Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268
(Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 25 No. 3 Article ID B4412 2026
Original Research Paper
https://doi.org/10.46488/NEPT.2026.v25i03.B4412
Open Access Journal

Spatio-Temporal Distribution and Diversity of Butterflies (Lepidoptera: Papilionoidea) across Biotopes in the Kumaun Division of Western Himalaya: Implications for Habitat Modification and Environmental Monitoring

Surabhi Bisht and Manoj Kumar Arya†
Insect Biodiversity Laboratory, Department of Zoology, D.S.B. Campus, Kumaun University, Nainital-263001, Uttarakhand, India
†Corresponding author: Manoj Kumar Arya; dr.manojkumar19@rediffmail.com

Abbreviation: Nat. Env. & Poll. Technol.
Website: www.neptjournal.com

Received: 13-11-2025
Revised: 02-02-2026
Accepted: 28-02-2026

Key Words:
Biotopes
Conservation
Diversity of butterflies
Environmental monitoring
Lepidoptera
Species richness

Citation for the Paper:
Bisht, S. and Arya, M.K. 2026. Spatio-temporal distribution and diversity of butterflies (Lepidoptera: Papilionoidea) across biotopes in the Kumaun division of Western Himalaya: Implications for habitat modification and environmental monitoring. *Nature Environment and Pollution Technology*, 25(3), B4412. https://doi.org/10.46488/NEPT.2026.v25i03.B4412

Note: From 2025, the journal has adopted the use of Article IDs in citations instead of traditional consecutive page numbers. Each article is now given individual page ranges starting from page 1.

ABSTRACT

The abundance and diversity of butterflies in an ecosystem are crucial for informing conservation strategies. This research surveyed butterfly communities across three distinct biotopes in Kumaun, Uttarakhand, India. Random sampling was conducted from March 2023 to February 2024 in agricultural fields, riverine areas, and urban settlements. A total of 94 butterfly species from six families were documented: Nymphalidae (42 species), Pieridae (19), Lycaenidae (17), Papilionidae (08), Hesperiidae (05), and Riodinidae (03). Beta diversity analyses indicated significant variation among biotopes. The riverine habitat exhibited the highest alpha diversity and species richness, followed by urban and agricultural areas. Agricultural land and river catchment site shared the most species, whereas urban and agricultural biotopes showed the least similarity. Butterfly diversity peaked during summer and post-monsoon across all habitats. Seven species are listed under Schedule II, and one under Schedule IV of the Indian Wildlife (Protection) Act, 1972. The decline in butterfly diversity in agricultural landscapes points to habitat loss driven by expanding agricultural frontiers in Nainital district. Overall, the findings underscore the value of butterfly communities as ecological indicators for monitoring habitat changes and environmental health in the Western Himalaya.

1. INTRODUCTION

Habitat heterogeneity significantly influences biodiversity by enhancing niche availability and resource diversity (Bazzaz 1975, Tews et al. 2004, Braga & Diniz 2015). Among terrestrial insects, butterflies from the order Lepidoptera are frequently utilized as ecological indicators because they are easy to monitor and highly responsive to environmental and climate changes (Kocher & Williams 2000). However, ecosystems modified by humans and agricultural landscapes typically prove inadequate for supporting insect diversity, particularly butterflies (Sagwe et al. 2015, Chettri et al. 2018, Samraj & Agnihotri 2021). Landscape degradation driven by rapid climate change, urbanization, and agricultural expansion poses a significant threat to biodiversity (Sagwe et al. 2015, Gallou et al. 2017). Understanding the ecological impacts of habitat loss and fragmentation requires assessing the vulnerability of different biotopes to landscape change (Weißhuhn 2019). Since many butterflies have specific habitat requirements (Leon-Cortes et al. 2004), tracking their abundance and distribution across various biotopes can aid in making timely conservation decisions (Blair & Launer 1997, Munyuli 2013, Fontaine et al. 2016, An & Choi 2021).

The Indian Himalayan Region (IHR) boasts a rich diversity of butterflies. Numerous studies have documented butterfly diversity and habitat associations across both protected and unprotected areas within the IHR (Singh & Bhandari

2003, 2006, Uniyal 2007, Bhardwaj & Uniyal 2011, Sarma et al. 2012, Qureshi et al. 2014, Kumar et al. 2016, Chettri et al. 2018, Paunikar & Sharma 2022). Despite extensive research in the Western Himalaya (Joshi & Arya 2007, Bhardwaj et al. 2012, Kumar et al. 2017, Verma & Arya 2018, Arya et al. 2020a, Samraj & Agnihotri 2021, Verma & Arya 2022), the spatial variation of butterfly assemblages within the Kumun region of Uttarakhand remains insufficiently explored. Similarly, existing records from Nainital district in Kumaun division (Smetacek 2002, 2010, 2011a, 2011b, 2012a, 2012b, Tyagi et al. 2011, Meena & Dayakrishna 2017, Sondhi 2017, Arya et al. 2018, Arya et al. 2020b, Chandra et al. 2023) lack comparative or habitat-based analyses. As a result, systematic documentation of butterfly diversity across the diverse biotopes of the Kumaun Himalaya remains inadequate. Given the scarcity of studies comparing how different biotopes influence butterfly communities seasonally, a detailed assessment is necessary to understand habitat-specific responses. Therefore, this study investigates the effects of habitat simplification on butterfly communities by analyzing (a) species assemblage structure and composition in urban, riverine, and agricultural habitats, (b) seasonal variations in diversity, and (c) the conservation value of these biotopes. The research also evaluates the potential of butterflies as bioindicators of habitat integrity amid expanding agriculture and urban development.

Unlike previous studies from the Kumaun Himalaya, which primarily include checklist-based inventories or site-specific records, this study employs a comparative biotope-based approach to evaluate butterfly assemblages across different land-use systems. It fills this gap by offering a spatio-temporal assessment of butterfly diversity in agricultural, riverine, and urban landscapes within the Kumaun division, providing valuable insights into habitat alteration and its effects on environmental monitoring.

2. MATERIALS AND METHODS

2.1. Study Area

The study area is located in the Kumaun Himalayan region of Uttarakhand, northern India. The district of Nainital, covering 4,251 km², lies at elevations ranging from 151 m to 2,581 m above sea level and is the sixth largest district in the state. It features diverse topographic regions with contrasting landscapes that generate microclimatic variations, which in turn influence soil properties and vegetation patterns. Changes in vegetation, relief, and slope also impact faunal assemblages (Acharya & Vijayan 2015). This study focuses on three structurally distinct biotopes differentiated by elevation, biotic stress levels, vegetation types, and disturbance intensity. These are the Agriculture Biotope, the Riverine Biotope, and the Urban Biotope, situated at approximately 350 m, 950–1,150 m, and 2,100–2,300 m above sea level, respectively (Fig. 1). Due to terrain differences, each biotope experiences variations in rainfall patterns, relative humidity, and monthly temperatures. These climatic parameters were recorded using a digital min/max thermo-hygrometer.

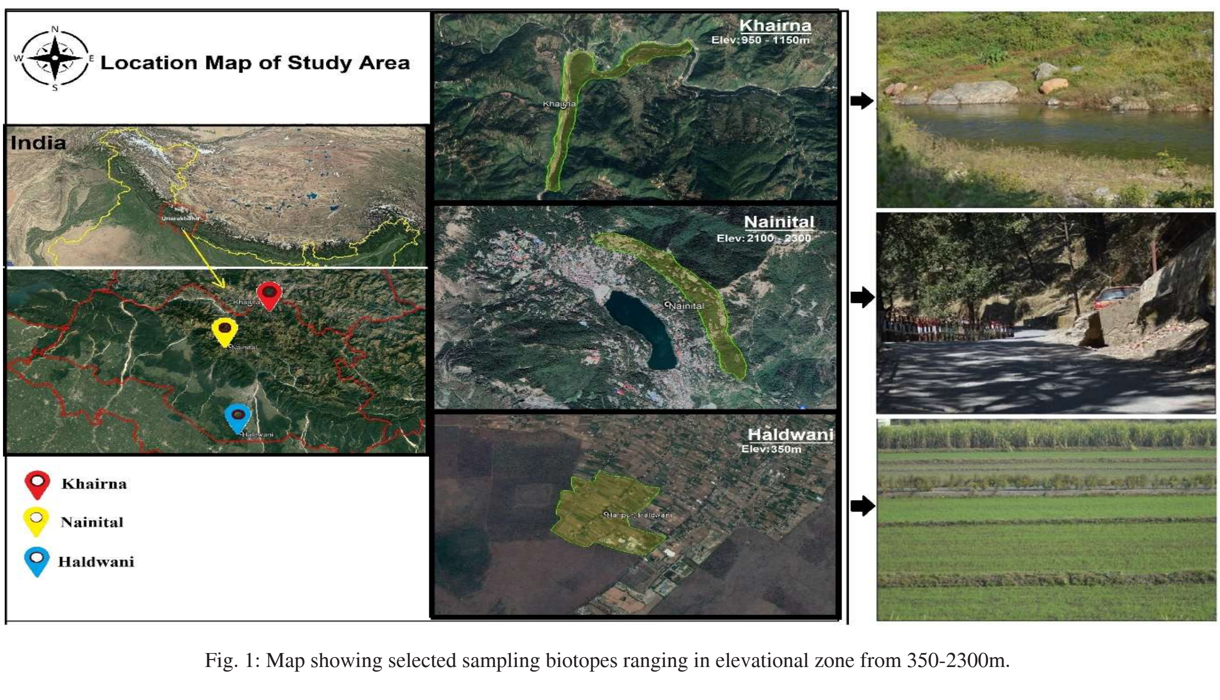


Fig. 1: Map showing selected sampling biotopes ranging in elevational zone from 350-2300m.

