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Associations of butterflies across different forest types in Uttarakhand, western Himalaya, India: implications for conservation planning

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Abstract: Champion & Seth classified Indian forests into different ‘forest types and sub-types’, based on similarity of dominant vegetation and structural arrangement of species in each. However, it is not known if the species composition and community structure of butterflies is also different in each forest sub-type. If this is the case then each forest sub-type harbouring unique species can be taken as units of conservation on a sub-regional scale. The present study assesses for the first time the species composition and community structure of butterflies across 20 different and prominent ‘forest sub-types’ found across the state of Uttarakhand, western Himalaya. Data collected over eight years (2006–2009; June 2012; 2017–2020) using random seasonal sampling covering 307 transects revealed 370 butterfly taxa. Hierarchical clustering of butterfly abundances revealed seven different butterfly communities spread over 19 forest subtypes. Of these four forest sub-types (3C/C2a moist Shiwalik sal forest; 12/C2c moist temperate deciduous forest; 12/C1a ban oak forest; & 3C/C2c moist Terai sal forest) were identified as most important as they hold most of the butterfly diversity of the state including 58 rare taxa identified according to ‘rarity’ out of the total. GIS based mapping of these 58 priority species over laid on the protected area network and forest cover distribution in the state revealed many forested sites outside the PA network supporting these rare taxa. These sites along a physio-geographical gradient with important forest sub-types and rare taxa can be recommended and listed as new sites for conservation in the state.

Keywords: Ban Oak, butterfly, protected area network, physiogeography, rarity, tropical moist deciduous forest, vegetation.
INTRODUCTION

Butterflies, amongst invertebrates, are suitable indicators for ecological studies (Lomov et al. 2006), as the taxonomy, geographical distribution and status of many species are relatively well known (Pollard 1977; Thomas 1983; Thomas & Mallorie 1985; Murphy & Wilcox 1986). They are phytophagous, primary herbivores, good pollinators and surrogates plant diversity living close by their food plants (Ehrlich & Raven 1964; Gilbert & Smiley 1978; Pyle 1980). The precise and restricted environmental requirements of particular butterflies make them of considerable value as a group of indicator taxa that indicate the broader effects of environmental changes or reflects a particular suite of ecological conditions or habitat heterogeneity (Pyle 1980; Gilbert 1980, 1984; Brown 1982; Rosenberg et al. 1986; Murphy et al. 1990; New 1991; Kermen 1992; Pearman et al. 1995). Strong association between vegetation structure and composition makes Lepidoptera a particularly useful bioindicator for monitoring eco-restoration programs (Kremen et al. 1993; New et al. 1995).

Habitat is an important requisite for the proliferation and conservation of a butterfly species (Gilbert & Singer 1975), as species prefer particular habitats, closely related to their life history, breeding, larval and adult food resources and destruction of forest severely affects species habitats (Wells et al. 1983) and many species which were once common become rare. Thus, identification and conservation of priority landscapes, is very important. Champion & Seth (1968) classified Indian forests into different ‘forest types’ their sub units as ‘forest sub-types’, based on the similarity of dominant vegetation and structural arrangement of species within each of them, i.e., ‘IV montane temperate forest’ is one of VI major ‘forest types’ found across India (other 5 categories being “I. moist tropical forests, II. dry tropical forests; III montane sub-tropical forests; V sub-alpine forests, and VI alpine forests” classified by Champion & Seth (1968)), while its lowest unit in the hierarchy is a ‘sub-type’, e.g., “12C/1a Ban oak forest” (Here, ‘12’ signifies “12 Himalayan moist temperate forest” in a group of three (the other two being 11 Montane wet temperate forests & 13 Himalayan dry temperate forests). Then further sub-division of this sub-group “12” into three groups: C1–C3, where “C,” signifies ‘C’, lower western Himalayan temperate forest’ (other 2 being “C2 upper west Himalayan temperate forest” and “C3 east Himalayan temperate forest”) and lastly its last sub-division which is depicted as “1a”, i.e., “1a Ban oak forest (Q. incana)” (Quercus incana = Q. leucotrachyphora) amongst the set of two (the other being “1b Moru oak forest (Q. dialata)” (Quercus dialata = Q. floribunda) (Champion & Seth 1968)]. In this way, different ‘forest subtypes’ have been classified and labelled in India.

However, it is not known if the species composition and community structure of lower groups of animals such as butterflies are also different within each ‘forest-sub-type’ or each have a unique community of butterflies. If this is the case then each forest sub-type harbouring unique and rare species can be taken as a unit of conservation on a sub-regional scale (western Himalaya) or state level (Uttarakhand). In this study we tried to evaluate and examine potential ‘forest sub-types’ or ‘a group of forest sub-types’ that have unique butterfly diversity which can be taken up as units of conservation of biodiversity at the state level. Besides, this can also be helpful in identification of new conservation areas with forest habitats outside the PA network and thus fill gaps in their connectivity, in the state. The rationale behind this is that many butterfly species are restricted to forested habitats in the state, have geographical distribution spread across the Himalayan region, i.e., western, central, and eastern Himalaya along a wide altitudinal gradient, e.g., Pale Green Sailer Neptis zaida zaida Doubleday, [1848] or Broad-banded Sailer, N. sanka sanka Kollar, [1844]) (Nymphalidae) both occur in the state between 800–2,500 m, as observed in the present study. Fragmentation of their forested habitats on a larger spatial and temporal scale, may lead to isolated populations, local extinctions that can significantly affect their distribution, as they do not migrate. Thus, gaps and connectivity of the protected areas needs to be maintained for long term conservation.

STUDY AREA

The study was carried out in Uttarakhand state of India which covers an area of 53,483 km², which is 1.63% of the geographical area of the country, and lies between 28.716–31.466 N latitude & 77.566–81.05 E longitude. This predominantly mountainous state, shares its borders with Himachal Pradesh to the west and Uttar Pradesh to the south. It also shares international borders with Nepal in the east and China (Tibet) to the north. The state is mainly representative of the western Himalaya, the climate and vegetation vary greatly with altitude, from glaciers at the highest elevations, and temperate to subtropical at the lower elevations. Nanda Devi peak is the highest point at 7,816 m in the state while the lowest areas at ~100m lie in the Terai grasslands.
The average annual rainfall is 1,500 mm and the annual temperature varies from below 0°C to 43°C. Major rivers, Ganga, Yamuna, Ramganga, & Sharda, drain the state along with their tributaries. The Himalayan range in Uttarakhand is divided into the distinct non-montane and montane physiographic zones. The lower zone comprises the ‘Bhabhar’ region in non-montane lowland woodlands having Gangetic moist deciduous forests and the Terai region (below 500 m) running parallel to it, which comprises mainly the marshes and grasslands (Botanical Survey of India 2021). The montane region is divided into sub-Himalaya, which consists of the Shiwalik ranges, the lower Himalayan ranges, and the Doon (flat long valleys) lying north of the Shiwaliks (~500–1,000 m). Above this region are the lesser Himalaya (~1,000–3,000 m) followed mid Himalaya (~3,000–4,000 m) and then greater Himalaya (~4,000–6,000 m) (Khanduri et al. 2013) and the trans-Himalaya (above 5,000 m), also known as the Tethys Himalayas and the Indo-Tibet plateau, the region is in the rain shadow area that transforms into the cold desert.

Forests cover an area of 24,303.04 km² in the state, which constitutes 45.44% of the state’s geographical area (FSI 2019). The state is represented by biogeographic zone 2B western Himalaya and 7B Shiwaliks of India (Rodgers & Pawar 1988). The state is rich in biodiversity having about 102 species of mammals, 692 birds (https://ebird.org/region/IN-UL), 13 amphibians & 53 reptiles (Vasudevan & Sondhi 2010), and 124 fishes (https://forest.uk.gov.in/wildlife-management). Some of the globally endangered fauna like the Asiatic Elephant Elephas maximus, Snow Leopard Panthera uncia, Tiger Panthera tigris, Leopard Panthera pardus, Musk Deer Moschus chrysogaster, Swamp Deer Rucervus duvaucelii, Cheer Pheasant Catreus wallichii, and the King Cobra Ophiophagus hannah are found in the state. Uttarakhand shelters around 4,000 species of plants, belonging to 1,198 genera, under 192 families, of which ~34 species have been listed as threatened (Nayar & Sastry 1987, 1988, 1990; https://indiabiodiversity.org/). The PA network cover 12 percent of the total geographical area of the state, which includes six national parks, seven wildlife sanctuaries, four conservation reserves, and one biosphere reserve (Appendix 1).

