine forest (S3) and dry riverine forest (S5). 26 species were found across all the habitat types, while nine species were found as habitat specific in the study area (Appendix 1).

DISCUSSION

The present study revealed that the protected Nandhour landscape of TAL, with 89 species belonging to six families hosts good diversity (Hs 3.927) and richness (Hm 9.484) of butterflies (Appendix 1, Table 3). The recorded butterfly richness constituted about 17.50% of the total known species from Uttarakhand (Sondhi & Kunte 2018). Previous to this study, there are known records of 20 species in Nandhour Village (S1), 34 species in Butterfly Zone (S2), 32 species in Machhli Van (S3), 26 species in Suryadevi Temple (S4), and 28 species in Jaulasal (S5), which altogether constituted 53 species of butterflies from the protected area of Nandhour (Arya & Dayakrishna 2017). Of them, 42 species were also recorded in the present study, while the rest 47 species (out of 89 species) represent new records for the Nandhour Landscape (Appendix 1). The unreported butterfly species included *Spialia galba* (Hesperiidae), *Pachliopta aristolochiae*, *Graphium doson* (Papilionidae),

Ixias marianne, *Colotis* sp., *Belenois aurota* (Pieridae), *Neopithecops zalmora*, *Freyeria trochylus* (Lycaenidae), *Hypolimnas misippus*, *Cupha erymanthis*, *Neptis sankara*, and *Ypthima huebneri* (Nymphalidae). Most of these species are either common or uncommon in Uttarakhand (Sondhi & Kunte 2018). Such results substantiate the importance of natural forest habitats in sustaining and maintaining the rich butterfly diversity. More intensive and consistent monitoring protocols could result in the addition of new butterfly species to the protected landscape of Nandhour.

In comparison to modern empirical studies conducted previously in different forest ecosystems of Uttarakhand, Samraj & Agnihotri (2021) reported 92 butterfly species in the nearby Terai region of Pantnagar, Verma & Arya (2021) reported 98 species in the Pancheshwar Multipurpose Project Site of district Champawat, Arya et al. (2020a) recorded 56 species in the Corbett Tiger Reserve, Arya et al. (2020b) reported 46 species in the Binsar Wildlife Sanctuary, Bhardwaj et al. (2012) recorded 79 species in the Tons Valley of Garhwal region, Smetacek (2012) reported 243 species from a dying watershed in the Kumaon region, Bhardwaj & Uniyal (2011) reported 34 species in the Gangotri National Park, Singh (2009) recorded 143 species in the Kedarnath Musk Deer Reserve, Joshi & Arya (2007) reported 54 species in the Pindari area of Nanda Devi Biosphere Reserve, Joshi (2007) reported 40 species in the Motichur Sanctuary of Rajaji National Park, Singh & Bhandari (2003, 2006) recorded 183 species in the Dehradun Valley of Garhwal region. Furthermore, annual rainfall patterns have a significant impact on tropical butterflies (Wolda 1988; Valtonen et al. 2013), and the occurrence of dry-wet seasonal cycles generate bi-annual rhythms in species diversity and similarity of butterfly communities by bringing changes in the host plant dynamics of the region (Grøtan et al. 2012, 2014). The reported high diversity and richness during dry summers (Mar–May) and wet monsoons (Aug–Oct) is in concordance with previous findings from the study area (Arya & Dayakrishna 2017), as well as from the regions experiencing tropical to sub-tropical type of climate in India (Gupta et al. 2019; Arya et al. 2020a).

Amongst the sampled habitats, butterfly richness was significantly low in the site (S1) characterized by human habitation and agricultural land (Figure 4). Local transportation, increased cultivation with use of chemical fertilizers & pesticides, and other human activities might have resulted in the least diversity and richness in S1 (Table 3). Generalist species like *P. brassicae*, *P. demoleus*, *P. polytes*, *C. pomona*, *E. hecabe*

and *P. guttatus* dominated this habitat (Appendix 1). It is known that declines in soil properties caused by pollution from anthropogenic toxins and habitat simplification through agriculture could result in reduced diversity and local extinctions of butterflies (Öckinger et al. 2006; Gilburn et al. 2015; Braak et al. 2018). On the other hand, the relatively less disturbed sites characterized by dense moist and open dry riverine habitats (S3 & S5), had the highest number of species and ample diversity (Figure 4, Table 3). Natural forests, especially associated with the riverine ecosystems usually have greater environmental heterogeneity, provide unique vegetation & large quantities of diverse resources, better mating & ovipositioning sites, safety from predation, and low disturbance, hence are highly preferred by several butterflies, including specialist species (Cabette et al. 2017; An & Choi, 2021).

Species namely, *A. selenophora* (in S3), *C. agrarius*, *L. confusa*, *Y. asterope* (in S5), *Pseudocoladenia fatih*, *T. nara*, *Charaxes bharata*, *Hestinalis nama*, *Kallima inachus*, and *Vagrans egista* (in both S3 & S5) were found as habitat specific butterflies in the riverine forests (Appendix 1). Similarly, *A. amantes*, *F. asoka* were unique to the moist Shiwalik Sal forest (S7), *A. stigmata*, *Ypthima narenda* to the subtropical Chir Pine forest (S6), and *Zizula hylax* to the butterfly zone (S2). These findings suggest that since the Nandhour landscape comprises of a variety of forest habitats types, it provides a congenial living environment and a diverse food supply for many species. Also, these results corroborate with a few earlier findings from nearby regions that revealed a high butterfly diversity and richness in natural habitats, but a low diversity and richness in habitats disturbed or managed by the human activities (Arya et al. 2020a; Samraj & Agnihotri 2021; Verma & Arya 2021).