2.1.1. Agriculture Biotope (aB)

The study site is situated in Haripur Jamansingh village, Haldwani, characterized by arable lands that reflect a rural environment. The region experiences warmer summers with comparatively higher rainfall than in winters. Annually, kharif crops such as paddy and maize are cultivated, while rabi crops include wheat, sugarcane, pulses, mustard, and *Trifolium alexandrinum*. Additionally, fruit-bearing and ornamental plants along field margins or hedgerows consist of *Catharanthus roseus, Hibiscus, Pyrostegia venusta, Tagetes species, Artocarpus heterophyllus, Mangifera indica, Carica papaya, Punica granatum,* and *Phyllanthus emblica*. Human activities such as surface burning, litter removal, fodder collection, and small-scale construction are prevalent. Butterflies were observed along two transects: one bordering the field margins and another within the crop fields.

2.2.2. Riverine Biotope (rB)

The location is situated along the banks of the Kosi River near Jyari village, Khairna. The riverbed has an average width of about 80 meters and flows in a north-west direction. The region features a mix of broad-leaved and needle-leaved trees, dense shrubs, and ground vegetation. Common tree species planted along the banks include *Cinnamomum tamala, Syzygium cumini,* and *Prunus persica*, while naturally occurring vegetation comprises *Pinus roxburghii, Ricinus communis*, and various *Ficus* species. The shrub and ground layers are dominated by *Berberis asiatica, Callicarpa macrophylla, Lantana camara, Hypericum oblongifolium, Zanthoxylum armatum, Debrigessia longifolia, Ageratina adenophora*, and *Conyza japonica*. The river acts as a boundary, separating a relatively pristine mountainous area on the right bank from a semi-modified landscape on the left bank, which includes small markets and highway crossings. Human activities such as woodcutting for fuel, grazing, fodder collection, and construction along the riverbank have led to alterations in the surrounding forest cover. Butterfly communities were sampled across two transects established on both sides of the Kosi River, providing insight into the local biodiversity.

2.2.3. Urban Biotope (uB)

The urban biotope, belonging to the town of Nainital, represents a highly disturbed landscape characterized by dense human settlements and a rapid influx of tourists. The region has a monsoon-dominated climate, with peak rainfall occurring from mid-June to September. The tree layer consists of a mix of evergreen and deciduous species, including *Acer oblongum, Aesculus indica, Buddleja asiatica, Cupressus torulosa, Quercus leucotricophora, Q. floribunda*, and *Rhododendron arboreum*. Common shrubs and herbs comprise *Berberis sp., Debrigessia longifolia, Pyracantha crenulata, Rubus ellipticus, Ageratina adenophora, Bidens pilosa, Cirsium* sp., *Erigeron* sp., *Rumex nepalensis, Salvia* sp., and *Urtica dioica*. The surrounding forests are often subjected to grazing, as well as fuel wood and fodder collection. The expansion of settlements and occasional forest fires have increased human pressures. Transects were selected to reflect different levels of anthropogenic impact: one experienced recurrent human disturbances, while the other was located in a moderately disturbed area adjacent to forest cover (Table 1).

2.2. Sampling and Identification of Butterflies

Monthly sampling of butterfly species was conducted twice monthly in each biotope from March 2023 to February 2024. Each visit lasted three consecutive days, covering each transect between 08:00 and 15:00. Two 500-meter line transects were established in each biotope, with butterfly counts based on wing morphology performed using the point count method and the modified Pollard Walk Method (Pollard 1977). Due to the varying physiography of the biotopes, transects were strategically placed within a landscape span of approximately 3 km to ensure representative habitat coverage. Along each transect, ten fixed point-count stations were set at regular intervals, with butterfly abundance recorded for five minutes at each station while maintaining a consistent pace within the observer's radius.

Although detectability may differ among biotopes, sampling effort, time of day, transect length, and observation

Table 1: Characteristic features of biotopes selected for butterfly sampling.

Biotope	Location	Elevation [m]	Geographical coordinates	Landscape Element & Vegetation Type	Level of Disturbance
Agriculture (*aB*)	Haldwani	350	29°09'16.1″N Latitude 79°28'40.6″E Longitude	Cultivation fields of cereal and vegetable crops for agricultural practices	Moderate
Riverine (*rB*)	Khairna	950-1150	29°29'56.7″N Latitude 79°30'19.2″E Longitude	Low-lying area Needle and broad-leaved and plantation forests with good cover of grasses	Low
Urban (*uB*)	Nainital city	2100-2300	29°23′ 29.643″ N Latitude 79°28′ 8.436″ E Longitude	Hilly terrain Mixed deciduous forest near human habitation	High

duration were standardized to facilitate comparative analysis. Some cryptic species, such as *Celastrina* spp., *Lethe confusa,* L. *verma,* and *Neptis* spp., which could not be reliably identified in the field from photographs, were collected with butterfly nets, identified, and then released unharmed. No harm was inflicted on any individual during the study. Butterfly identification followed field guides by Kehimkar (2014) and Sondhi and Kunte (2018). The presence of preferred host plants within 2.5 meters of either side of each transect was recorded following Clark et al. (2007).

2.3. Analysis of Data

Five major groups of butterflies were classified based on the occurrence frequency of individuals across all biotopes: Very Rare (1-3 individuals), Rare (4-10 individuals), Uncommon (11-20 individuals), Common (21-40 individuals), and Very Common (>41 individuals). These categories are descriptive and intended to reflect field observations rather than infer the population status of butterflies. To analyze the collected data, the months were grouped into four seasons: (i) summer: March, April, May; (ii) monsoon: June, July, August; (iii) post-monsoon: September, October, November; and (iv) winter: December, January, February.

The functional roles of butterflies, based on information about their larval host plants, were examined using published sources from around the world, including Wynter-Blyth (1957), Veenakumari et al. (1997), Robinson et al. (2023), Smetacek (2011c), Smetacek & Smetacek (2011), Ghorai & Sengupta (2014), Sengupta et al. (2014), Naik & Mustak (2015), Joshi et al. (2016), Nitin et al. (2018), and Sondhi & Kunte (2018). Based on their range of host plant utilization, butterfly species were classified into three categories reflecting host specificity: Monophagous- feeding on plant species within a single genus, Oligophagous- feeding on plant genera within a single family, and Polyphagous- feeding on a diverse array of larval food plants across multiple plant families (Smetacek 2012a).

Using this classification, oligophagous and polyphagous butterflies were regarded as host generalists, whereas monophagous butterflies were considered host specialists. Additionally, the patterns of abundance and species richness across different biotopes and seasons were analyzed separately. A heat map was created to illustrate the seasonal evenness or equitability of species, plotted against normalized abundance—calculated using the formula proposed by Naik et al. (2022). et al. (2022).

$$xi - min(x)/max(x) - min(x)$$

(Where x= absolute frequency and N= total)

The heat map was created to visualize the distribution of butterflies across different seasons, with Hierarchical Cluster Analysis (HCA) conducted to explore relationships between seasons and species assemblages. This analysis utilized normalized abundance data, which is appropriate for presence-absence matrices that display strong seasonal variation. The heat map was generated online using Heatmapper (http://www.heatmapper.ca/, Babicki et al. 2016). Rank-abundance curves illustrating species distribution patterns across various biotopes were produced after log-transforming the abundance data. To evaluate sampling efforts, individual-based rarefaction curves were calculated for each biotope using the software PAST version 3.4 (Magurran 2004, Hammer et al. 2001). Similarly, butterfly diversity among families and biotopes was assessed using alpha diversity indices such as Shannon's Index (Hs) for species diversity (Shannon & Weaver 1949), Simpson's Index (D) for species dominance (Simpson 1949), and Margalef's Index (Hm) for species richness (Margalef 1972), all calculated with PAST 3.4. To compare butterfly richness and abundance across biotopes, One-way ANOVA was performed using SPSS version 22, followed by pairwise comparisons with Tukey's HSD test at a 5% significance level. Additionally, the Jaccard similarity index (J) was employed to measure the similarity in species composition among biotopes based on shared species, using the formula provided by Niwattanakul et al. (2013).

$$(J = a \cup b)/(a \cap b)$$

Where a = the number of species of butterflies present at Site A and b = *the* number of species of butterflies present at Site B.

Bray-Curtis cluster analysis based on single linkage similarity was performed using Biodiversity Pro (Lambshead et al. 1997, McAleece 1998).

3. RESULTS

3.1. Species Richness, Family Composition, and Status of Butterfly Fauna

A total of 94 species, belonging to 66 genera and six families, were identified across the three study sites during the research period. The Nymphalidae family was the most prevalent, representing 44.7% of the species, followed by Pieridae (20.2%), Lycaenidae (18.1%), Papilionidae (8.5%), Hesperiidae (5.3%), and Riodinidae (3.2%). Table 2 presents an inventory of the butterfly species identified, their seasonal abundance, and their polyphagy categories across different biotopes. Fig. 2 highlights some of the notable butterfly species observed during the study.