**Previous studies on butterflies in Uttarakhand**

Studies on natural history and checklists of different areas in Uttarakhand state have been carried out as early as 1886 (Doherty 1886; Mackinnon & de Nicéville 1889; Hannyngton 1910–11; Ollenbach 1930; Shull 1958, 1962; Baindur 1993; Smetacek 2002, 2004, 2012; Bhardwaj et al. 2012; Bhardwaj & Uniyal 2013; Singh &
Bhandari 2003, 2006; Singh & Sondhi 2016; Verma & Arya 2018; Sondhi & Kunte 2018; Singh & Singh 2021) and the total number of butterfly species recorded in the state so far is ~ 500 species, based on these records. However, none of these studies give an account on the association of butterfly species with different forest sub-types as classified by Champion & Seth (1968), found across the state of Uttarakhand. The author had earlier studied butterfly-forest type associations in 11 major “forest sub-types” in the state of Arunachal Pradesh (eastern Himalaya), India (Singh 2017) and identified four forest sub-types: 2B/1S1 sub-Himalayan light alluvial plains semi-evergreen forests; 2B/C1a Assam alluvial plains semi-evergreen forests; 2B/2S2 eastern alluvial secondary semi-evergreen forests, and 3/1S2 b Terminalia-Duabanga as major forest sub-types supporting 415 butterfly taxa along with many rare and endemic species in the northeastern region and eastern Himalaya, but the forest sub-types occurring in these two Himalayan states are totally different from each other.

**METHODS**

Random sampling surveys were carried out for eight years under two different projects (2006–2009 and 2017–2020, respectively) across 11 districts of Uttarakhand state covering all the six butterfly seasons (spring, summer, pre-monsoon, monsoon, post-monsoon, autumn, and winter; Smith 1989) of the year. Surveys were carried out using ‘Pollard Walk’ on the line transects (Pollard & Yates 1993). Sampling on each transect (ca. 1 km) was done and butterflies were observed up to 20 m on both the sides of the trail for 1 h in a stretch between 1000 h and 1600 h to collect data on individual butterfly species abundance. Each sampling survey was carried out by the author, while 1–2 helpers were also used for recording data, collection of insect and plant material from time to time. Coordinates of all the locations for 307 samplings carried out were recorded using a GPS (Etrex Garmin Vista) (Figure 1) covering 20 major forest sub-types (FSI 2011; Figure 2 & Appendix ii) existing across the state of Uttarakhand.

Identification and distribution range of each taxa was assessed based on published literature (Moore 1874, 1890–1992, 1893–1896, 1896–1899, 1899–1900, 1901–1903, 1903–1905; Swinhoe 1905–1910, 1910–1911, 1911–1912 & 1912–1913; Bingham 1905; Talbot 1939, 1947; Evans 1932; Wynter-Blyth 1957; D’Abrera 1982, 1985, 1986; Haribal 1992; Smith 1989, 2006; Kehimkar 2008, 2016; Singh 2011; Smetacek 2015; Gasse 2017; Sondhi & Kunte 2018) and websites (http://www.ifoundbutterflies.org/ and http://flutters.org/). Comparison of a few specimens was also done with specimens at the National Forest Insect Collection (NFIC) at Forest Research Institute, Dehradun, Uttarakhand, India, for identification.

Dominant vegetation (mainly trees & shrubs) in the respective forest sub-types were also identified and confirmed by ground truthing by laying down 10 x 10 m quadrates, collected plant material and preparing herbariums. Photographs and herbarium specimens were identified in the field and many were identified and confirmed from plant taxonomists based at Systematic Botany Branch, Botany Division, FRI, Dehradun and literature (Brandis 1906; Rai et al. 2017; http://www.gbif.org).

**Evaluating species of conservation priority: rarity analysis of butterflies**

The degree of “rarity” characterizing a species is usually an indicator of extinction risk (Rabinowitz et al. 1986; Pimm et al. 1988; Arita et al. 1990; Primarck 1993; Gaston 1994; Brown 1995; Gaston & Blackburn 1995) and provides a basis to identify threatened species (Rabinowitz 1981; Arita et al. 1990; Daniels et al. 1991; Berg & Tjernberg 1996). In general, species characterized by small geographic range, habitat specialization, and low abundance, are at higher risk of extinction than a widely distributed, habitat generalist and with high abundance. Rabinowitz et al. (1986) have examined types of rarity, and in what important ways rare species differ from one another. They first distinguish three traits, characteristic of all taxa recorded: (i) Geographical range - whether a species occurs over a broad area or whether it is endemic to a particular area; (ii) Habitat specificity - the degree to which a species occurs in a variety of biotopes’ or ‘habitats’ is restricted to one or a few specialized sites versus generalists; and (iii) Local population size - whether a species occurs in large populations somewhere within range or has small populations whenever it is found.

In the present study, Rabinowitz et al. (1986) classification of rarity based on the three above traits was used. Only those species were filtered out the total as rare which had: (i) narrow geographical range, i.e., those species which had narrow distribution restricted only to western and central Himalaya as against those with wide distribution, i.e., Himalaya, northeastern India, & Peninsular India; (ii) restricted to two or less forest sub-types as against more than two forest sub-
types; and (iii) having small local population size across their distribution range, i.e., those taxa which were classified as ‘very rare’, ‘rare’, and ‘not rare’ by Evans (1932) and Kehimkar (2008), as against ‘fairly common’, ‘common’, and ‘very common’.

Hierarchical clustering of different forest sub-types based on butterfly species distribution and relative abundance.

The data of relative abundance of all the species of butterflies sampled against 20 different forest sub-types was pooled and averaged to relative abundance per sampling in each of the forest sub-type to remove varied sampling bias and was done using statistical software “NCSS Data Analysis 2021, v21.0.2”, to know the dissimilarly of forest sub-types in terms of butterfly species composition.

RESULTS AND DISCUSSION

The field surveys revealed 370 butterfly taxa (Papilionidae (31); Pieridae (32); Nymphalidae (138); Lycaenidae (97); Hesperiidae (62) and Riodinidae (7); see appendix.iii), which accounted to ca 75% of the species recorded from the state so far. If we exclude ~ 40 historic records (Singh & Sondhi 2016; Sondhi & Kunte 2018), then it totals to 80% of the total species found in the state. The study also reported new range extensions from central and eastern Himalaya, i.e., Dark Sapphire (Singh & Seal 2019); Scarce Lilacfork Lethe dura gammiei (Moore, [1892]) (Singh & Singh 2019), Dubious Five ring Ypthima parasakra parasakra Eliot, 1987 (Singh & Singh 2022) and records like White-ringed Meadowbrown, Hyponephlele davendra davendra (Moore, 1865) (Singh & Singh 2021; Pale Jezebel Delias sanaca sanaca (Moore, [1858]) (Singh 2016); Mountain Tortoiseshell Aglais rizana (Moore, 1872) (Singh & Singh 2019); White-wedged Woodbrown Lethe dakwania Tytler, 1939.

Figure 2. Distribution of major forest types surveyed in Uttarakhand.
Butterflies across different forest types in Uttarakhand

Figure 3. Seasonality of butterflies in Uttarakhand.

Figure 4. Relative distribution of butterfly species in different forest sub-types in Uttarakhand.

Figure 5. Percentage of butterfly species in each forest sub-type in relation to the proportional area covered by each forest sub-type in Uttarakhand.

(Singh & Singh 2021), to the state. Some rare records like Garhwal Swordtail *Graphium garhwalica* (Katayama, 1988), Highbrown Silverspot, *Argynnis jainadeva* jainadeva Moore, 1864; Regal Apollo, *Parnassius charltonius* Gray, [1853] and new range extensions (Red-tailed Forester, *Lethe sinonix sinorix* (Hewitson, [1863]) and Nepal Comma *Polygonia c-album cognata* Moore, [1899]) are reported in this paper.