As per the Indian Wildlife (Protection) Act 1972, five species identified in the present study are legally protected under different schedules (Appendix 1). Butterflies namely, *L. boeticus* (Lycaenidae), *Libythea lepita*, *Neptis soma* (Nymphalidae) are listed under Schedule II, and *E. core*, *Euploea mulciber* (Nymphalidae) are listed under Schedule IV (Anonymous 2006). Endemic butterflies of the Indian Himalayan Region included *Potanthus dara* (Hesperiidae), *D. durga* (Riodinidae), *H. sena* (Lycaenidae), *Acraea issoria*, *Aglaia caschmirensis*, *Athyma cama*, *Neptis hylas*, and *Ypthima nikaea* (Nymphalidae) (Appendix 1). Such faunal records along with the reported rich diversity of butterflies signify a high conservation value of the study area. This means, the region must be conserved more intensely, especially by focusing on scientific management of riverine forest

habitats located in and around the sanctuary. Butterflies are an excellent ecological indicator group for scaling and quantifying riverine characteristics because of their strong relationship with larval food plants, and riverine zones are thus conservation priority sites (Cabette et al. 2017; An & Choi 2021). Stream sides or muddy bogs in riverine forests are important microhabitats for those adult butterflies seeking rich puddling grounds to intake water and nutrients lacking in their larval diet (Nelson 2007; Verma & Arya 2021).

Human induced pressures in forest habitats from activities such as increased cultivation, forest fires, cattle grazing, illicit felling & logging, and collecting fuelwood, fodder & forest products could threaten the existence of several butterfly species in the protected landscape of Nandhour. These disturbances could have adverse impacts on their host plants in natural habitats, while the use of pesticides and fertilizers in cultivated areas adjacent to the sanctuary could be detrimental to rich biodiversity of the region (Braak et al. 2018; An & Choi 2021; Verma & Arya 2021). Being phytophagous, butterflies play vital role in the 'green' food webs of tropical ecosystems (Kitching et al. 2020), and form a critical food base for organisms at higher trophic levels (Bonebrake et al. 2010). Agricultural chemicals cause butterfly declines and may disrupt their complex ecological interactions, potentially harming insectivorous species such as birds and bats (Gilburn et al. 2015; Forister et al. 2016). Thus, it is extremely important that the soil properties in the cultivated lands of the protected Nandhour Landscape should not be deteriorated by the use of any sort of biocide, and the practice of organic farming must be encouraged by the concerned authorities for better socio-economic development of local inhabitants as well as for regional biodiversity conservation and natural balance.

CONCLUSION

The present study indicates the high conservation value of ecologically fragile natural habitats in sustaining rich diversity including several habitat specific, legally protected, and endemic butterflies of the Himalayas. However, overexploitation, illegal utilizations, excessive grazing, unauthorized access, and non-forestry related developments could cause declines in diversity by directly limiting important food choices and resources. Such activities should be regulated and strictly monitored in the protected Nandhour landscape. Special emphasis should be placed on the preservation and restoration of



Image 1. *Aeromachus stigmata*
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Image 2. *Borbo bevani* ©HC

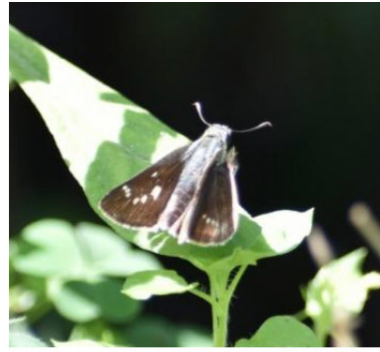


Image 3. *Parnara guttatus*
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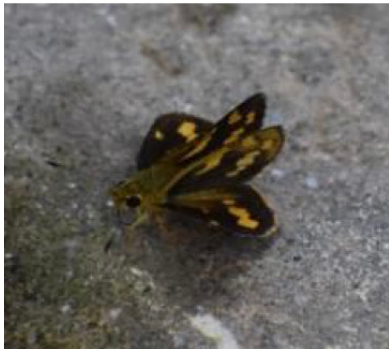


Image 4. *Potanthus dara* ©HC

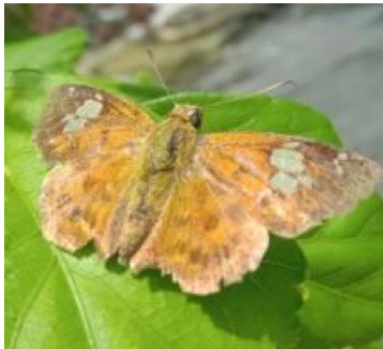


Image 5. *Pseudocoladenia fatih*
©HC



Image 6. *Tagiades litigiosa*
©HC

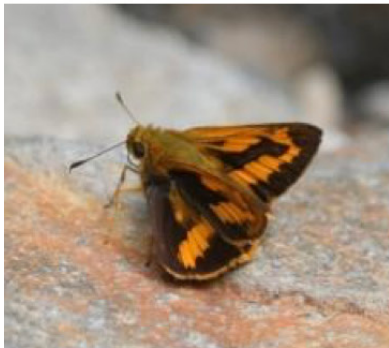


Image 7. *Telicota colon* ©AV

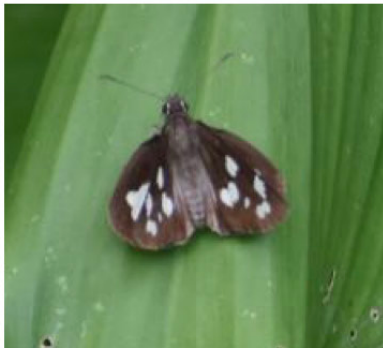


Image 8. *Udaspes folus* ©HC

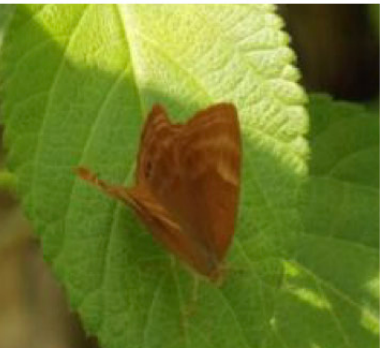


Image 9. *Abisara bifasciata*
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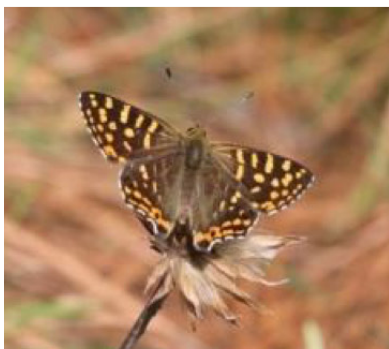