Out of a total of 94 butterfly species recorded, seven species (*Aporia agathon*, *Ceporia nerissa*, *Euchrysops cnejus*,

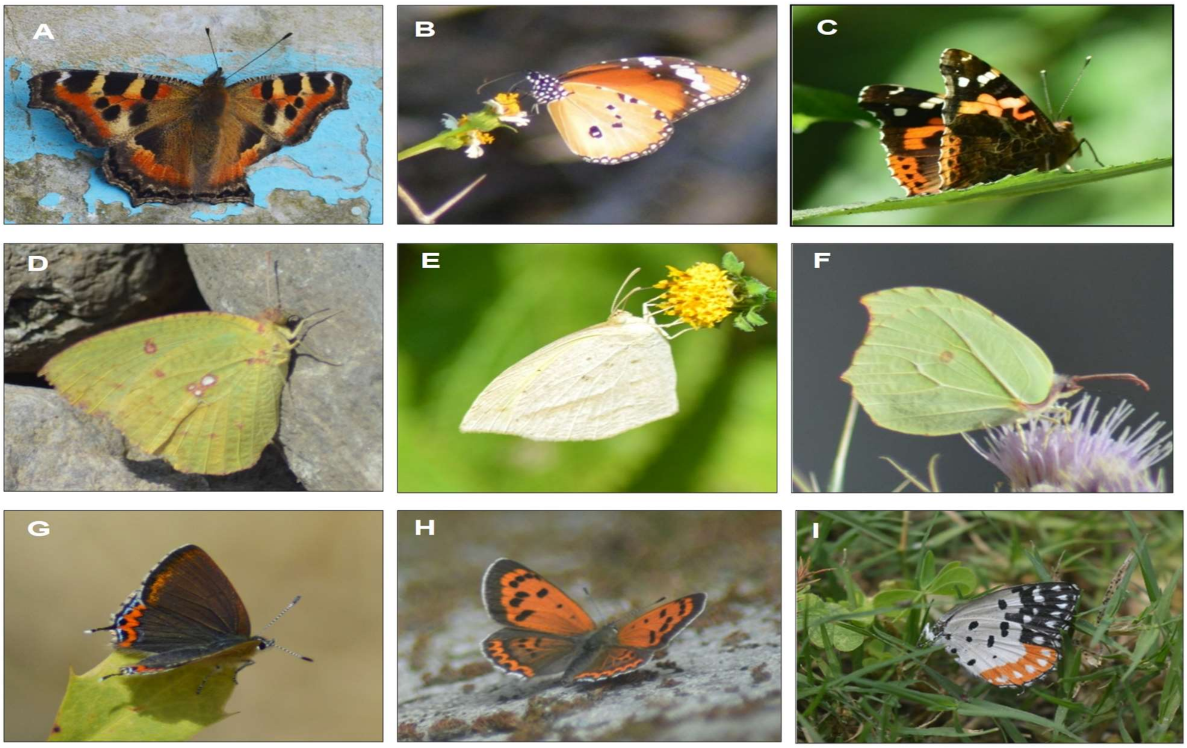


Fig. 2: Photo plates of butterflies identified from the study area. (A) *Aglais caschmirensis*. (B) *Danaus chrysippus*, (C) *Vanessa indica*, (D) *Catopsilia pyranthe*, (E) *Eurema laeta*, (F) *Gonepteryx nepalensis*, (G) *Heliophorus sena*, (H) *Lycaena panava*, (I) *Talicada nyseus*.

Table 2: Distribution, species composition, and seasonal abundance of butterfly populations in different biotopes (*aB*, *rB*, *uB*) during the study period.

Family	Scientific Name	(*aB*)				(*rB*)				(*uB*)			
		S	M	PM	W	S	M	PM	W	S	M	PM	W
Nymphalidae	*Acraea issoria* (Hübner) [P]	0	0	0	0	1	2	2	0	1	4	2	1
	Aglais caschmirensis (Kollar) [P]	0	0	0	0	6	8	12	4	34	16	18	8
	Ariadne ariadne (Linnaeus) [M]	2	4	5	3	0	2	5	2	0	0	0	0
	Ariadne merione (Cramer) [O]	2	2	35	31	4	6	20	0	0	0	0	0
	Argynnis hyperbius (Linnaeus) [P]	0	0	1	0	1	0	2	0	1	0	1	0
	Aulocera swaha (Kollar) [M]	0	0	0	0	0	0	0	0	3	2	6	1
	Callerebia annada (Moore) [O]	0	0	0	0	0	0	0	0	8	6	8	0
	Cyrestis thyodamas Doyere [P]	2	1	1	2	2	2	1	1	0	0	0	0
	Danaus chrysippus (Linnaeus) [P]	18	5	14	1	4	5	25	1	9	10	11	0
	Danaus genutia (Cramer) [O]	10	11	11	2	9	2	16	3	6	9	13	0
	Euploea core (Cramer)[P]	3	1	3	1	3	3	0	0	7	2	4	0
	Euthalia aconthea (Cramer) [P]	6	4	3	0	2	2	3	0	0	0	0	0
	Euthalia patala (Kollar) [M]	0	0	0	0	0	0	0	0	2	7	1	0
	Hypolimnas bolina (Linnaeus) [P]	3	6	2	0	1	2	4	0	0	0	0	0
	Issoria issaea (Gray) [P]	0	0	0	0	0	0	0	0	4	1	0	0
	Junonia almana (Linnaeus) [P]	12	5	1	10	16	1	1	1	9	3	3	0
	Junonia iphita (Cramer) [O]	4	0	2	0	5	1	2	0	15	4	1	0

Table Cont....

Family	Scientific Name	(*aB*)				(*rB*)				(*uB*)			
		S	M	PM	W	S	M	PM	W	S	M	PM	W
	Junonia lemonias (Linnaeus) [P]	2	4	5	1	4	1	3	0	3	0	2	0
	Junonia orithya (Linnaeus) [P]	9	6	5	2	5	3	2	0	0	0	0	0
	Kallima inachus (Doyere) [P]	0	0	0	0	4	1	0	0	0	0	0	0
	Kaniska canace (Linnaeus) [P]	0	0	0	0	0	1	0	0	1	0	1	0
	Lasiommata schakra (Kollar) [M]	0	0	0	0	0	0	0	0	5	8	4	0
	Lethe confusa Aurivillus [O]	0	0	0	0	0	1	0	0	1	4	2	0
	Lethe verma (Kollar) [O]	0	0	0	0	0	0	0	0	0	4	2	0
	Melanitis leda (Linnaeus) [O]	0	0	0	0	0	2	0	0	0	4	3	0
	*Mycalesis visala*Moore [O]	1	5	3	1	0	2	1	0	0	0	0	0
	Neptis hylas (Linnaeus) [P]	11	5	8	0	4	0	4	0	9	2	8	1
	Neptis sappho (Pallas) [M]	6	5	8	1	10	1	6	0	0	0	0	0
	Orinoma damaris Gray [M]	0	0	0	0	0	0	0	0	0	0	1	0
	Parantica aglea (Stoll)[O]	2	1	3	0	3	3	5	0	4	6	2	0
	Parantica sita (Kollar)[O]	0	3	3	0	2	2	0	0	2	6	2	0
	Phalanta phalantha (Drury) [P]	0	0	0	0	1	1	27	1	6	0	19	3
	Pseudergolis wedah (Kollar)[O]	0	0	0	0	11	9	8	1	0	0	0	0
	Sephisa dichroa (Kollar) [P]	0	0	0	0	0	0	0	0	1	2	0	0
	Symbrenthia lilaea (Hewitson)[O]	7	2	0	4	1	1	5	0	3	0	9	0
	Tirumala limniace (Cramer)[O]	0	2	0	0	1	1	0	0	0	0	0	0
	Vanessa cardui (Linnaeus) [P]	0	0	0	0	4	0	3	0	14	1	7	0
	Vanessa indica (Herbst) [P]	0	0	0	0	3	0	9	0	26	2	16	4
	Ypthima baldus (Fabricius) [O]	4	14	8	2	2	3	2	2	0	0	0	0
	Ypthima huebneri Kirby[M]	11	14	7	3	4	2	1	0	0	0	0	0
	Ypthima nareda (Kollar) [M]	0	0	0	0	2	1	0	0	0	2	1	0
	Ypthima nikaea Moore[M]	0	0	0	0	0	0	1	0	4	4	3	0
Pieridae	*Aporia agathon* [P]	0	0	0	0	0	0	0	0	16	10	0	0
	Belenois aurota (Fabricius) [P]	8	2	4	1	4	3	1	0	4	0	0	0
	Catopsilia pomona (Fabricius) [O]	14	18	12	6	11	3	11	2	10	6	8	1
	Catopsilia pyranthe (Linnaeus)[O]	9	14	10	16	7	3	9	3	11	6	7	0
	Cepora nerissa (Fabricius) [O]	13	6	3	1	7	1	2	0	0	0	0	0
	Colias erate (Esper)[O]	5	0	1	0	3	1	1	0	5	1	0	0
	Colias fieldii Menetries [P]	27	1	0	0	10	0	0	0	24	4	2	0
	Delias belladonna (Fabricius)[O]	0	0	0	0	3	1	2	0	11	4	2	0
	Eurema andersonii (Moore)[M]	11	1	10	3	3	0	7	0	4	3	2	0
	Eurema blanda (Boisduval) [P]	4	4	6	10	4	2	8	1	0	0	0	0
	Eurema brigitta (Stoll)[P]	8	4	14	4	4	5	11	0	9	5	15	0
	Eurema hecabe (Linnaeus)[O]	24	20	12	24	8	4	12	0	22	7	11	0
	Eurema laeta (Boisduval)[O]	13	6	8	3	6	0	14	2	12	9	14	0
	Gonepteryx nepalensis Doubleday [P]	0	0	0	0	3	0	6	0	7	10	10	2
	Leptosia nina (Fabricius)[P]	1	4	3	3	0	2	1	1	0	0	0	0
	Pareronia hippia (Fabricius)[O]	1	1	4	0	0	2	4	0	0	0	0	0
	Pieris brassicae (Linnaeus) [P]	29	19	20	10	28	10	14	8	29	24	15	2
	Pieris canidia (Linnaeus)[P]	35	17	16	17	32	13	17	8	28	27	20	3

Table Cont....