The relative abundance of species ranged 1–1,596 individuals. These species were then ranked into four abundance classes based on their quartile division, i.e.,
Butterflies across different forest types in Uttarakhand

Singh

Butterflies across different forest types in Uttarakhand are more diverse in the latter two than in the former. The diversity of nectar and larval food plants available in broad-leaved or mixed conifer-broad-leaved forests, as compared to pure conifer forest stands, support less diversity of butterflies as compared to the pure conifer-broad-leaved forests, as the diversity of nectar and larval food plants available are more diverse in the latter two than in the former.

Preference for Forest Sub-types

The highest number of species were recorded in 12/C1a Ban Oak Forest (292 species; Fig.4) followed by 3C/C2a Moist Shiwalik Sal Forest (220) and 12/C2c Moist Temperate Deciduous Forest (165), respectively which suggests that these forest sub-types hold the major diversity of butterflies found in the state. The number of species sampled were the least in 13/C2b Dry Deodar Forest (14), 15/C1 Birch Rhododendron Scrub (6) and 15/E1 Dwarf Rhododendron Scrub (2), respectively (Figure 4) suggesting them to be poor butterfly habitats, while the other 14 forest sub-types lay between them.

The percentage of butterfly species in each forest sub-type in relation to the proportional area covered by each in the state (Figure 5), suggests that forest sub-types: 9/C1b Upper or Himalayan Chir Pine Forest; 12/C2b West Himalayan Upper Oak/Fir Forest and 14/C1 B Western Himalayan Sub-alpine Birch/Fir Forest, support a relatively lower number of butterfly species per unit area as compared to the rest of the other forest sub-types (Figure 4). On the other hand forest sub-types: 3C/C2 Moist Shiwalik Sal Forest; 12/C1a Ban Oak Forest; 12/C2C Moist Temperate Deciduous Forest and 12/C1d Western Mixed Coniferous Forest have a relatively higher density of butterfly species per unit area amongst all the forest sub-types covered (Figure 5). The primary reason for this is that pure conifer forest stands support less diversity of butterflies as compared to the pure broad-leaved or mixed conifer-broad-leaved forests, as the diversity of nectar and larval food plants available are more diverse in the latter two than in the former.

Hierarchical clustering of forest sub-types

It was found that 7 forest-types butterfly clusters, 5 independent forest-subtypes and 2 clusters of 2 and 11 forest sub-types, respectively exist in the state (Fig.6). These are

1. 3C/C2a Moist Shiwalik Sal Forest.
2. 12/C2c Moist Temperate Deciduous Forest
3. 12/C1a Ban Oak Forest.
4. 3C/C2c Moist Terai Sal Forest
5. 9/C1b Upper or Himalayan Chir Pine
6. 5B/C2 Northern Dry Mixed Deciduous Forest & 5B/C1a Dry Shiwalik Sal Forest.
7. 12/C1b Moru Oak; 12/C2b Western Himalayan
   Upper Oak Forest/Fir; 12/C1d Western Mixed Coniferous;
   12/2S1 Low Level Blue Pine; 12/C2a Khasru Oak Forest;
   14/C1a West Himalayan Sub-alpine Fir; 14/C1 Best
   Himalayan Sub-alpine Birch/Fir/ 14/1S2 Deciduous Sub-
   alpine Scrub & 15/C1 Birch/Rhododendron Scrub.
The dendrogram (Figure 6) suggests that the butterfly community of 3C/C2a Moist Shiwalik Sal Forest is totally distinct from that of 12/C2c Moist Temperate Deciduous Forest and 12/C1a Ban Oak forest. While 12/C1a Ban Oak Forest and 12/C2c Moist Temperate Deciduous Forest show greatest similarity. While diversity of 5B/C2 Northern Dry Mixed Deciduous Forest and 5B/C1a Dry Shiwalik Sal is different from that of 3C/C2c Moist Terai Sal Forest or 3C/C2a Moist Shiwalik Sal Forest. Eleven forest sub-types show another cluster being distinct from other groups (Figure 6). Four forest sub-types that are most important in the state in terms of number of both butterfly species and with distinct dissimilarity of butterflies are 3C/C2a Moist Shiwalik Sal Forest; 12/C2c Moist Temperate Deciduous Forest; 12/C1a Ban Oak Forest and 3C/C2c Moist Terai Sal Forest.

Species preference of forest sub-types

Scatter plot (Figure 7) of individual butterfly species (n= 370) suggests that only one generalist species (Painted Lady Vanessa cardui) had preference for all 14 forest sub-types. While the number of species showing preference for more than five or more forest sub-types were fewer as compared to species showing preference for less than four forest sub-types (Figure 7 Horizontal bars) in the state. The maximum number of species showed preference for two forest sub-types (n= 90 species) followed by preference for only one forest sub-type (n= 60 species). This suggests that a large number of habitat specialist species exist in the state.
Butterflies across different forest types in Uttarakhand

Rarity in butterflies sampled in Uttarakhand: taxa of conservation priority

Out of the 370 taxa sampled in Uttarakhand, 58 were evaluated as rare species of conservation priority /concern based on rarity analysis (Rabinowitz 1981; Rabinowitz et al. 1986) (Appendix IV).

The 58 taxa of conservation concern evaluated based on rarity are scattered all across the state in at least 12 forest sub-types (Figure 8). It was also determined that most of the butterfly taxa of conservation priority occur in 12/C1a Ban Oak Forest followed by 12/C2c Moist Temperate Deciduous forest, 3C/C2 Moist Shiwalik Sal Forest and a few taxa in 12/C2b Western Himalayan Upper Oak/Fir Forest; 12/C1d Western Mixed Coniferous Forest, respectively (Figures 8–15).

The present study proved that individual ‘forest sub-types'(Champion & Seth 1968) or a group of ‘forest sub-types’ having high species richness, unique and rare butterfly taxa can be taken up as units of conservation at the state level in the Himalayan region as representatives of lower groups of animals, i.e., butterflies. Three most important forest sub-types: 12/C1a Ban Oak Forest followed by 12/C2c Moist Temperate Deciduous Forest and 3C/C2 Moist Shiwalik Sal Forest, respectively, hold the maximum number of butterflies, including many rare and protected taxa, in the state amongst the 20 forest sub-types evaluated, thus they form priority over the rest.

The 58 butterfly taxa conservation priority in the state lies both within and outside the PA network, but mainly in forested areas (Figure 16). Concentrations
Butterflies across different forest types in Uttarakhand

Figure 8. Spread of species of conservation priority species (orange bars) in different forest sub-types in relation to the total number of species sampled in them.

Figure 9. Map depicting the locations recorded for 58 species of conservation priority in 12 different forest sub-types across Uttarakhand.
Butterflies across different forest types in Uttarakhand

Figure 10. Important clusters of sites holding species of conservation priority in 12/C1a Ban Oak Forest in Uttarakhand.

Figure 11. Important clusters of sites holding species of conservation priority in 12/C2c Moist Temperate Deciduous Forest in Uttarakhand.
Butterflies across different forest types in Uttarakhand

Figure 12. Important clusters of sites holding species of conservation priority in 3C/C2a Moist Shiwalik Sal Forest in Uttarakhand.

Figure 13. Important cluster of sites holding species of conservation priority in 14/C1a West Himalayan Sub-alpine Fir Forest in Uttarakhand.
Figure 14. Important cluster of sites holding species of conservation priority in 14/1S2 Deciduous Sub-alpine Scrub in Uttarakhand.

Figure 15. Important clusters of sites holding species of conservation priority in 3C/C2c Moist Terai Sal Forest in Uttarakhand.
Figure 16. Locations of 58 butterfly species of conservation priority in relation to forest cover and the protected area network (16 no.), of Uttarakhand state along with 17 clusters where these species are concentrated.

Figure 17. Locations of 17 clusters showing concentration of 58 butterfly species of conservation priority in relation to their altitudinal distribution in the state of Uttarakhand.
of 58 species of conservation priority are marked in 17 circles (Figure 16) and at least 12 of these occur outside the PA network based on the findings of the present study. Important forest sub-types identified falling in these clusters having species of conservation concern can thus be recommended for conservation or future PAs. Seventeen concentrations/clusters that are located in different physiographic zones represented in the state are, three in Trans Himalaya; three in Greater Himalaya; eight in Lesser Himalaya; one in Shiwalk/Dun; one in Bhabar; and one in Tarai area along an elevation gradient, rather than a few as currently represented in the PA network of the state (Figure 17 & Appendix V).