Image 10. *Dodona durga* ©AV

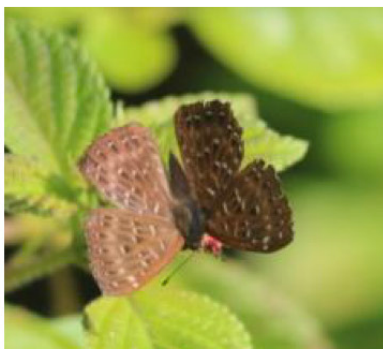


Image 11. *Zemerus flegyas*
©AV



Image 12. *Catopsilia pomona*
©HC



Image 13. *Catopsilia pyranthe*
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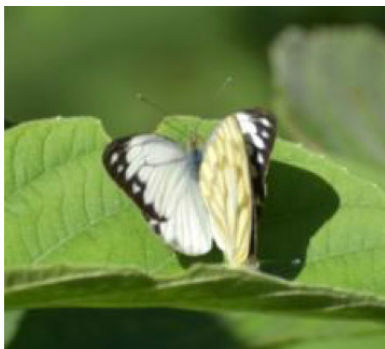


Image 14. *Cepora nerissa*
©HC



Image 15. *Colias erate* ©AV

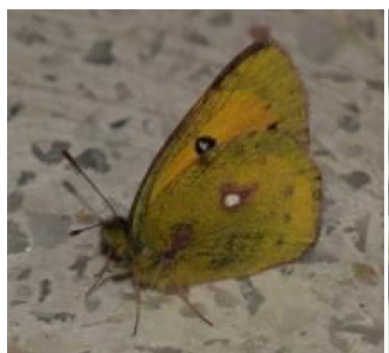


Image 16. *Colias fieldii* ©HC

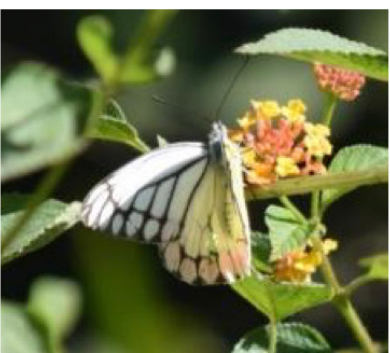


Image 17. *Delias eucharis*
©HC



Image 18. *Eurema hecabe*
©HC



Image 19. *Eurema andersonii*
©HC



Image 20. *Eurema blanda* ©AV

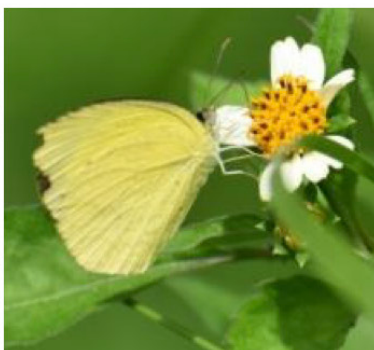


Image 21. *Eurema brigitta* ©HC



Image 22. *Eurema laeta* ©HC

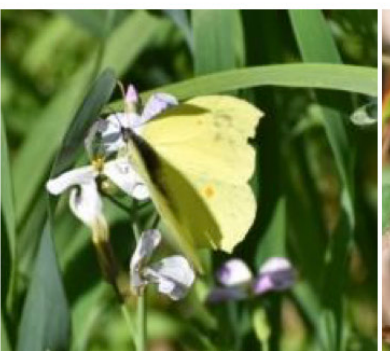


Image 23. *Gonepteryx rhamni*
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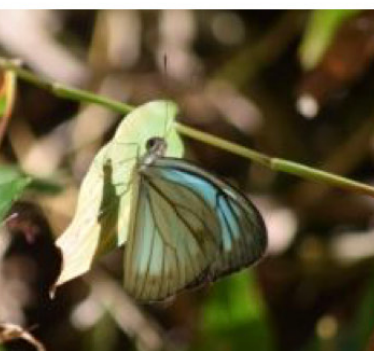


Image 24. *Pareronia valeria*
©HC



Image 25. *Pieris brassicae*
©HC



Image 26. *Pieris canidia* ©HC



Image 27. *Graphium nomius*
©HC



Image 28. *Graphium sarpedon*
©HC



Image 29. *Papilio bianor* ©HC



Image 30. *Papilio clytia* ©HC



Image 31. *Papilio demoleus*
©HC



Image 32. *Papilio polytes* ©HC



Image 33. *Papilio protenor*
©HC

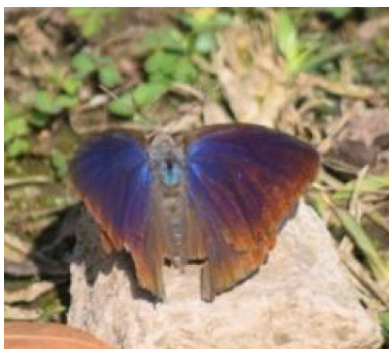


Image 34. *Arhopala amantes*
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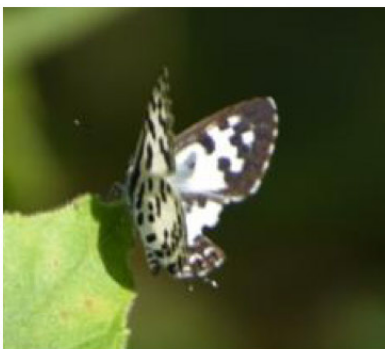