Family	Scientific Name	(*aB*)				(*rB*)				(*uB*)			
		S	M	PM	W	S	M	PM	W	S	M	PM	W
	Pontia daplidice (Linnaeus)^{P}	13	4	2	1	3	0	1	0	1	3	0	0
Lycaenidae	*Catochrysops strabo* (Fabricius)^{P}	0	1	4	1	1	0	2	0	0	0	0	0
	Celastrina argiolus (Linnaeus)^{P}	0	0	0	0	0	0	0	0	10	6	13	1
	Celastrina huegelii (Moore) ^{P}	0	0	0	0	0	0	0	0	2	3	9	7
	Celatoxia marginata (de Niceville) ^{M}	0	0	0	0	0	0	0	0	1	3	6	0
	Euchrysops cnejus (Fabricius) ^{O}	0	0	7	12	2	0	5	0	0	0	0	0
	Heliophorus moorei (Hewitson) ^{M}	0	0	0	0	0	0	0	0	0	0	1	0
	Heliophorus sena (Kollar) ^{P}	0	0	0	0	11	1	8	0	52	24	17	7
	Jamides celeno (Cramer) ^{P}	2	0	1	0	0	1	2	0	0	0	0	0
	Lampides boeticus (Linnaeus) ^{O}	11	2	1	0	2	2	2	0	14	3	0	0
	Lycaena panava (Westwood) ^{M}	0	0	0	0	0	0	0	0	12	38	6	0
	Lycaena phlaeas (Linnaeus) ^{P}	0	0	0	0	0	0	0	0	2	3	3	0
	Pseudozizzeria maha (Kollar) ^{P}	27	21	23	9	7	6	6	1	5	2	4	1
	Talicada nyseus (Guerin-Meneville) ^{O}	20	7	37	21	10	6	14	5	0	0	0	0
	Udara sp. ^{O}	0	0	0	0	2	1	0	1	1	1	1	0
	Zizeeria karsandra (Moore) ^{P}	43	18	16	14	5	3	4	2	0	2	2	0
	Zizina otis (Fabricius) ^{P}	3	2	3	0	2	1	2	0	0	0	0	0
	Zizula hylax (Fabricius) ^{P}	4	1	2	0	2	0	1	0	0	0	0	0
Papilionidae	*Atrophaneura varuna* (White) ^{P}	0	0	0	0	0	1	0	0	3	7	5	0
	Byasa polyeuctes (Fruhstorfer)^{P}	0	0	0	0	0	0	0	0	4	14	7	0
	Graphium sarpedon (Linnaeus) ^{P}	0	0	0	0	2	0	0	0	1	2	1	0
	Papilio bianor Cramer ^{O}	0	0	0	0	7	0	0	0	8	0	0	0
	Papilio demoleus Linnaeus ^{P}	10	9	3	3	2	2	1	0	4	2	0	0
	Papilio machaon Linnaeus ^{P}	0	0	0	0	1	0	0	0	2	0	0	0
	Papilio polytes Linnaeus ^{O}	10	16	14	5	17	12	17	4	9	13	18	0
	Papilio protenor Cramer^{P}	0	0	0	0	0	2	0	0	2	1	0	1
Hesperiidae	*Borbo bevani* (Moore) ^{O}	3	1	5	6	2	2	6	0	1	4	5	0
	Celaenorrhinus munda (Moore) ^{O}	0	0	0	0	0	0	0	0	0	3	0	0
	Celaenorrhinus pero de Niceville ^{O}	0	0	0	0	0	0	0	0	1	1	2	0
	Parnara guttatus (Moore) ^{P}	2	6	6	0	3	2	5	2	0	0	0	0
	Potanthus dara (Kollar)^{O}	0	0	0	0	1	3	1	0	0	0	1	0
Riodinidae	*Abisara fylla* (Westwood) ^{O}	0	0	0	0	1	0	0	0	1	2	0	0
	Dodona Durga (Kollar)^{P}	0	0	0	0	0	1	1	0	7	3	2	0
	Zemeros flegyas (Cramer) ^{M}	1	1	0	0	2	2	0	0	3	0	0	0

Abbreviations: S: Summer, M: Monsoon, PM: Post Monsoon, W: Winter, ^{M}: Monophagus, ^{O}: Oligophagus, ^{P}: Polyphagus (Source: Wynter-Blyth 1957, Sondhi & Kunte 2018, Robinson et al. 2023)

Eurema andersonii, *Euthalia patala*, *Lampides boeticus*, and *Papilio machaon*) are listed under Schedule II of the Indian Wildlife (Protection) Act (1972), with one species, *Euploea core*, classified under Schedule IV. Additionally, 11 species are categorized as "Least Concerned" on the IUCN Red List of Threatened Species (IUCN 2020), including *Belenois aurota, Danaus chrysippus, Euploea core, Eurema brigitta, Graphium sarpedon, Junonia almana, Junonia orithya, Lampides boeticus, Phalanta phalantha, Pontia daplidice,* and *Vanessa cardui*. Table 3 presents the site-wise records of legally protected species observed during the study. Of the 3,592 individuals recorded, 25.53% were very common, 28.72% common, 17.02% uncommon, 23.40% rare, and 5.31% very rare, highlighting the dominance of a few abundant species in the Kumaun region.

Table 3: Status of butterfly species under the Indian Wildlife (Protection) Act, 1972.

Family	Species Name	Biotope			Protection Status IWPA, 1972
		aB	*rB*	*uB*	
Papilionidae	*Papilio machaon*			✓	Schedule-II
Pieridae	*Aporia agathon*			✓	Schedule-II
	Ceporia nerissa	✓			Schedule-II
	Eurema andersonii	✓	✓	✓	Schedule-II
Lycaenidae	*Euchrysops cnejus*	✓	✓		Schedule-II
	Lampides boeticus	✓	✓	✓	Schedule-II
Nymphalidae	*Euthalia patala*			✓	Schedule-II
	Euploea core	✓	✓	✓	Schedule-IV

Abbreviations: *aB*= Agriculture biotope, *rB*= Riverine biotope, *uB*= Urban biotope, ✓= Presence, IWPA: Indian Wildlife (Protection) Act (Source: Anonymous 2006)

Table 4: Variation in diversity indices of butterfly species observed in different biotopes.

Family	Genus	Species	Individuals	Diversity Indices (Hs)		
				aB	*rB*	*uB*
Nymphalidae	29	42	1236	2.77	3.16	2.99
Pieridae	12	19	1319	2.52	2.52	2.46
Lycaenidae	14	17	694	1.67	2.04	1.82
Papilionidae	4	8	242	0.65	0.98	1.67
Hesperiidae	4	5	74	0.69	1.04	1.12
Riodinidae	3	3	27	0	0.95	0.86

The Shannon diversity indices for different butterfly families revealed variations among the biotopes studied (Table 4). Nymphalidae displayed the highest diversity in all biotopes, especially in *rB* (Hs=3.16), indicating that riverine environments support a more diverse butterfly community. Conversely, families Riodinidae and Hesperiidae showed lower diversity indices, likely due to their reduced populations in the current study.

3.2. Relationship between Butterfly Diversity and Biotopes

Across the selected biotopes, 76 butterfly species were documented in the riverine biotope (*rB*), 70 species in the urban biotope (*uB*), and 52 species in the agricultural biotope (*aB*). Species analysis revealed clear differences in assemblages, with steeper upper asymptotic curves observed across all biotopes (Fig. 3). The *aB* and *uB* biotopes reached asymptotes earlier than *rB*, indicating lower species richness. Asymptotic rarefaction curves for all biotopes suggest that sampling efforts were adequate throughout the study and that differences in richness are likely due to ecological variation rather than sampling bias. The one-way ANOVA results showed significant differences in species richness among biotopes ($F= 6.130$, $P < 0.05$), emphasizing the

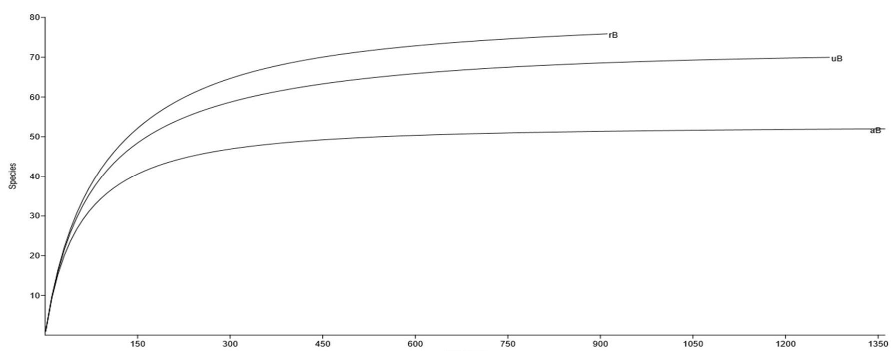


Fig. 3: Individual-based rarefaction curves for butterfly assemblages in different biotope types.