Also, new conservation sites can be identified from these 17 clusters/concentrations of rare butterfly taxa especially in the ‘Lesser Himalaya’ where the number of PAs are almost negligible. This type of approach in identifying areas of conservation priority is more inclusive and suitable at a sub-regional or state level in restoring linkages and corridors in the PA network, rather than solely based on a broader geographic scale, i.e., zoogeographic zones. Many of these sites with high butterfly richness that lie outside the PAs and close to the villages and towns with suitable logistical support for boarding, lodging and travel can be promoted for sustainable and inclusive butterfly ecotourism activities in the state.
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### Appendix I. List of protected areas in Uttarakhand state, India

| Name                          | Area (km²) |
|-------------------------------|------------|
| 1 Corbett National Park       | 520.82     |
| 2 Gangotri National Park      | 2390       |
| 3 Govind National Park        | 558.88     |
| 4 Nanda Devi National Park    | 624.6      |
| 5 Rajaji National Park        | 819.54     |
| 6 Valley of Flowers Park      | 87.50      |
| 7 Askot Wildlife Sanctuary    | 600        |
| 8 Asan Conservation Reserve   | 4.44       |
| 9 Binsar Wildlife Sanctuary   | 45.59      |
| 10 Govind Wildlife Sanctuary  | 481.05     |
| 11 Jhilmil Conservation Reserve | 37.84   |
| 12 Kedarnath Wildlife Sanctuary | 975.20 |
| 13 Benog/Mussoorie Wildlife Sanctuary | 10.82 |
| 14 Nandhaur Wildlife Sanctuary | 269.96 |
| 15 Pauragarh Conservation Reserve | 58.25 |
| 16 Sonanadi Wildlife Sanctuary | 301.18 |
| 17 Naina Devi Bird Conservation Reserve | 111.90 |

![Location of protected areas in Uttarakhand state of India](image-url)
### Appendix II. Vegetation composition of forest sub-types sampled in the state taken up for study.

| Forest sub-type                                      | Area (km²) | Percent of state cover | Dominant trees                                                                                           |
|-------------------------------------------------------|------------|------------------------|----------------------------------------------------------------------------------------------------------|
| 1 3/C2a Moist Shiwalik Sal Forest                    | 3158       | 12.97                  | Shorea robusta, Anogeissus latifolia, Terminalia tomentosa, T. bellerica, Adina cordifolia, Lannea coromandelica, Mallotus philippensis |
| 2 3/C2c Moist Terai Sal Forest                       | 542        | 2.19                   | Shorea robusta, Adina cordifolia, Tala, Terwa nudiflora, Syzygium cuminii, Litsea glutinosa, Lagerstroemia parviflora, Cordia dichotoma, Putranjiva roxburghii, Litsea monopetala, Pogostemon benghalensis |
| 3 SB/C1a Dry Shiwalik Sal Forest                     | 236        | 1.5                    | Shorea robusta, Anogeissus latifolia, Buchanania lanza, Terminalia tomentosa, Bauhinia variegate, Emblica officinalis, Acacia catechu, Pinus roxburghii, Schleichera oleosa, Cassia fistula, Zizyphus xylorrhiza (B. vahlii-shrub) |
| 4 SB/C2 Northern Dry Mixed Deciduous Forest          | 678        | 2.82                   | Anogeissus latifolia, Boswellia serrata, Acacia catechu, Shorea robusta, Bauhinia spp., Bauhanania lanza, Diospyros tomentosa, Terminalia bellerica, Kytiaoclycina, Sterculia loppeus, Myrtagnya parviflora, Aegle marmelos, Butea monosperma, Flacourtia indica, Zizyphus mauritiana |
| 5 5/152 Khair Sissu Forest                           | 236        | 0.98                   | Dalbergia sisso, Acacia catechu, Zizyphus mauritiana, Ehretia laevis, Holoptelea integrifolia. |
| 6 9/C1b Upper or Himalayan Chir Pine Forest          | 6278       | 26.07                  | Pinus roxburghii, Quercus leucotrichophora, Pinus roxburghii ararum, Pyrus pashia, Myrica esculenta, Pyrazanthum crenulata, Symplacos crapeoids. |
| 7 12/C1a Ban Oak Forest                             | 4798       | 20.23                  | Quercus leucotrichophora, Rhododendron ararum, Rhododendron ararum, Lonicera ovalifolia, T. semecarpifolia, Q. floribunda, Carpinus viminea, Betula alnoides |
| 8 12/C1b Moru Oak Forest                             | 9317       | 3.95                   | Quercus floribunda, Q. leucotrichophora, Pinus wallichiana, Betula alnoides, Carpinus viminea, Acer caesium, Michulis dutehi, Aesculus indica, Abies pinow, Picea smithiana, Juglas regia. |
| 9 12/C1c Moist Deodar Forest                         | 485        | 1.96                   | Cedrus deodara, Pinus wallichiana, Quercus leucotrichophora |
| 10 12/C1d Western Mixed Coniferous Forest- Spruce, Blue Pine, Silver Fir | 513        | 2.19                   | Picea smithiana, Cedrus deodara, Abies pinow, Pinus wallichiana, Quercus floribunda, Q. semecarpifolia, Q. leucotrichophora, Acer caesium, A. pictum, A. acuminatum, Euonymus lacerus, Taxus baccata, Betula alnoides. |
| 11 12/C1e Moist Temperate Deciduous Forest           | 246        | 1.07                   | Alnus nepatens, Aesculus indica, Acer caesium, A. pictum, Pinus roxburghii, Quercus semecarpifolia, Fagus crenulata, Fraxinus ornus, Rhododendron ararum. |
| 12 12/C2a Kharasu Oak Forest (Q. semecarpifolia)     | 227        | 0.99                   | Quercus semecarpifolia, Abies pinow, Betula alnoides, Q. floribunda, Acer caesium, Ilex dipyrren, Taxus baccata. |
| 13 12/C2b West Himalayan Upper Oak/Fir Forest        | 1087       | 4.57                   | Abies pinow, Picea smithiana, Quercus semecarpifolia, Q. floribunda, Pinus roxburghii, Ilex dipyrren, Sorbus solios, Rhododendron ararum, Barbatum, Ulmus wallichiana, Aesculus indica, Corylus colurna |
| 14 12/151 Low Level Blue Pine Forest                 | 384        | 1.54                   | Pinus wallichiana, Quercus leucotrichophora |
| 15 13/C2b Dry Deodar Forest                          | 363        | 1.46                   | Cedrus deodara, Pinus wallichiana, Picea smithiana, Corylus colurna |
| 16 14/C1a West Himalayan Sub-Alpine High Level Fir Forest | 195 | 0.78                 | Abies spectabilis, Pinus wallichiana, Picea smithiana, Rhododendron complanulatum, Taxus baccata, Prunus padus |
| 17 14/C1b West Himalayan Sub-Alpine Birch/ Fir Forest | 583        | 2.47                   | Abies spectabilis, Acer caesium, Picea smithiana, Quercus semecarpifolia, Rhododendron complanulatum, R. anthropogon, Lonicera ovalifolia, Sorbus soliosas |
| 18 14/152 Deciduous Sub-Alpine Scrub                  | 200        | 0.86                   | Betula utillus |
| 19 15/C1 Birch/Rhododendron Scrub Forest             | 136        | 0.56                   | Betula utillus, Rhododendron complanulatum, Sorbus soliosa, Quercus semecarpifolia |
| 20 15/E1 Dwarf Rhododendron Scrub Forest              | 32         | 0.13                   | Rhododendron anthropogon, R. lepidotatum, R. complanulatum, Ilex dipyrren |

Source: Champion & Seth (1968).
Appendix III. Complete list of butterflies sampled in 20 different forest types of Uttarakhand ranked according to their relative abundances (2006–2009 & 2017–2020).