Image 35. *Castalius rosimon*
©HC

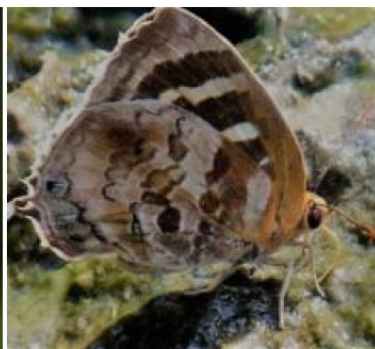


Image 36. *Flos asoka* ©HC

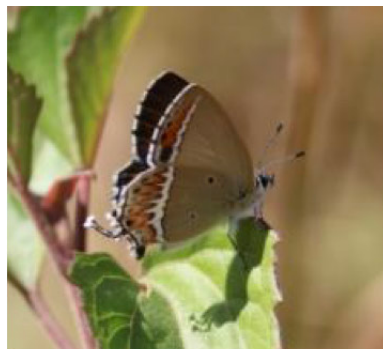


Image 37. *Heliophorus sena*
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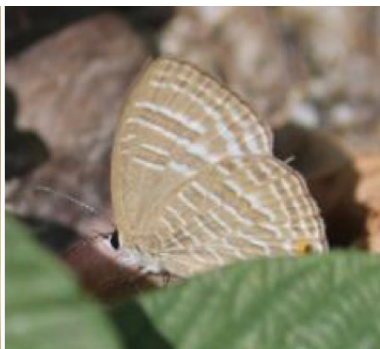


Image 38. *Jamides celeno*
©AV

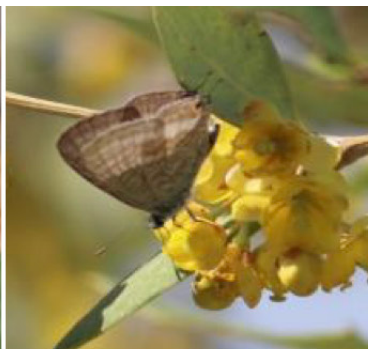


Image 39. *Lampides boeticus*
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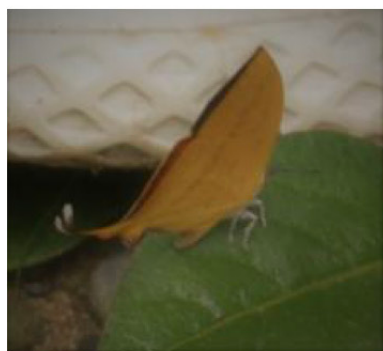


Image 40. *Loxura atymnus*
©HC

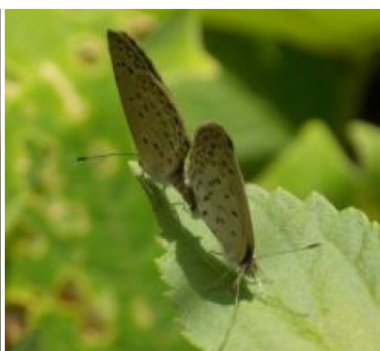


Image 41. *Pseudozizeeria maha* ©HC



Image 42. *Talicada nyseus*
©HC



Image 43. *Tarucus nara* ©HC



Image 44. *Zizeeria karsandra*
©HC

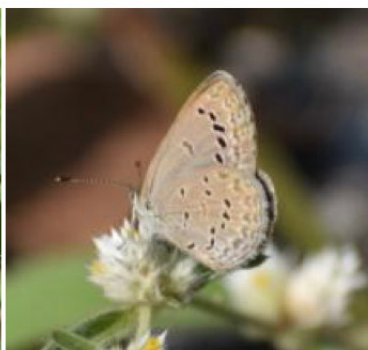


Image 45. *Zizina otis* ©HC



Image 46. *Zizula hylax* ©HC

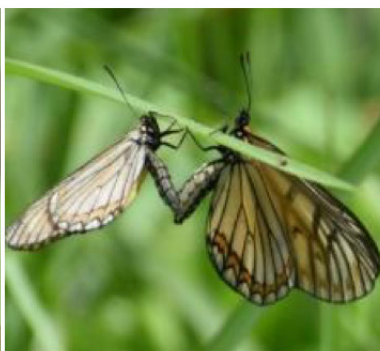


Image 47. *Acraea issoria* ©HC

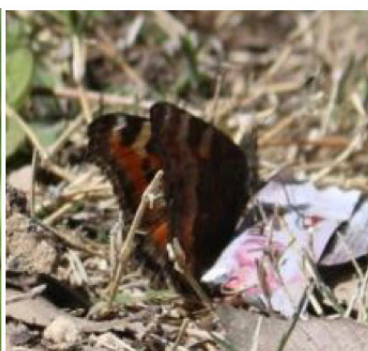


Image 48. *Aglais caschmirensis* ©AV



Image 49. *Ariadne merione*
©HC



Image 50. *Athyma cama* ©HC



Image 51. *Athyma perius* ©AV



Image 52. *Athyma selenophora*
©HC



Image 53. *Charaxes agrarius*
©HC



Image 54. *Charaxes bharata*
©HC



Image 55. *Cyrestis thyodamas*
©AV



Image 56. *Danaus chrysippus*
©HC

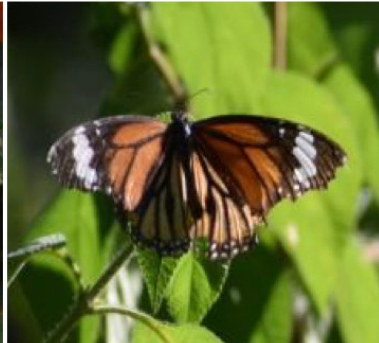


Image 57. *Danaus genutia*
©HC

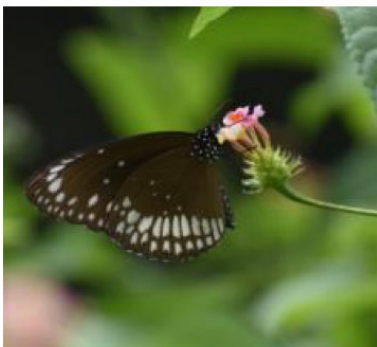


Image 58. *Euploea core* ©HC

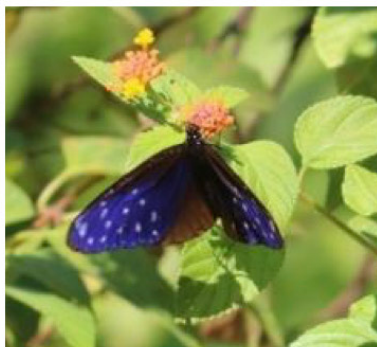


Image 59. *Euploea mulciber*
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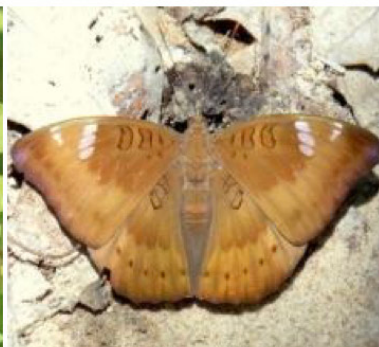