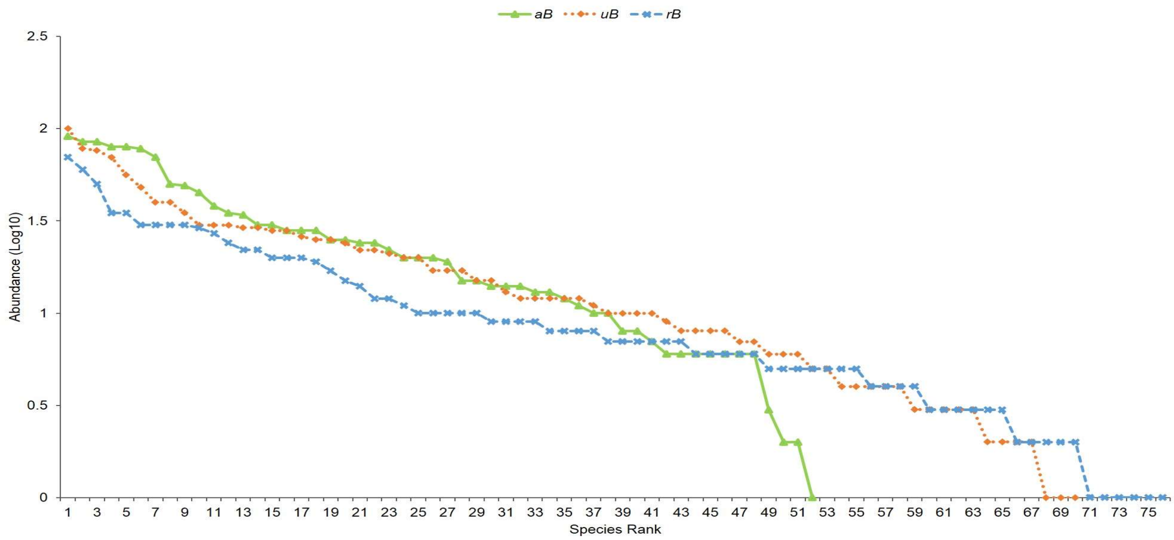


Fig. 4: Rank-abundance curves of butterfly species assemblages in three biotopes.

Table 5: Diversity indices of butterfly communities from the study area.

Diversity indices	*aB*	*rB*	*uB*
Butterfly species	52	76	70
Individuals	1377	929	1286
Dominance_D	0.03	0.02	0.03
Simpson_1-D	0.96	0.97	0.96
Shannon_H	3.57	3.88	3.79
Margalef	7.05	10.97	9.63

impact of land-use and micro-habitat structure on butterfly communities. However, species abundance did not differ significantly ($F= 1.722$, $P > 0.05$).

Alpha diversity indices such as Shannon-Wiener alpha diversity (Hs) and Margalef richness (Hm) revealed that the riverine biotope (*rB*) supported the highest level of species diversity and richness, with Hs=3.88 and Hm=10.97. The *uB* followed, with Hs=3.79 and Hm=9.63, while the agriculture biotope (*aB*) exhibited the lowest diversity and richness, with Hs=3.57 and Hm=7.05. Simpson's dominance index (D) was also highest in (*rB*) at 0.97, indicating a community structure that is more even but dominated by a few species (Table 5). The rank abundance plot for *aB* was steeper, suggesting an unequal distribution, whereas the curves for uB and rB displayed smooth patterns, reflecting a more balanced distribution of butterfly assemblages (Fig. 4).

Vegetation heterogeneity across different biotopes significantly influenced butterfly assemblages. Comparative data on larval host plants, collected from studies by prominent researchers, indicated that the butterfly community displayed

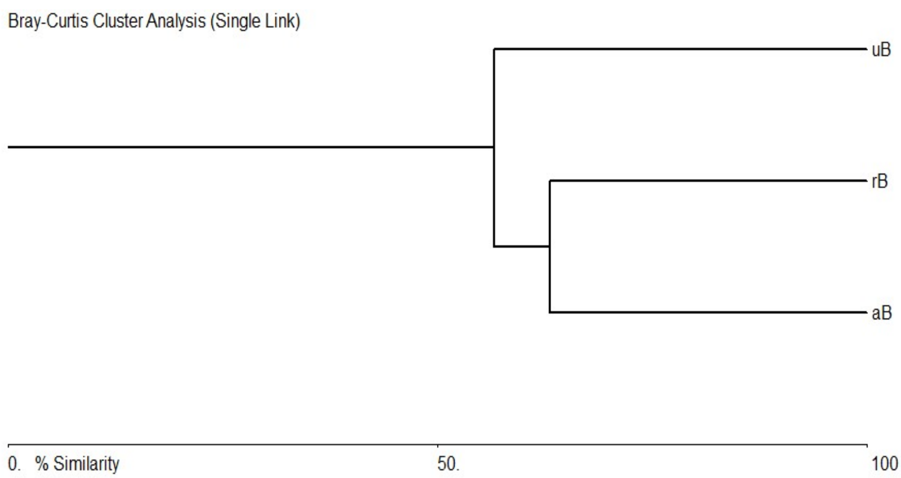
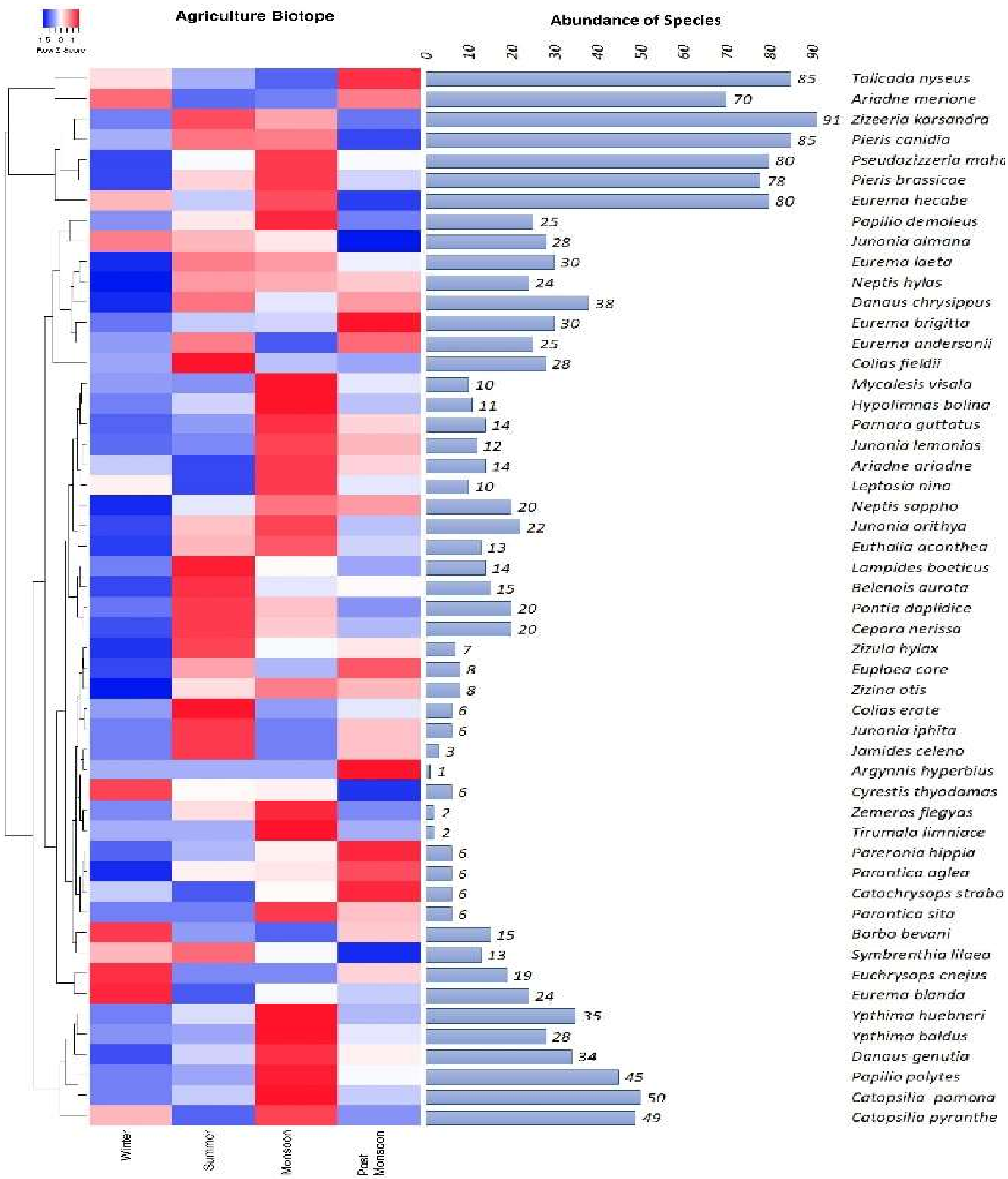


Fig. 5: Bray-Curtis cluster analysis showing similarity of butterfly assemblages across biotopes using single linkage method.

Table 6: Jaccard similarity coefficients among different biotopes.