| Butterfly species A. | Butterfly species |
|----------------------|------------------|
| Very Common          |                  |
| 1 Eurema hecabe      | 43 Danaus chrysippus (Linnaeus, 1758) |
| (Linnaeus, 1758)      | 44 Lethe verma verma (Kollar, [1844]) |
| 2 Coptopilia pomona   | 45 Ypthima inca (Hewitson, [1865]) |
| (Fabricius, 1775)     | 46 Ypthima baldus (Fabricius, 1775) |
| 3 Ypthima sakra sakra| 47 Pereronia hippa (Fabricius, 1787) |
| Moore, [1858])        | 48 Castalus rosimon (Fabricius, 1775) |
| 4 Pieris candia indic| 49 Heliothrus tamu tamu (Kollar, [1844]) |
| s (Evans, 1883)       | 50 Acraea isoria (Hübner, [1819]) |
| 5 Celastrina huegeli   | 51 Lampsides boeticus (Linnaeus, 1767) |
| huegeli (Moore, 1882) | 52 Cyrestis thydamos ganesha (Kollar, 1848) |
| 6 Aporia agathon      | 53 Jamides celena celena (Cramer, [1775]) |
| (Gray, 1831)          | 54 Delias belladonna (Hewitson, [1869]) |
| 7 Junonia iphita      | 55 Neopithecos zalmora (Butler, [1870]) |
| iphita (Cramer, [1799]) | 56 Euploea mucibera (Cramer, [1777]) |
| 8 Callerebia nirmala  | 57 Euaspis millonia (Hewitson, [1869]) |
| (Moore, 1865)         | 58 Sepha sidae (Kollar, [1844]) |
| 9 Aglais caschmiensis| 59 Issoria isoria (Doherty, 1886) |
| acesis (Fruhstorfer, 1912) | 60 Prosotas dubiosa (Evans, [1925]) |
| 10 Papilio polyes     | 61 Junonia attites (Linnaeus, 1763) |
| romulus Cramer, [1775] | 62 Callerebia anna (Cramer, [1775]) |
| 11 Pseudozizeeria    | 63 Ypthima nareda (Kollar, [1844]) |
| maha maha (Kollar, [1844]) | 64 Danaus genutia (Cramer, [1779]) |
| 12 Ancylopessa pupa   | 65 Papilio demoleus (Linnaeus, 1758) |
| (Horsfield, [1828])  | 66 Mycalesis peruseus (Fabricius, 1798) |
| 13 Aulocera swaha    | 67 Arhopala ganesha (Moore, [1858]) |
| swaha (Kollar, [1844]) | 68 Colias erate (Esper, 1805) |
| 14 Dodona durga      | 69 Eurema blanda (Boisduval, 1836) |
| durga (Kollar, [1844]) | 70 Junonia hierta (Fabricius, 1798) |
| 15 Leptosia nina     | 71 Parantica sita sita (Kollar, [1844]) |
| (Fabricius, 1793)     | 72 Zizeeria karsandra (Moore, 1865) |
| 16 Neptis hyas varma | 73 Cupha erymanthis lotis (Sulzer, 1776) |
| varma Moore, 1872     | 74 Athyma perus perius (Linnaeus, 1758) |
| 17 Vanessa indica    | 75 Kaniska canace canace (Linnaeus, 1763) |
| indica (Herbst, 1794) | 76 Ixias pyrene (Linnaeus, 1764) |
| 18 Euploea core      | 77 Zizeina oti oti (Fabricius, 1787) |
| core (Hewitson, [1780]) | 78 Hypolimnas bolina (Drury, 1773) |
| 19 Arhopala amontes  | 79 Chrysopephyris birupa Moore, 1877 |
| opelia (Swinhoe, 1886) | 80 Acraea terpsicore (Linnaeus, 1758) |
| 20 Pieris brassicae  | 81 Lycaena phlaeas baralacha (Moore, 1884) |
| (Linnaeus, 1758)      | 82 Delias eucharis (Drury, 1773) |
| 21 Neptis mahendra   | 83 Celaenorrhinus leucocera (Kollar, [1844]) |
| mahendra Moore, 1872 | 84 Junonia almana almana (Linnaeus, 1758) |
| 22 Gonepteryx rhami | 85 Junonia anthya (Linnaeus, 1758) |
| nepalensis Doubleday, 1847 |                  |
| 23 Vanessa linnaeus  |                  |
| (Linnaeus, 1758)      |                  |
| 24 Celastrina        |                  |
| lavendulalis limitatus (Moore, 1879) |                  |
| 25 Ypthima huebneri  |                  |
| Kirby, 1871          |                  |
| 26 Junonia lemonias  |                  |
| lemonias (Linnaeus, 1758) |                  |
| 27 Lethe sidonis     |                  |
| (Hewitson, 1863)     |                  |
| 28 Ariadne merione   |                  |
| taeumara (Moore, 1884) |                  |
| 29 Lesiommata schakra|                  |
| schakra (Kollar, [1844]) |                  |
| 30 Symbrenthia ilaea|                  |
| khianiana Moore, [1875] |                  |
| 31 Phalanta phalantha|                  |
| phalantha (Drury, [1773]) |                  |
| 32 Callerebia hybrid|                  |
| Butler, 1880         |                  |
| 33 Arhopala atrax   |                  |
| (Hewitson, 1862)     |                  |
| 34 Callerebia scando|                  |
| scando (Kollar, [1844]) |                  |
| 35 Parantica aglea  |                  |
| melanoide (Moore, 1883) |                  |
| 36 Athyma oapina     |                  |
| oapina Kollar, 1844  |                  |
| 37 Heliothrus sena   |                  |
| (Kollar, [1844])     |                  |
| 38 Prosotas nora     |                  |
| ardates (Moore, [1875]) |                  |
| 39 Coptopilia pyranthe (Linnaeus, 1758) |                  |
| 40 Colias fieldii    |                  |
| Ménétrés, 1855       |                  |
| 41 Ypthima nilaiea  |                  |
| Moore, [1875]        |                  |
| 42 Cepora nerissa    |                  |
| phryne (Fabricius, 1775) |                  |
| Butterfly species | Butterfly species |
|-------------------|-------------------|
| 86 | Aporia leucadice (Eversmann, 1843) |
| 87 | Polyxenes ektola ektola (Hewitson, 1869) |
| 88 | Symbrenthia hyspis cotanda Moore, [1875] |
| 89 | Megisba malaya sikkima Moore, 1884 |
| 90 | Neptis anata ananta Moore, [1858] |
| 91 | Graphium nainius nainius (Esper, 1799) |
| 92 | Belenois aura aurata (Fabricius, 1793) |
| 93 | Pseudergolis wedah wedah (Kollar, [1844]) |
| 94 | Anthopoda dodona (Moore, [1858]) |
| 95 | Poiretia laja laja (Stoll, [1780]) |
| 96 | Pieris hebetor hebetor Moore, [1866] |
| 97 | Lethe isana isana (Kollar, [1844]) |
| 98 | Leptotes plinius plinius (Fabricius, 1793) |
| 99 | Neptis sankara sankara (Fabricius, [1844]) |
| 100 | Byasa laterellae laterellae (Donovan, 1826) |
| 101 | Lethe nicetas (Hewitson, 1863) |
| 102 | Triumala septentrionis septentrionis (Butler, 1874) |
| 103 | Parnara guttatus mangala (Moore, [1866]) |
| 104 | Eurema andersonii jordani Corbet & Pendlebury, 1932 |
| 105 | Stichophaena nois (Forster, 1771) |
| 106 | Ausonia danava danava (Moore, [1858]) |
| 107 | Celaenorrhinus patula de Nicéville, 1889 |
| 108 | Graphium sarpedon sarpedon (Fabricius, 1798) |
| 109 | Belenois aura aurata (Fabricius, 1793) |
| 110 | Eurema hyperbius hyperbius (Fabricius, [1777]) |
| 111 | Pseudergolis wedah wedah (Kollar, [1844]) |
| 112 | Byasa laterellae laterellae (Donovan, 1826) |
| 113 | Lethe nicetas (Hewitson, 1863) |
| 114 | Triumala septentrionis septentrionis (Butler, 1874) |
| 115 | Parnara guttatus mangala (Moore, [1866]) |
| 116 | Eurema andersonii jordani Corbet & Pendlebury, 1932 |
| 117 | Stichophaena nois (Forster, 1771) |
| 118 | Ausonia danava danava (Moore, [1858]) |
| 119 | Celaenorrhinus patula de Nicéville, 1889 |
| 120 | Graphium sarpedon sarpedon (Fabricius, 1798) |
| 121 | Belenois aura aurata (Fabricius, 1793) |
| 122 | Eurema hyperbius hyperbius (Fabricius, [1777]) |
| 123 | Parnara guttatus mangala (Moore, [1866]) |
| 124 | Eurema andersonii jordani Corbet & Pendlebury, 1932 |
| 125 | Stichophaena nois (Forster, 1771) |
| 126 | Ausonia danava danava (Moore, [1858]) |
| 127 | Celaenorrhinus patula de Nicéville, 1889 |
| 128 | Graphium sarpedon sarpedon (Fabricius, 1798) |
| 129 | Belenois aura aurata (Fabricius, 1793) |
| Butterfly species | Butterfly species |
|-------------------|-------------------|
| 175 | Neope pulaha pandya (Talbot, 1947) |
| 176 | Telinga lepcha lepcha (Moore, 1880) |
| 177 | Arhopala rama rama (Kollar, [1844]) |
| 178 | Euchrysys caniceps caniceps (Fabricius, 1798) |
| 179 | Spindasis vulcanus vulcanus (Fabricius, 1775) |
| 180 | Notocrypta feisthamelii alysos (Moore, [1866]) |
| 181 | Telicota colon colon (Fabricius, 1775) |
| 182 | Loxura atrignus continentalis (Moore, [1858]) |
| 183 | Neptis cortica cortica Moore, 1872 |
| 184 | Lapelia avara avara (Kollar, 1844) |
| 185 | Papilio paris paris Linnaeus, 1758 |
| 186 | Athyma asura asura Moore, [1858] |
| 187 | Aricia agestis naziva (Moore, [1866]) |
| 188 | Deudorix epiphras epiphras (Moore, [1858]) |
| 189 | Papilio selina selina (Moore, 1874) |
| 190 | Burura javana javana (Moore, [1866]) |
| 191 | Labyrinth oasulas oasulas (Moore, [1866]) |
| 192 | Meandrus acherinus acherinus (Fabricius, 1803) |
| 193 | Charaxes bernardus hierax (Moore, 1879) |
| 194 | Mycalesis francisco sancatera Moore, [1858] |
| 195 | Neptis somo somo Eliot, 1969 |
| 196 | Neptis xanda xanda Doubleday, [1848] |
| 197 | Hypolycaena kina kina Hewitson, [1869] |
| 198 | Borbo beiani (Moore, 1878) |
| 199 | Sarangesa purnendra purnendra Moore, 1882 |
| 200 | Graphium eurus casimiriensis (Rothschild, 1895) |
| 201 | Hestina persimilis zella Butler, 1869 |
| 202 | Paralasa kalinda kalinda Moore, 1865 |
| 203 | Polygonia c-album cognata Moore, [1899] |
| 204 | Telinga nicotia (Westwood, [1850]) |
| 205 | Freyeria trochylus orientalis Forster, 1980 |
| 206 | Pratapa icheta icheta (Hewitson, [1865]) |
| 207 | Caprona agastis agastis (Moore, [1858]) |
| 208 | Celastrina gigas (Hemming, [1928]) |
| 209 | Neptis sappho astola Moore, 1872 |
| 210 | Notocrypta feisthamelii alysos (Moore, [1866]) |
| 211 | Neptis somo somo Eliot, 1969 |
| 212 | Celastrina gigas (Hemming, [1928]) |
| 213 | Neptis sappho astola Moore, 1872 |
| 214 | Notocrypta feisthamelii alysos (Moore, [1866]) |
| 215 | Neptis sappho astola Moore, 1872 |
| 216 | Notocrypta feisthamelii alysos (Moore, [1866]) |
| 217 | Neptis sappho astola Moore, 1872 |
| 218 | Neptis sappho astola Moore, 1872 |