Image 60. *Euthalia aconthea*
©HC



Image 61. *Hestinalis nama*
©HC

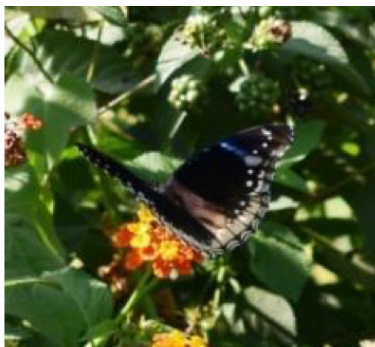


Image 62. *Hypolimnas bolina*
©HC

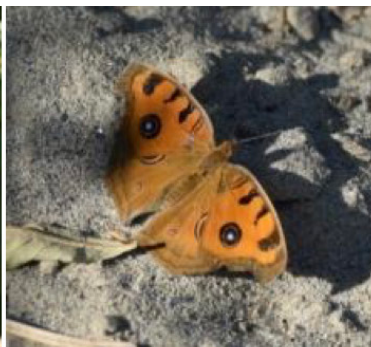


Image 63. *Junonia almana*
©HC

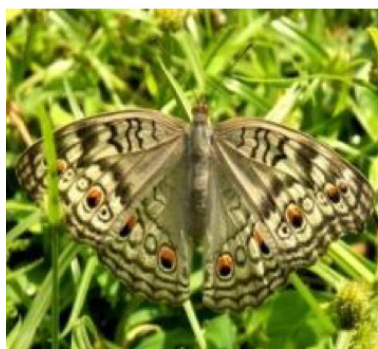


Image 64. *Junonia atlites* ©HC



Image 65. *Junonia iphita* ©AV

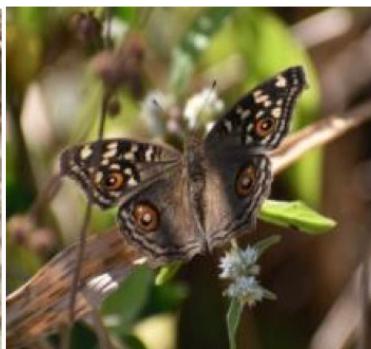


Image 66. *Junonia lemonias*
©HC



Image 67. *Junonia orithya* ©HC



Image 68. *Kallima inachus*
©AV



Image 69. *Kaniska canace*
©AV

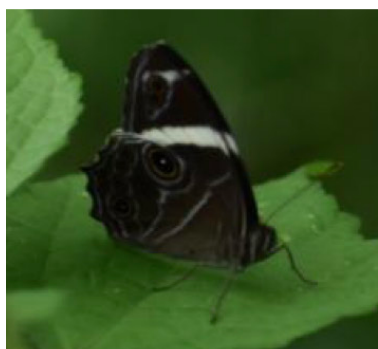


Image 70. *Lethe confusa* ©HC



Image 71. *Lethe rohria* ©HC

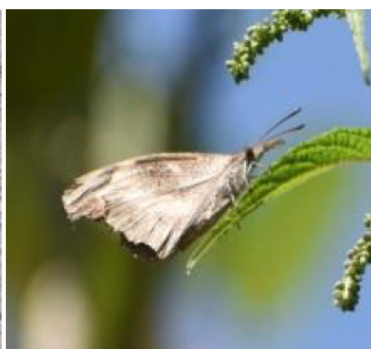
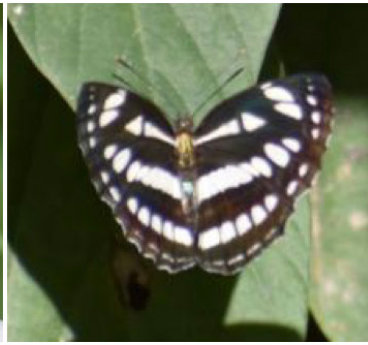
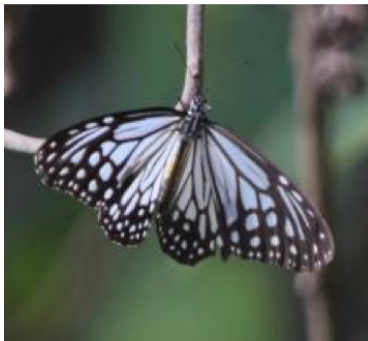
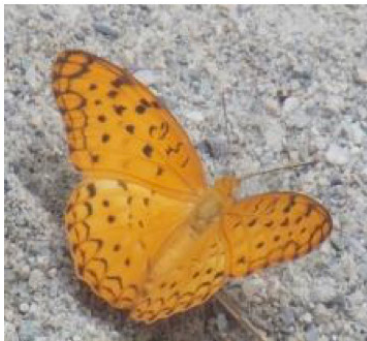
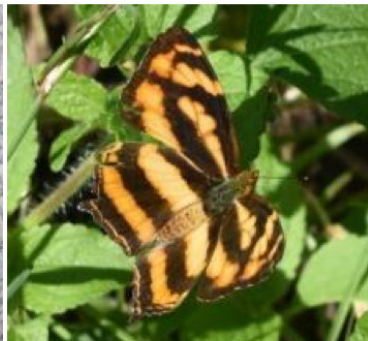
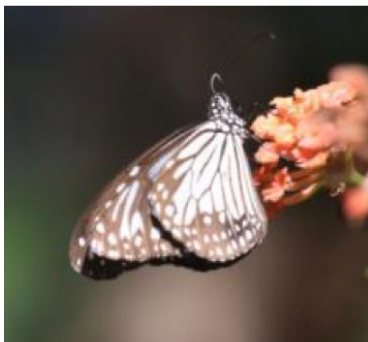
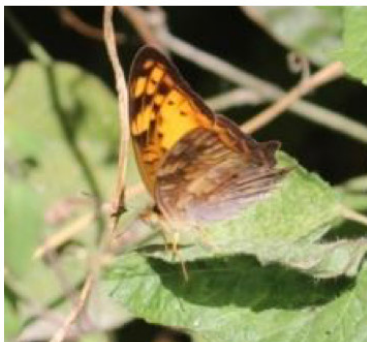
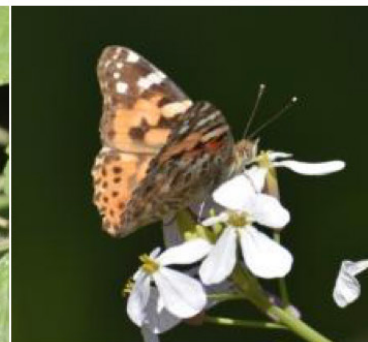
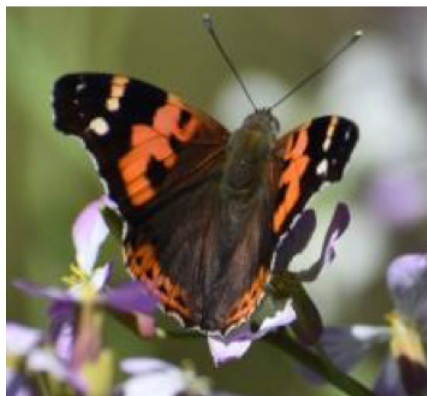
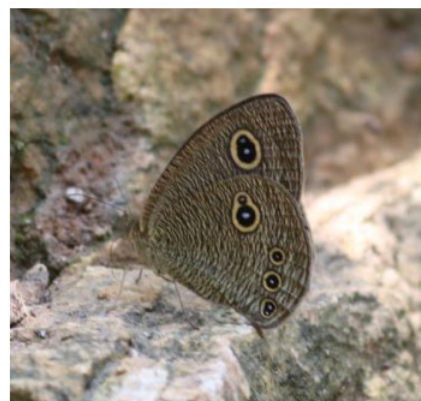


Image 72. *Libythea lepita* ©HC

Image 73. *Melanitis leda* ©HCImage 74. *Mycalesis perseus* ©HCImage 75. *Neptis hylas* ©HCImage 76. *Neptis clinia* ©HCImage 77. *Neptis soma* ©AVImage 78. *Pantoporia hordonia* ©HCImage 79. *Parantica aglea* ©HCImage 80. *Phalanta phalantha* ©HCImage 81. *Symbrenthia lilaea* ©HCImage 82. *Tirumala limniace* ©HCImage 83. *Vagrans egista* ©AVImage 84. *Vanessa cardui* ©HC

Image 85. *Vanessa indica* ©HCImage 86. *Ypthima asterope* ©HCImage 87. *Ypthima kasmira* ©HCImage 88. *Ypthima narenda* ©HCImage 89. *Ypthima nikaia* ©AV

interconnected natural forests supporting rich diversity, as well as providing better gene flow between butterfly populations. The establishment of several biodiversity offsets in different habitats will aid in the proliferation of butterflies. Government authorities and local bodies associated with management of the sanctuary should focus on activities related to plantation of more host plants and continuous monitoring programs to ensure their effective long-term conservation in the landscape.

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Appendix 1. Checklist of butterflies recorded from the Nandhour Landscape, Uttarakhand, India (March 2018–February 2020).