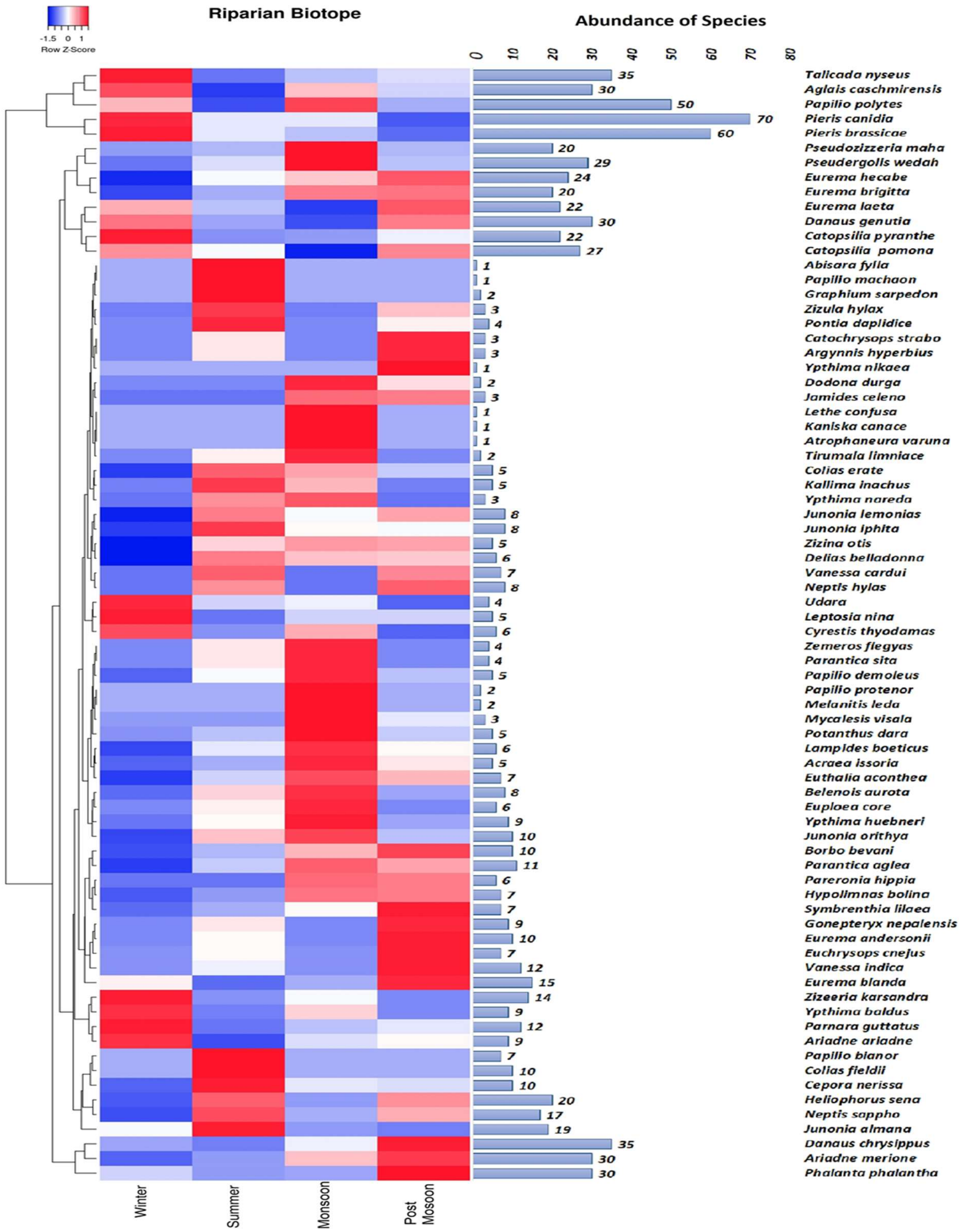
	aB	*rB*	*uB*
aB	*		
rB	0.68	*	
uB	0.32	0.54	*

broad feeding preferences. Out of 94 species, 47 (50%) were polyphagous, 33 (35.1%) were oligophagous, and 14 (14.89%) were monophagous (Table 2). The agricultural biotope had the highest proportion of host generalists at 90.3%, followed by the urban biotope at 84.28%, with only a small fraction (10%) being specialists restricted to forest edges. Conversely, the riverine biotope supported the largest



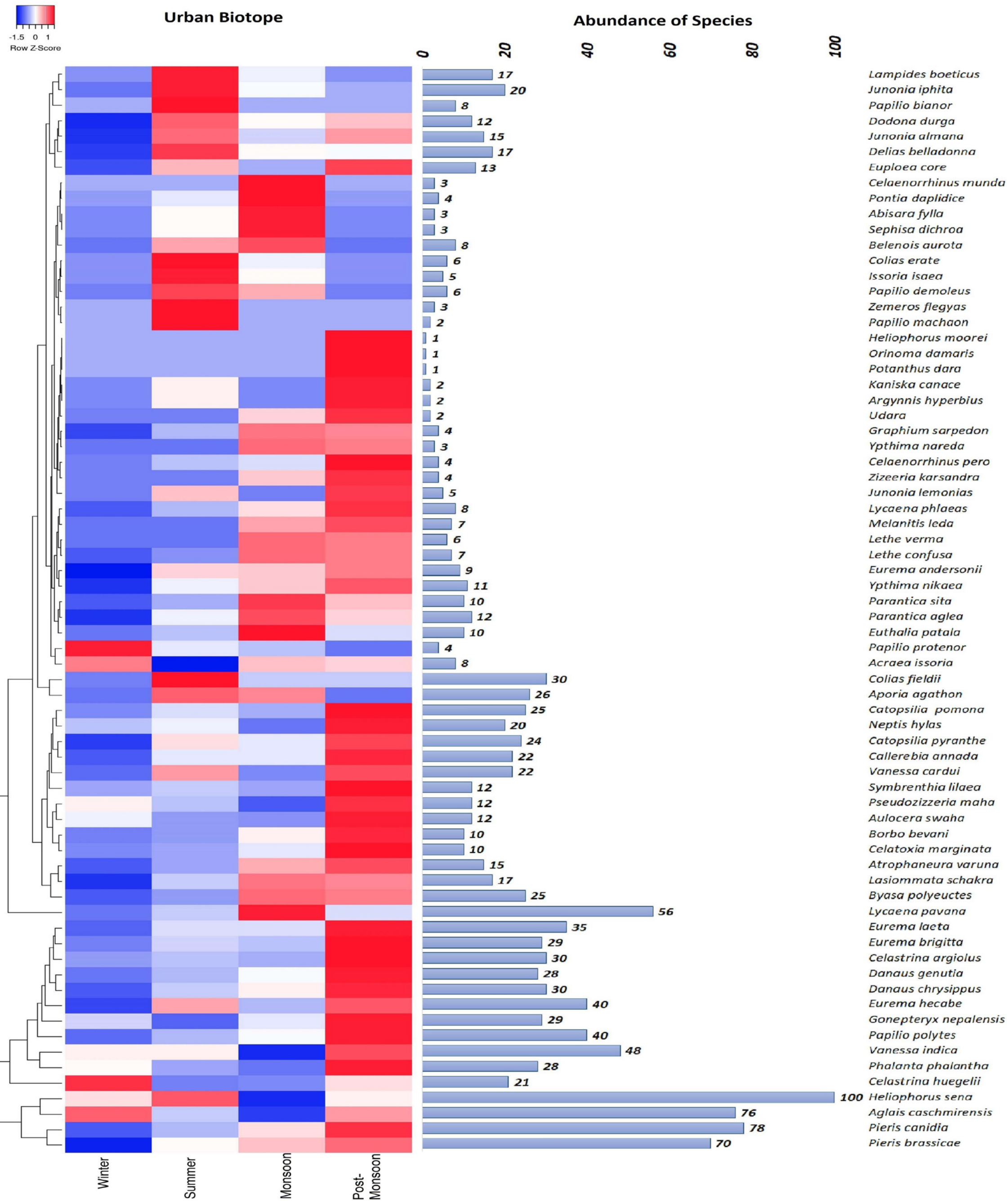
A

Figure Cont....



B

Figure Cont....



C

Fig. 6: Heat map showing patterns of normalized abundance of butterfly species in different seasons at different biotopes during the study period. (A) Agriculture, (B) Riverine, (C) Urban.

proportion of monophagous species (14.47%) among the three biotopes, reflecting relatively undisturbed vegetation.

3.3. Species Diversity and Biotope Association

Single-linkage Bray-Curtis cluster analysis indicated the greatest similarity between riverine and agricultural biotopes at 62.74%, with the urban biotope showing a 56.77% similarity (Fig. 5). There were 52 species common to riverine and agricultural areas, 51 between riverine and urban, and 28 between urban and agricultural biotopes. Based on the distance matrix and cluster results, Jaccard's coefficient was highest between *aB* and *rB* at 0.68, followed by *rB* and *uB* at 0.54. The lowest similarity index, 0.32, was observed between *aB* and *uB* (Table 6).

3.4. Season-wise Distribution of Butterfly Fauna

The study demonstrated that butterflies across all biotopes exhibited a distinct seasonal pattern, with both overall species richness and individual abundance varying markedly throughout the year. Bi-annual peaks in species richness were observed during the summer (March-May) and post-monsoon (September-November) across all study sites. In contrast, winter showed the lowest richness, primarily due to lower temperatures and limited plant resources. Meanwhile, species abundance reached its highest levels during summer in areas *aB* and *uB*, comprising 33.7% and 40.04% of individuals, respectively, and during the post-monsoon season in *rB*, accounting for 39.7% of individuals.