Butterflies across different forest types in Uttarakhand Singh
| Butterfly species                              | Butterfly species                              |
|------------------------------------------------|------------------------------------------------|
| 264 Dilipa morgiana (Westwood, [1851])         | 308 Baoris farri (Moore, [1878])                |
| 265 Nymphalis xanthomelas fervescens (Stichel, [1908]) | 309 Bibasis sena sensa (Moore, [1866])         |
| 266 Calostrina angiolus kollari (Westwood, [1852]) | 310 Atrophaneura aidonea (Doubleday, 1845)      |
| 267 Spindasis ictis ictis (Hewitson, 1865)       | 311 Graphium garhwalica (Katayama, 1988)        |
| 268 Zuesis chrysomalus Hübner, [1819]            | 312 Aporia agathon caphusa (Moore, 1872)        |
| 269 Caprona ransonnetti potiphera (Hewitson, 1873) | 313 Gonepteryx mahaguru mahaguru (Gustl, 1857)  |
| 270 Potanthus dora (Kollar, [1844])              | 314 Ariadne ariadne pallidior (Fruhstorfer, 1899) |
| 271 Tagiades menaka menaka (Moore, [1866])       | 315 Charaxes solon solon (Fabricius, 1793)       |
| 272 Tarucus callinara (Butler, 1886)             | 316 Pantoporia sandoka dawsoni Eliot, 1969      |
| 273 Anthene emolus emolus (Godart, [1824])       | 317 Tanaecia julii appiodes (Ménétriers, 1857)  |
|                                                   | 318 Ypthima avanta Moore, [1875]                |
|                                                   | 319 Flas asoka (de Nicéville, [1884])           |
| D. Uncommon                                      | 320 Petrelaea dana (de Nicéville, [1884])       |
| 274 Aulocera brahiminus (Blanchard, 1853)        | 321 Rapala pheretima petasiris (Hewitson, [1863]) |
| 275 Symbrenthia nipponica hysudra Moore, 1874    | 322 Sinthusa chandrana chandrana (Moore, 1882)  |
| 276 Freyenia puti (Kollar, [1844])               | 323 Spalgis epius epius (Westwood, [1851])      |
| 277 Iraota timoleon timoleon (Stoll, [1790])     | 324 Virachola isocrates (Fabricius, 1793)       |
| 278 Tagiuria cippus cippus (Fabricius, 1798)     | 325 Dadana oudia philegra Fruhstorfer, 1914     |
| 279 Tagiuria dieus dieus (Hewitson, [1865])      | 326 Celaenorrhinus pero pero de Nicéville, 1889 |
| 280 Chaoaes benjiminini japonica (Murray, 1875)   | 327 Coladenia indrani indrani (Moore, [1866])   |
| 281 Hyarotis adрастus prabo (Moore, [1866])      | 328 Ochlodes brahma (Moore, 1878)               |
| 282 Petalops conjuncta conjuncta (Herrich-Schäffer, 1869) | 329 Odontoptilum angulata angulata (C. Felder, 1862) |
| 283 Graphium doson aequalis (Page & Treadaway, 2014)| 330 Sesoria dohertyi dohertyi (Watson, 1893)    |
| 284 Aporia agathon phryxe (Boisduval, 1836)      | 331 Taractrocera maevis (Fabricius, 1793)       |
| 285 Charaxes dolon dolon Westwood, [1848]         | 332 Papilio alcon alcon alcon (C. & R. Felder, [1864]) |
| 286 Mimathyma ambica ambica (Kollar, [1844])     | 333 Papilio memnon agenor Linnaeus, 1758        |
| 287 Ypthima indecora Moore, 1882                | 334 Paraxius epaphus Oberthür, 1879             |
| 288 Ancema ctesis ctesia (Hewitson, [1865])      | 335 Appias larage (Doubleday, 1842)              |
| 289 Chaetopraucta odata pelei Forster, 1980      | 336 Appias libythea (Fabricius, 1775)            |
| 290 Curetis bulus bulus (Westwood, [1851])       | 337 Aghalis rizana (Moore, 1872)                |
| 291 Thermozyphrus ataxus ataxus (Westwood, [1851]) | 338 Athyma inora inora Westwood, 1850          |
| 292 Virachola perse perse (Hewitson, [1863])     | 339 Euptychia midamus (Linnaeus, 1758)          |
| 293 Aeromachus stigmata stigmata (Moore, [1878])  | 340 Hyponephele pulchella (C. & R. Felder, [1867]) |
| 294 Celaenorrhinus dhanada (Moore, [1866])       | 341 Lethe askwania Tytler, 1939                 |
| 295 Tagiades rapax rapax (Moore, [1866])         | 342 Mycalesis suaveolens ranatei Smetacek, 2012 |
| 296 Gandoca harina assamica Moore, 1906          | 343 Everes hugeli hugeli (Gistel, 1857)          |
| 297 Neptis narayana Moore, 1858                  | 344 Helioptilus indicus (Fruhstorfer, 1908)     |
| 298 Ypthima hannygtoni hannygtoni Eliot, 1967    | 345 Horago viola Moore, 1882                    |
| 299 Arhopala paragama paragama (de Nicéville, 1882) | 346 Pratapa deva lila Moore, [1884]              |
| 300 Aporia sibylla sibylla (Stoll, [1782])       | 347 Spindasis elima uniformis (Moore, 1882)      |
| 301 Aeromachus dubius Elwes & Edwards, 1897      | 348 Tagiuria jehana jehana Moore, [1884]        |
| 302 Badamia exclamationis (Fabricius, 1775)       | 349 Baoris pagana (de Nicéville, 1887)          |
| 303 Argynnis javanaeja javanaeja Moore, 1864      | 350 Coloris kumara (Moore, 1878)                |
| 304 Aulocera padma padma (Kollar, [1844])         | 351 Eristalis torus Evans, 1941                 |
| 305 Lethe balsdeva aisa Fruhstorfer, 1911        | 352 Peosta masuriensis masuriensis (Moore, 1878) |
Butterflies across different forest types in Uttarakhand