	Common name	Scientific name	Presence (+) and absence (-) across sites								Seasonality	Relative abundance
			S1	S2	S3	S4	S5	S6	S7	S8		
	Family: Hesperidae											
01	Veined Scrub Hopper	<i>Aeromachus stigmata</i> (Moore)*	-	-	-	-	-	+	-	-	R	0.13
02	Lesser Rice Swift	<i>Borbo bevani</i> (Moore)*	+	+	+	+	+	+	+	+	S, R, W	1.29
03	Straight Swift	<i>Parnara guttatus</i> (Moore)	+(a)	+	+	+	+	+	+	+	S, R, W	1.82
04	West Himalayan Dart	<i>Potanthus dara</i> (Kollar)* ^ε	-	-	+	+	+	-	-	-	R	0.38
05	West Himalayan Pied Flat	<i>Pseudocoladenia fatih</i> (Kollar)*	-	-	+	-	+	-	-	-	S, R	0.34
06	Water Snow Flat	<i>Tagiades litigiosa</i> Moschler*	-	-	+	+	-	+	-	+	R	0.22
07	Dark Palm Dart	<i>Telicota colon</i> (Fabricius)	-	-	+(a)	+(a)	+(a)	-	-	+	S, R	0.14
08	Grass Demon	<i>Udaspes folus</i> (Cramer)*	+	-	-	-	+	+	-	-	R	0.13
	Family: Riodinidae											
09	Double-banded Judy	<i>Abisara bifasciata</i> Moore*	-	-	+	-	-	-	+	-	R	0.07
10	Common Punch	<i>Dodona durga</i> (Kollar)* ^ε	-	-	+	+	+	+	+	+	S, R, W	1.39
11	Punchinello	<i>Zemeros flegyas</i> (Cramer)*	-	+	+	-	+	+	+	+	S, R, W	0.43
	Family: Pieridae											
12	Lemon Emigrant	<i>Catopsilia pomona</i> (Fabricius)	+(a)	-	+	+	+	+	+	+	S, R, W	6.78
13	Mottled Emigrant	<i>Catopsilia pyranthe</i> (Linnaeus)	+(a)	-	+	+	+	+	+	+	S, R, W	3.85
14	Common Gull	<i>Cepora nerissa</i> (Fabricius)	-	-	+(a)	-	+	-	-	+	S, R	0.78
15	Eastern Pale Clouded Yellow	<i>Colias erate</i> (Esper)*	-	+	+	-	+	+	-	+	S, R, W	0.35
16	Dark Clouded Yellow	<i>Colias fieldii</i> Menetries	+	+	+(a)	+	+(a)	+	+	+	S, R, W	0.92
17	Indian Jezebel	<i>Delias eucharis</i> (Drury)	+	-	-	-	-	-	-	+	S, R, W	0.73
18	Common Grass Yellow	<i>Eurama hecabe</i> (Linnaeus)	+(a)	-	+	+	+	+	+	+	S, R, W	4.48
19	One-spot Grass Yellow	<i>Eurema andersonii</i> (Moore)	-	-	+	+	+	-	-	-	R	0.45
20	Three-spot Grass Yellow	<i>Eurema blanda</i> (Boisduval)	-	-	+	+	+	-	-	-	S, R	0.80
21	Small Grass Yellow	<i>Eurema brigitta</i> (Stoll)*	+	+	+	-	+	-	-	-	S, R, W	2.22
22	Spotless Grass Yellow	<i>Eurema laeta</i> (Boisduval)	+(a)	+	+	+	+	+	+	+	S, R, W	5.05
23	Pale Brimstone	<i>Gonepteryx rhamni</i> (Linnaeus)*	+	+	+	+	+	+	+	+	S, R, W	1.20
24	Indian Wanderer	<i>Pareronia valeria</i> (Cramer)	-	-	+	-	+	-	+	+	S, R, W	0.48
25	Large Cabbage White	<i>Pieris brassicae</i> (Linnaeus)*	+	+	+	+	+	+	+	+	S, R, W	5.84
26	Asian Cabbage White	<i>Pieris canidia</i> (Linnaeus)	+(a)	-	+	+	+	+	+	+	S, R, W	3.97
	Family: Papilionidae											
27	Spot Swordtail	<i>Graphium nomius</i> (Esper)	-	-	+(a)	+(a)	-	-	-	+	S	0.42
28	Common Bluebottle	<i>Graphium sarpedon</i> (Linnaeus)*	-	-	+	-	+	-	+	+	S, R	0.78
29	Common Peacock	<i>Papilio bianor</i> Cramer*	-	-	+	+	+	+	-	+	S, R, W	0.71
30	Common Mime	<i>Papilio clytia</i> (Linnaeus)*	-	-	+	-	-	-	-	+	S	0.16
31	Lime Swallowtail	<i>Papilio demoleus</i> (Linnaeus)	+(a)	-	+	+	+	+	+	+	S, R, W	2.88
32	Common Mormon	<i>Papilio polytes</i> (Linnaeus)	+(a)	-	+	+	+	+	+	+	S, R, W	3.70