The heat map illustrating seasonal abundance reveals irregular species occurrences throughout the year (Fig. 6). In panel *aB*, dominant species such as *Zizeeria karsandra, Pieris canidia*, and *Eurema hecabe* were relatively scarce during winters and post-monsoon periods, whereas *Talicada nyseus* and *Ariadne merione* remained comparatively abundant. Twenty-seven species, including *Mycalesis visala, Hypolimnas bolina, Ypthima yubneri,* and *Y. baldus,* peaked during the monsoon and were nearly absent in other seasons.

In *rB*, species distribution appeared to be influenced by river-mediated microclimate. Most species extended across two to three seasons rather than exhibiting strict seasonality. Species such as *Junonia lemonias*, *Zizina otis*, and *Delias belladonna* were present in three seasons, while approximately 24 species, including *Papilio polytes*, *Eurema brigitta*, *Cyrestis thyodamas*, and *Ariadne merione*, were recorded in two seasons.

In *uB*, several dominant species, including *Heliophorus sena, Aglias caschmirensis, Pieris canidia, Vanessa indica,* and *Colias fieldii*, showed biannual peaks, primarily during summer and post-monsoon. Of the 70 species recorded in *uB*, 53 reached peak abundance during the post-monsoon period, suggesting favorable climatic and vegetational conditions.

4. DISCUSSION

Different habitats create unique mosaics that support a variety of butterfly assemblages. The biotopes of the Kumaun region play a significant role in maintaining butterfly diversity. The Nymphalidae family was the most dominant, consistent with findings from other studies (Bhardwaj et al. 2012, Chettri et al. 2018, Verma & Arya, 2018, Samraj & Agnihotri, 2021), exhibiting the highest species richness across all seasons and study sites. Its prevalence may be attributed to the polyphagous nature of its members, which allows them to tolerate disturbances and microclimatic variations. Conversely, the Riodinidae family was the least represented.

The butterfly communities observed across elevations ranging from 350 to 2300 meters above sea level within the Nainital district exhibit greater species richness in the riverine biotope (*rB*). Enhanced habitat heterogeneity, edge interfaces, and stable moisture conditions likely supported a diverse array of larval host plants and adult resources, which is reflected in the higher asymptotic rarefaction curve, rather than any sampling artifacts. Conversely, human activities in other biotopes have simplified their community structures. Several specialist species such as *Pieris canidia*, *P. brassicae*, *Papilio polytes*, *Talicada nyseus*, *Danaus chrysippus*, *Aglais caschmirensis*, *Ariadne merione*, *Danaus genutia*, and *Phalanta phalantha* were more prominent in *rB* (11.84% of total species richness present), suggesting the influence of moderate canopy cover and vegetation composition.

Similarly, in the (*uB*), dominant species included *Heliophorus sena, Pieris canidia, Aglais caschmirensis, P. brassicae, Lycaena panava,* and *Vanessa indica*, constituting 8.57% of the total species. Although situated near forest edges, disturbances such as forest clearings, grazing, roadside traffic, and extreme climatic conditions likely reduced species richness compared to (*rB*). These disturbances favored some disturbance-tolerant generalist species, resulting in higher abundance but lower diversity within the urban biotope.

In agricultural land (*aB*), species richness was reduced, probably due to disturbance factors such as frequency of activities, pesticide application, tillage for pest control, crop harvesting, and periodic surface burning affecting larval food plants. These land use changes may have caused homogenization of species communities, shifting them from less mobile specialists to more mobile generalists, and thereby decreasing functional diversity (Bhardwaj et al. 2012, Börschig et al. 2013, Singh et al. 2017). The dominant generalist species in this biotope included *Zizeeria karsandra, Talicada nyseus, Pieris canidia, Eurema hecabe, Pseudozizeeria maha, Pieris brassicae, Ariadne merione,* and *Catopsilia pomona*. Their polyphagy and higher survival rates contributed to their highest abundance and a steeper rarefaction curve in *aB*. These findings underscore the emerging challenges of agricultural expansion in the rural district area for the first time.

Since the ecology of butterfly communities is influenced by multiple factors, seasonal conditions play a crucial role in determining their life cycle and distribution patterns

(Kunte 1997). Agricultural and urban habitats showed the highest abundance during the summer season, consistent with findings from other studies (Padhye et al. 2006, Parandhaman et al. 2012), possibly due to the presence of diverse vegetation and sequential flowering stages that provide ample food resources. This contrasts with some studies that report higher butterfly numbers during the rainy season (Kunte 1997, Pozo et al. 2008, Hussain et al. 2011, Manwar & Wankhade 2014). Conversely, (*rB*) exhibited greater abundance during the late monsoon, aligning with Gohel & Rava (2019) and Arya et al. (2020b), likely reflecting the availability of host plants. Winter consistently recorded the lowest species richness and abundance across all biotopes. Overall, these spatial and temporal variations highlight the potential of butterfly communities to serve as sensitive ecological indicators of land-use changes in the Kumaun Himalaya.

Under the Indian Wildlife (Protection) Act of 1972, several Schedule II species and one Schedule IV species were recorded. Our study revealed that some legally protected species, such as *Euthalia patala* and *Papilio machaon*, were found as rare or very rare, while few others appeared to be common or very common, such as *Aporia agathon*, *Cepora nerissa*, *Euchrysops cneju*s, *Lampides boeticus*, *Euploea cor*e, and *Eurema andersonii*. This suggests that these biotopes are crucial for the survival of these threatened species as well, and therefore, vegetation management and conservation should focus on the most preferred plant families.

5. CONCLUSIONS

This study examines the interaction between butterflies and their environment, enabling the assessment of their role as bio-indicators of the ecological health of Himalayan ecosystems amidst increasing disturbances. A total of 30 species, accounting for 31.91% of all species surveyed, were found across all three biotopes, suggesting a broad distribution and stable populations. The findings emphasize the significance of riverine habitats for butterfly diversity, as these areas host the highest number of species and provide well-structured habitats. To reduce the impact of human activities on butterfly populations in urban and agricultural environments, it is crucial to address issues such as habitat degradation and pesticide use, while also involving local communities. Additionally, conserving host tree species and native larval plants along riverbanks, maintaining hedgerows in agricultural fields, and protecting forest-edge microhabitats within urban areas should be prioritized to ensure the sustainability of butterfly diversity.

6. ACKNOWLEDGMENTS

We are thankful to the Head, Department of Zoology, D.S.B. Campus, Kumaun University, Nainital, for encouraging the commencement of this research and necessary facilities. The authors sincerely thank research companions for assistance in the field work and local people for their help during this study. The efforts of various reviewers during the preparation of the manuscript are also acknowledged.

7. REFERENCES

Acharya, B.K. and Vijayan, L., 2015. Butterfly diversity along the elevation gradient of Eastern Himalaya, India. *Ecological Research*, 30(5), pp.909–919. [DOI]

An, J.-S. and Choi, S.-W., 2021. Butterflies as an indicator group of riparian ecosystem assessment. *Journal of Asia-Pacific Entomology*, 24(1), pp.195–200. [DOI]

Anonymous, 2006. *The Wildlife (Protection) Act, 1972*. Natraj Publishers, Dehradun, India, pp.325.

Arya, M.K., Verma, A. and Neha, 2018. Biodiversity assessment of butterflies in Kumaun Lesser Himalayan oak forest for promoting ecotourism at City Nainital. *Journal of Himalayan Ecology and Sustainable Development*, 13(1), pp.75–95.

Arya, M.K., Verma, A. and Tamta, P., 2020a. Diversity of butterflies (Lepidoptera: Papilionoidea) in a temperate forest ecosystem, Binsar Wildlife Sanctuary, Indian Himalayan Region. *Nature Environment and Pollution Technology*, 19(3), pp.1133–1140. [DOI]

Arya, M.K., Dayakrishna and Verma, A., 2020b. Patterns in distribution of butterfly assemblages at different habitats of Corbett Tiger Reserve, Northern India. *Tropical Ecology*, 61(2), pp.180–186. [DOI]

Babicki, S., Arndt, D., Marcu, A., Liang, Y., Grant, J.R., Maciejewski, A. and Wishart, D.S., 2016. Heatmapper: web-enabled heat mapping for all. *Nucleic Acids Research*, 44(W1), pp.W147–W153. [DOI]

Bazzaz, F.A., 1975. Plant species diversity in old-field successional ecosystems in Southern Illinois. *Ecology*, 56(2), pp.485–488. [DOI]

Bhardwaj, M. and Uniyal, V.P., 2011. High-altitude butterfly fauna of Gangotri National Park, Uttarakhand: Patterns in species, abundance, composition and similarity. *ENVIS Bulletin: Arthropods and Their Conservation in India (Insects and Spiders)*, 14(1), pp.38–48.