| Butterfly species | 353 | Sasia grahami grahami (Evans, 1926) |
|-------------------|-----|---------------------------------|
| 354               | Papilio bootes janaka Moore, 1957 |
| 355               | Papilio helena helena Linnaeus, 1758 |
| 356               | Parnassius charltonius Gray, (1853) |
| 357               | Colias etrica (Boisduval, 1836) |
| 358               | Delias acalis pyramus [Wallace, 1867] |
| 359               | Charaxes agrarius Swinhoe, [1887] |
| 360               | Hyponephele davendra davendra (Moore, 1865) |
| 361               | Lethe goolpara goolpara (Moore, [1866]) |
| 362               | Polygonia c-album agnicula (Moore, [1866]) |
| 363               | Ypthima parasakra Eliot, 1987 |

| Butterfly species | 364 | Heliophorus epicles latilimbata (Fruhstorfer, 1908) |
|-------------------|-----|-------------------------------------------------|
| 365               | Miletus chinesis assamensis (Doherty, 1893) |
| 366               | Spindasis lohita himalayanus (Moore, 1884) |
| 367               | Hasora chromus (Cramer, [1870]) |
| 368               | Thoressa aina (de Nicéville, 1889) |
| 369               | Maneca bhota bhotea (Moore, 1884) |
| 370               | Coleonornis pyrrha de Nicéville, 1889 |

The relative abundance of butterfly taxa ranging from 1–1,596 individuals. The taxa are ranked into four abundance classes based on their quartile divisions, i.e., Q1= 1–7 Uncommon; Q2= 8–21= Fairly Common; Q3= 22–69= Common; Q4= 70–1,596= Very Common; Median value= 21.

Appendix IV. Butterfly taxa of conservation priority in Uttarakhand.

| Family/Scientific name | Common name | Distribution | Associated forest sub-type* | Abundance status | WPA status | Altitudinal distribution (m) |
|------------------------|-------------|--------------|-----------------------------|------------------|------------|-----------------------------|
| **PAPILLIONIDAE**      |             |              |                             |                  |            |                             |
| 1                      | Byasa dasara daravana (Moore, 1858) | Great Windmill | WH; CH | 12C1a; 12/ C1b | NR | NA | 150–2750 |
| 2                      | Graphium eurous caschmirensis (Rothschild, 1895) | Six-bar Swordtail | WH; CH | 12C1a | NR | NA | 1000–2800 |
| 3                      | Graphium garhwalica (Katayama, 1988) | Garhwal Swordtail | WH | 12C1a | R | NA | 1600–2300 |
| 4                      | Parnassius charltonius Gray, [1853] | Regal Apollo | WH; PA | 12C1a | R | NA | 3600–4400 |
| **PIERIDAE**           |             |              |                             |                  |            |                             |
| 5                      | Aporia agathon caphusa (Moore, 1872) | Garhwal Great Blackvein | WH; CH | 14/C1a | NR | NA | 1200–3050 |
| 6                      | Aporia agathon phryxe (Boisduval, 1836) | Kashmir Great Blackvein | WH | 12C1a | NR | NA | Up to 2100 |
| 7                      | Delias acalis pyramus (Wallace, 1867) | Redbreast Jezebel | WH; CH | 3C/C2a | NR | NA | Up to 1500 |
| 8                      | Delias sanaca sanaca (Moore, [1858]) | Pale Jezebel | WH | 12/C1a; 12/ C1b | NR | Sch - I | 1200–3000 |
| 9                      | Gonepteryx mahaguru mahaguru Gistel, 1857 | Lesser Brimstone | WH; CH | 12/C1a; 12/ C2c | NR | NA | Above 2100 |
| **NYMPHALIDAE**        |             |              |                             |                  |            |                             |
| 10                     | Aglais rizana (Moore, 1872) | Mountain Tortoiseshell | WH; EH | 14/152 | R | Sch - II | 2400–4500 |
| 11                     | Lethe dura gammei (Moore, [1892]) | Scarce Lilacfork | WH; EH | 12/C1a; 12/ C2b | VR | Sch - I | 1800–2200 |
| 12                     | Polygonia c-album agnicula (Moore, 1872) | Nepalese Comma | WH; CH | 14/C1a | R | Sch - II | 2200–4500 |
| 13                     | Ypthima parasakra parasakra Eliot, 1987 | Dubious Five-ring | WH; CH; EH | 12/251 | R | NA | 2000–2700 |
| 14                     | Argynnis jainadeva jainadeva Moore, 1864 | Highbrown Silverspot | WH | 14/C1a | NR | NA | 2400–4700 |
| 15                     | Callercibia hyagriva hyagriva (Moore, [1858]) | Brown Argus | WH | 9/C1b | R | Sch - II | 1500–2400 |
| 16                     | Callercibia scanda scanda (Kollar, [1844]) | Pallid Argus | WH | 12/C1a; 12/ C1b | NR | NA | 1200–2800 |
| 17                     | Charaxes dolon dolon Westwood, [1848] | Statley Nawab | WH; CH | 12/C1a; 9/ C1b | R | Sch - II | 1430–1900 |
| 18                     | Euthalia patala patala (Kollar, [1844]) | Grand Duchess | WH | 12/C1a | NR | NA | 400–2500 |
| 19                     | Hestina persimilis zeillo Butler, 1869 | Siren | WH | 12/C1a; 3C/ C2a | R | Sch - II | 750–1460 |
| Family/Scientific name | Common name | Distribution | Associated forest sub-type* | Abundance status | WPA status | Altitudinal distribution (m) |
|------------------------|-------------|--------------|-----------------------------|-----------------|-----------|-----------------------------|
| **20** Hyponephe davendra davendra (Moore, [1865]) | White-ringed Meadowbrown | WH; PA | 12/C1c | R | Sch-ii | 900–2400 |
| **21** Hyponephe lepuchella (C. & R. Felder, [1867]) | Tawny Meadowbrown | WH; PA | 12/C2b | NR | NA | 3000–3600 |
| **22** Lethe baladeva aiso Fruhstorfer, 1911 | Treble Silverstripe | WH; CH | 12/C1a; 12/C2c | R | Sch-ii | 1800–2200 |
| **23** Lethe dakwania Tytler, 1939 | White-wedged Woodbrown | WH | 12/C2c | R | NA | 2300–2900 |
| **24** Lethe gaalpara gaolpara (Moore, [1866]) | Large Goldenfork | WH; CH | 12/C2c | R | Sch-ii | 1800–3000 |
| **25** Lethe isana isana (Kollar, [1844]) | Common Goldenfork | WH | 12/C1a; 12/C1d; 9/C1b | R | NA | 1500–2700 |
| **26** Mycalesis suaveolens ranotei Smetacek, 2012 | Wood-Mason’s Bushbrown | WH; CH | 12/C1a | R | Sch-ii | 700–1700 |
| **27** Neope pulaha pandyia (Talbot, 1947) | Veined Labyrinth | WH | 12/C1a; 12/C2c; 12/C251 | R | Sch-ii | 1500–3050 |
| **28** Neope yama buckleyi Talbot, 1947 | Dusky Labyrinth | WH; CH | 12/C1a; 12/C2c | NR | Sch-ii | 1200–2370 |
| **29** Neptis anantaananta Moore, [1858] | Yellow Sailer | WH | 12/C1a; 12/C2c | R | NA | 400–2300 |
| **30** Neptis clinia praedicta Smetacek, 2011 | Sullied Sailer | WH | 3C/C2a; 3C/C2c; 12/C1a | NR | NA | Low |
| **31** Neptis sankara sankara (Kollar, [1844]) | Broad-banded Sailer | WH | 3C/C2a; 5B/C2; 12/C1a | NR | NA | 800–2500 |
| **32** Neptis Zaida Zaida Doubleday, [1848] | Pale Green Sailer | WH; CH | 3C/C2a; 12/C1a | R | Sch-ii | 900–2500 |
| **33** Nymphalis xanthomelas fervescens (Stichel, [1908]) | Large Tortoiseshell | WH; CH | 12/C1a; 12/C2b; 14/C1a | R | NA | 900–3200 |
| **34** Paranasa kalinda kalinda Moore, 1865 | Scarce Mountain Argus | WH | 3C/C2a; 3C/C2c; 12/C1a | R | NA | 2700–3900 |
| **35** Polygonia c-album cognata Moore, [1899] | Kumaon Comma | WH | 12/C1a; 12/C2c | NR | NA | 2100–4800 |
| **36** Sephisa dichroa (Kollar, [1844]) | Western Courtier | WH; CH | 12/C1a; 12/C1b; 12/C2c | NR | NA | 1500–2740 |
| **37** Symbrenthia niphanda hysudra Moore, 1874 | Blue-tail Jester | WH; CH | 12/C1a; 12/C2c | R | Sch-ii | 1000–2600 |
| **38** Telinga Lepcha lepcha (Moore, 1880) | West Himalayan Lepcha-Bushbrown | WH; CH | 12/C1a; 12/C2c; 3C/C2a | NR | NA | 1100–2400 |
| **39** Ypthima avanta Moore, [1875] | Jewel Five-ring | WH; CH | 12/C1a | NR | NA | 600–1800 |
| **40** Ypthima hannyngtoni hannyngtoni Eliot, 1967 | Garwhal Large Branded Five-ring | WH; CH | 12/C1a; 12/C1b | NR | NA | 2100–2300 |
| **41** Ypthima indecora Moore, 1882 | Western Five-ring | WH; CH | 12/C1a; 12/C2c | NR | NA | 1300–1700 |
| **42** Ypthima kedarnathensis Singh, 2007 | Garwhal Six-ring | WH; CH | 12/C1a; 12/C2c | R | NA | 1600–2200 |