	Common name	Scientific name	Presence (+) and absence (-) across sites								Seasonality	Relative abundance
			S1	S2	S3	S4	S5	S6	S7	S8		
33	Spangle	<i>Papilio protenor</i> Cramer*	-	-	+	+	-	+	-	+	S, R	0.55
Family: Lycaenidae												
34	Large Oakblue	<i>Arhopala amantes</i> (Hewitson)*	-	-	-	-	-	-	+	-	R	0.10
35	Common Pierrot	<i>Castalius rosimon</i> (Fabricius)	-	-	+	-	+	-	-	+	S, R, W	0.42
36	Spangled Plushblue	<i>Flos asoka</i> (de Niceville)*	-	-	-	-	-	-	+	-	S	0.05
37	Sorrel Sapphire	<i>Heliophorus sena</i> (Kollar) ^E	+	+	+	-	+	+	+	+	S, R, W	3.20
38	Common Cerulean	<i>Jamides celeno</i> (Cramer)	+	-	+	-	+	+	+	-	S, R, W	1.06
39	Pea Blue	<i>Lampides boeticus</i> (Linnaeus)#	+	-	+	+	+	+	+	+	S, R, W	1.91
40	Yamfly	<i>Loxura atymnus</i> (Stoll)*	-	-	-	-	+	-	+	+	R	0.36
41	Pale Grass Blue	<i>Pseudozizeeria maha</i> (Kollar)*	+	+	+	+	+	+	+	+	S, R, W	5.69
42	Red Pierrot	<i>Talica niseus</i> (Guerin-Meneville)*	-	-	+	+	-	+	-	-	S, R	0.66
43	Striped Pierrot	<i>Tarucus nara</i> (Kollar)	-	-	+	-	+	-	-	-	R	0.05
44	Dark Grass Blue	<i>Zizeeria karsandra</i> (Moore)*	+	+	+	+	+	+	+	+	S, R, W	2.81
45	Lesser Grass Blue	<i>Zizina otis</i> (Fabricius)*	+	+	+	+	-	-	-	-	S, R, W	1.35
46	Tiny Grass Blue	<i>Zizula hylax</i> (Fabricius)*	-	+	-	-	-	-	-	-	S	0.16
Family: Nymphalidae												
47	Yellow Coster	<i>Acraea issoria</i> (Hubner)* ^E	-	-	+	-	+	+	-	+	S, R	0.68
48	Indian Tortoiseshell	<i>Aglaia caschmirensis</i> (Kollar)* ^E	+	+	+	+	+	+	+	+	S, R, W	1.26
49	Common Castor	<i>Ariadne merione</i> (Cramer)	+	+	+	+	+	+	+	+	S, R, W	0.88
50	Orange Staff Sergeant	<i>Athyma cama</i> Moore* ^E	-	-	+	-	+	-	-	+	S, R	0.15
51	Common Sergeant	<i>Athyma perius</i> (Linnaeus)*	-	-	+	-	-	-	+	+	S, R	0.40
52	Staff Sergeant	<i>Athyma selenophora</i> (Kollar)*	-	-	+	-	-	-	-	-	S	0.01
53	Anomalous Nawab	<i>Charaxes agrarius</i> Swinhoe*	-	-	-	-	+	-	-	-	R	0.07
54	Indian Nawab	<i>Charaxes bharata</i> Felder & Felder*	-	-	+	-	+	-	-	-	S, R	0.25
55	Common Map	<i>Cyrestis thyodamas</i> Boisduval	-	-	-	-	+	+	-	+	S, R	0.46
56	Plain Tiger	<i>Danaus chrysippus</i> (Linnaeus)	+	-	+	+	+	+	+	+	S, R, W	1.66
57	Striped Tiger	<i>Danaus genutia</i> (Cramer)	+	-	+	+	+	+	+	+	S, R, W	1.91
58	Common Crow	<i>Euploea core</i> (Cramer)#	+	-	+	+	+	+	+	+	S, R, W	2.14
59	Striped Blue Crow	<i>Euploea mulciber</i> (Cramer)#	-	-	+	-	+	-	+	+	S, R, W	0.37
60	Baron	<i>Euthalia aconthea</i> (Cramer)	+	+	-	-	+	-	-	+	S, R, W	0.36
61	Circe	<i>Hestialis nama</i> (Doubleday)*	-	-	+	-	+	-	-	-	S, R	0.38
62	Great Eggfly	<i>Hypolimnas bolina</i> (Linnaeus)	-	-	+	+	+	-	+	+	S, R, W	0.57
63	Peacock Pansy	<i>Junonia almana</i> (Linnaeus)	-	+	+	+	+	-	-	+	S, R, W	0.87
64	Grey Pansy	<i>Junonia atlites</i> (Linnaeus)	-	+	+	-	+	-	-	+	S, R, W	0.40
65	Chocolate Pansy	<i>Junonia iphita</i> (Cramer)	+	+	+	+	+	+	+	+	S, R, W	1.48
66	Lemon Pansy	<i>Junonia lemonias</i> (Linnaeus)	+	-	+	+	+	+	+	+	S, R, W	0.84
67	Blue Pansy	<i>Junonia orithya</i> (Linnaeus)	+	-	+	+	+	+	+	+	S, R, W	0.73

	Common name	Scientific name	Presence (+) and absence (-) across sites								Seasonality	Relative abundance
			S1	S2	S3	S4	S5	S6	S7	S8		
68	Orange Oakleaf	<i>Kallima inachus</i> (Doyere)*	-	-	+	-	+	-	-	-	R	0.16
69	Blue Admiral	<i>Kaniska canace</i> (Linnaeus)*	-	-	-	+	-	+	-	-	S	0.16
70	Bamboo Treebrown	<i>Lethe confuse</i> Aurivillius*	-	-	-	-	+	-	-	-	S	0.09
71	BandedTreebrown	<i>Lethe rohria</i> (Fabricius)*	-	-	-	+	-	+	-	-	S, R	0.42
72	Common Beak	<i>Libythea lepita</i> Moore*#	-	-	-	-	-	+	-	+	S, R	0.17
73	Common Evening Brown	<i>Melanitis leda</i> (Linnaeus)	+	-	+	-	+	+	+	+	S, R, W	0.65
			(a)		(a)		(a)					
74	Long-banded Bushbrown	<i>Mycalesis perseus</i> (Fabricius)	-	-	-	+	-	+	-	-	S, R	0.18
75	Common Sailer	<i>Neptis hylas</i> (Linnaeus)* ^E	-	+	+	+	+	+	+	+	S, R, W	1.16
76	Sullied Sailer	<i>Neptis clinia</i> Moore*	+	-	+	+	+	-	-	-	S, R, W	0.48
77	Creamy Sailer	<i>Neptis soma</i> Moore*#	-	-	+	+	-	+	-	+	S, R, W	0.88
78	Common Lascar	<i>Pantoporia hordonia</i> (Stoll)*	-	-	+	-	+	-	+	+	S, R, W	0.37
79	Glassy Tiger	<i>Parantica aglea</i> (Stoll)	+	-	+	+	+	+	+	+	S, R, W	1.26
80	Common Leopard	<i>Phalanta phalantha</i> (Drury)	+	-	+	+	+	-	+	+	S, R	0.38
			(a)		(a)	(a)	(a)					
81	Common Jester	<i>Symbrenthia lilaea</i> Moore	-	-	+	+	+	+	-	+	S, R	0.41
					(a)	(a)						
82	Blue Tiger	<i>Tirumala limniace</i> (Cramer)	+	-	+	+	+	-	+	+	S, R, W	0.82
					(a)	(a)						
83	Vagrant	<i>Vagrans egista</i> (Cramer)*	-	-	+	-	+	-	-	-	S, R	0.41
84	Painted Lady	<i>Vanessa cardui</i> (Linnaeus)	-	+	+	+	+	+	-	-	S, R, W	0.69
					(a)	(a)	(a)					
85	Indian Red Admiral	<i>Vanessa indica</i> (Herbst)*	+	+	+	+	+	+	+	+	S, R, W	1.22
86	Common Three-ring	<i>Ypthima asterope</i> (Klug)*	-	-	-	-	+	-	-	-	S, R	0.14
87	Common Four-ring	<i>Ypthima kasmira</i> Moore*	+	+	+	+	+	+	+	+	S, R	1.28
88	Large Three-ring	<i>Ypthima nareda</i> (Kollar)*	-	-	-	-	-	+	-	-	S, R	0.51
89	Kumaon Five-ring	<i>Ypthima nikaea</i> Moore* ^E	-	-	-	+	-	+	-	-	S, R	0.71

S—summer | R—rainy | W—winter | *—represents new records for the Nandhour Landscape | #—represents legally protected species under the Indian Wildlife (Protection) Act 1972 | E—represents endemic butterflies of the Indian Himalayan Region (Evans 1932; Wynter-Blyth 1957; Smetacek 2012; Kehimkar 2016) | a—represents species also reported by Arya & Dayakrishna (2017).

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 ravi@threatenedtaxa.org



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