D. LYCAENIDAE

| **43** Aricia agestis nazira (Moore, [1866]) | Orange-bordered Argus | WH; CH | 12/C1a | NR | NA | 1800–2980 |
| **44** Chrysozephyrus birupa Moore, 1877 | Fawn Hairstreak | WH; CH | 12/C1a; 12/C2c | NR | NA | above 1400 |
| **45** Esakiozephyrus icana icana (Moore, [1875]) | Dull-green Hairstreak | WH; CH | 12/C1a; 12/C1d | R | Sch-ii | 2000–3300 |
| **46** Euaspa millonia millonia (Hewitson, [1869]) | Water Hairstreak | WH; CH | 12/C1a | NR | NA | 1200–2000 |
| **47** Heliocharis morrei coruscans (Moore, [1882]) | Azure Sapphire | WH; CH | 12/C1a; 12/C2c | R | NA | 1300–3000 |
| **48** Pratapa icetas icetas (Hewitson, [1865]) | Dark Blue Royal | WH; CH | 12/C1a; 12/C2b; 12/C2c | R | Sch-ii | 1500–2700 |
| **49** Shizuyaozephyrus ziha (Hewitson, [1865]) | White-spotted Hairstreak | WH; CH | 12/C1a | R | Sch-ii | 1200–2000 |
| **50** Sinthusa chandrana chandrana (Moore, [1882]) | Broad Spark | WH; CH | 12/C1a; 12/C1d; 12/C2a | R | Sch-ii | Up to 1820 |
Butterflies across different forest types in Uttarakhand

| Family/Scientific name | Common name | Distribution | Associated forest sub-type* | Abundance status | WPA status | Altitudinal distribution (m) |
|------------------------|-------------|--------------|-----------------------------|------------------|------------|-----------------------------|
| Spindasis elimauni formi s (Moore, 1882) | Scarce Shot Silverline | WH; CH | 3/C2a | NR | Sch-II | Up to 2700 |
| Thermaezephyrus ataxus ataxus (Westwood, [1851]) | Wonderful Hainstreak | WH; CH | 12/C1a; 12/C2c | R | NA | 1800–2400 |
| Dodona dipoea nostia Fruhstorf, 1912 | Lesser Punch | WH | 12/C1a; 12/C2c | R | Sch-II | 1800–3000 |
| Dodona ouida phlegra Fruhstorf, 1914 | Mixed Punch | WH; CH | 12/C1a; 12/C2c | NR | NA | 1200–2400 |
| Celaenorrhinus peropero deNicéville, 1889 | Mussoorie Spotted Flat | WH | 12/C1a | R | NA | 1500–2000 |
| Potanthus dara (Kollar, [1844]) | Himalayan Dart | WH; CH | 12/C1a; 3/C2a | NR | NA | 1830–2590 |
| Sovia lucasii (Mabille, 1876) | Lucas's Ace | WH; EH | 9/C1b | R | NA | 1800–2000 |
|Thoressa oina (de Nicéville, 1889) | Garhwal Ace | WH; CH | 12/C1a | R | NA | 1370–2800 |

WH–Western Himalaya | CH–Central Himalaya | * Forest Sub-type reference Table 2 | Abundance Status (Evans 1932): VR–Very Rare | R–Rare | NR–Not Rare | WPA–Wildlife (Protection) Act 1972 (Anonymous 2006) | Sch–Schedule listed in WPA1972 (Anon 2006).

Appendix V. Locations of Western Himalayan forest sub-types identified holding butterfly species of conservation priority in the state of Uttarakhand spread over different physiographic zones along the elevation gradient.

| Physiographic zone | Forest Sub-type | District | Site/village/Reserve Forest |
|--------------------|----------------|---------|-----------------------------|
| A. Trans Himalaya (Above 3600m) | 14/C1a West Himalayan Sub-alpine Fir Forest | Chamoli | Ghamsali-Niti Pass |
| 14/352 Deciduous Sub-alpine Scrub | Chamoli | Mana-Badrinath & Valley of Flowers NP. |
| B. Greater Himalaya (2400–3600m) | 12/C1a Ban Oak Forest | Chamoli & Rudraprayag | Mandal-Chopta-Duggalbitta-Makkumath-Kedarnath WS |
| Uttarkashi dist | Tehri Garhwal | Buddha Kedar-Jhala |
| 12/C2c Moist Temperate Deciduous Forest | Chamoli & Rudra prayag | Mandal-Chopta-Makkumath-Duggalbitta |
| C. Lesser Himalaya (1200-2400m) | 12/C1a Ban Oak Forest | Dehradun & Tehri Garhwal | BenogWS-Mussoorie-Kotkimi-Rotu-ki-beli |
| Dehradun | Pauri-Talisain-Dudatoli ridge |
| Pithoragarh | Didihat-Thal |
| Nainital | Naina Devi Conservation reserve-Kilbury-Pangot-Vinayak Khal |
| Almora | Ranikhet |
| Binsar WS | |
| D. Shiwalik-Dun/Bhabar (Below 1200m) | 3C/C2a Moist Shiwalik Sal Forest | Dehradun | Timli RF-Karvapani RF |
| Dehradun | Jhuaja RF, Chowki Dhaulas-Rikhouli RF |
| Pauri | Rahuthua dhab-Mundipani-Nauri |
| E. Tarai (100–350m) | 3C/C2c Moist Terai Sal Forest | Nainital | Chorgalia-Jolasal-Senapani (Nandhaur WS) |
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