Bhardwaj, M., Uniyal, V.P., Sanyal, A.K. and Singh, A.P., 2012. Butterfly communities along an elevational gradient in the Tons Valley, Western Himalayas: Implications of rapid assessment for insect conservation. *Journal of Asia-Pacific Entomology*, 15(2), pp.207–217. [DOI]

Blair, R.B. and Launer, A.E., 1997. Butterfly diversity and human land use: Species assemblages along an urban gradient. *Biological Conservation*, 80(1), pp.113–125. [DOI]

Börschig, C., Klein, A.M., von Wehrden, H. and Krauss, J., 2013. Traits of butterfly communities change from specialist to generalist characteristics with increasing land-use intensity. *Basic and Applied Ecology*, 14(7), pp.547–554. [DOI]

Braga, L. and Diniz, I.R., 2015. Importance of habitat heterogeneity in richness and diversity of moths (Lepidoptera) in Brazilian Savanna. *Environmental Entomology*, 44(3), pp.499–508. [DOI]

Chandra, H., Arya, M.K. and Verma, A., 2023. Biodiversity of butterflies (Lepidoptera: Rhopalocera) in the protected landscape of Nandhour, Uttarakhand, India. *Journal of Threatened Taxa*, 15(1), pp.22448–22470. [DOI]

Chettri, P.K., Sharma, K., Dewan, S. and Acharya, B.K., 2018. Butterfly diversity in human-modified ecosystems of southern Sikkim, the Eastern Himalaya, India. *Journal of Threatened Taxa*, 10(5), pp.11551–11565. [DOI]

Clark, P.J., Reed, J.M. and Chew, F.S., 2007. Effects of urbanization on butterfly species richness, guild structure, and rarity. *Urban Ecosystems*, 10(3), pp.321–337. [DOI]

Fontaine, B., Bergerot, B., Le Viol, I. and Julliard, R., 2016. Impact of urbanization and gardening practices on common butterfly communities in France. *Ecology and Evolution*, 6(22), pp.8174–8180. [DOI]

Gallou, A., Baillet, Y., Ficetola, G.F. and Després, L., 2017. Elevational gradient and human effects on butterfly species richness in the French Alps. *Ecology and Evolution*, 7(11), pp.3672–3681. [DOI]

Ghorai, N. and Sengupta, P., 2014. Altitudinal distribution of Papilionidae butterflies along with their larval food plants in the East Himalayan landscape of West Bengal, India. *Journal of Biosciences and Medicines*, 2(1), pp.1–8. [DOI]

Gohel, V.H. and Rava, J.V., 2019. Butterfly diversity, seasonality and status at Junagadh, Gujarat, India. *International Journal of Environment, Ecology, Family and Urban Studies*, 9(2), pp.15–28.

Hammer, O., Harper, D.A.T. and Ryan, P.D., 2001. *PAST: Palaeontological Statistics Software Package for Education and Data Analysis*. Version 3.04. Palaeontologia Electronica, Oslo, Norway. Retrieved May 3, 2025, from https://palaeo-electronica.org/2001_1/past/issue1_01.htm

Hussain, K.J., Ramesh, T., Satpathy, K.K. and Selvanayagam, M., 2011. Seasonal dynamics of butterfly population in DAE Campus, Kalpakkam, Tamil Nadu, India. *Journal of Threatened Taxa*, 3(1), pp.1401–1414. [DOI]

IUCN, 2020. *The Red List of Threatened Species*. Retrieved August 15, 2025, from https://www.iucnredlist.org/

Joshi, P.C. and Arya, M.K., 2007. Butterfly communities along altitudinal gradients in a protected forest in the Western Himalayas, India. *The Natural History Journal of Chulalongkorn University*, 7(1), pp.1–9.

Joshi, R.K., Kapkoti, B., Rawal, R.S., Bhatt, I.D. and Dhyani, P.P., 2016. *Diversity of Butterflies in Surya-Kunj (Contribution to Nature Interpretation and Learning)*. G.B. Pant Institute of Himalayan Environment and Development, Kosi-Katarmal, Almora, Uttarakhand, India, pp.124.

Kehimkar, I., 2014. *The Book of Indian Butterflies*. Bombay Natural History Society and Oxford University Press, Mumbai, pp.497.

Kocher, S.D. and Williams, E.H., 2000. The diversity and abundance of North American butterflies vary with habitat disturbance and geography. *Journal of Biogeography*, 27(4), pp.785–794. [DOI]

Kumar, P., Devi, R. and Mattu, V.K., 2016. Diversity and abundance of butterfly fauna (Insecta: Lepidoptera) of sub-alpine area of Chanshal Valley, District Shimla (Himachal Pradesh). *Journal of Entomology and Zoology Studies*, 4(4), pp.243–247.

Kumar, K., Joshi, P.C. and Arya, M.K., 2017. Variation in population density and biomass of butterflies in Nanda Devi Biosphere Reserve (NDBR), West Himalaya, Uttarakhand. *Journal of Environment and Biosciences*, 31(1), pp.9–16.

Kunte, K.J., 1997. Seasonal patterns in butterfly abundance and species diversity in four tropical habitats in northern Western Ghats. *Journal of Biosciences*, 22(5), pp.593–603. [DOI]

Lambshead, P.J.D., Paterson, G.L.J. and Gage, J.D., 1997. *Biodiversity Professional*. Version 2.0. The Natural History Museum and The Scottish Association for Marine Science, London, pp.156.

Leon-Cortes, J.L., Perez-Espinoza, F., Marin, L. and Molina-Martinez, A., 2004. Complex habitat requirements and conservation needs of the only extant Baroniinae swallowtail butterfly. *Animal Conservation*, 7(3), pp.241–250. [DOI]

Magurran, A.E., 2004. *Measuring Biological Diversity*. Blackwell Publishing, Oxford, U.K., pp.256.

Manwar, N. and Wankhade, V., 2014. Seasonal variation in diversity and abundance of butterflies at Sawanga Vithoba Lake area, District Amravati, Maharashtra, India. *Journal of Biological Sciences*, 14(7), pp.485–493. [DOI]

Margalef, R., 1972. Homage to Evelyn Hutchinson, or why is there an upper limit to diversity? *Transactions of the Connecticut Academy of Arts and Sciences*, 44(1), pp.211–235.

McAleece, N., 1998. *Biodiversity Professional Beta*. The Natural History Museum and The Scottish Association for Marine Science, London, pp.142.

Meena, D.S. and Dayakrishna, 2017. Study on the species composition and status of free-ranging butterflies (Lepidoptera: Rhopalocera) in Pt. G.B. Pant High Altitude Zoo, Nainital, Uttarakhand. *Journal of Entomology and Zoology Studies*, 5(4), pp.1135–1139.

Munyuli, M.B.T., 2013. Drivers of species richness and abundance of butterflies in coffee–banana agroforests in Uganda. *International Journal of Biodiversity Science, Ecosystem Services and Management*, 9(4), pp.298–310. [DOI]

Naik, D. and Mustak, M.S., 2015. Additions to larval host plants of Indian butterflies (Lepidoptera). *Journal of the Bombay Natural History Society*, 112(3), pp.181–183.

Naik, D., Rao, R.S.P., Kunte, K. and Mustak, M.S., 2022. Seasonal dynamics and polyphenism of butterfly communities in the coastal plains of central Western Ghats, India. *Journal of Biosciences*, 47(79), pp.1–13. [DOI]

Nitin, R., Balakrishnan, V.C., Churi, P.V., Kalesh, S., Prakash, S. and Kunte, K., 2018. Larval host plants of the butterflies of the Western Ghats, India. *Journal of Threatened Taxa*, 10(4), pp.11495–11550. [DOI]

Niwattanakul, S., Singthongchai, J., Naenudorn, E. and Wanapu, S., 2013. Using of Jaccard coefficient for keyword similarity. In: *Proceedings of the International MultiConference of Engineers and Computer Scientists*. Vol. I. Hong Kong, pp.1–5.

Padhye, A.D., Dahanukar, N., Paingankar, M., Deshpande, M. and Deshpande, D., 2006. Season and landscape-wise distribution of butterflies in Tamhini, Northern Western Ghats, India. *Zoo's Print Journal*, 21(3), pp.2175–2181. [DOI]

Paunikar, S.D. and Sharma, G., 2022. Butterfly species diversity and distribution in protected forest areas of North-West Himalaya of India. *Biological Forum – An International Journal*, 14(4), pp.1004–1015.

Pollard, E., 1977. A method for assessing changes in the abundance of butterflies. *Biological Conservation*, 12(2), pp.115–134. [DOI]

Pozo, C., Luis-Martínez, A., Llorente-Bousquets, J., Salas-Suárez, N., Maya-Martínez, A., Vargas-Fernandez, I. and Warren, A.D., 2008. Seasonality and phenology of the butterflies (Lepidoptera: Papilionoidea and Hesperioidea) of Mexico's Calakmul region. *Florida Entomologist*, 91(3), pp.407–422.

Parandhaman, D., Sivasankaran, K., Meerasa, M.N. and Ignacimuthu, S., 2012. Diversity of butterflies in different habitats from Tamil Nadu, part of Western Ghats (Lepidoptera: Rhopalocera). *Elixir Applied Biology*, 51, pp.10861–10865.

Qureshi, A.A., Bhagat, R.C. and Bhat, D.M., 2014. Diversity of butterflies (Lepidoptera: Papilionoidea and Hesperioidea) of Dachigam National Park, Jammu and Kashmir, India. *Journal of Threatened Taxa*, 6(1), pp.5389–5392. [DOI]

Robinson, G.S., Ackery, P.R., Kitching, I.J., Beccaloni, G.W. and Hernández, L.M., 2023. *HOSTS – A Database of the World's Lepidopteran Hostplants*. Natural History Museum, London. Retrieved September 30, 2024, from https://data.nhm.ac.uk/dataset/hosts/resource/877f387a-36a3-486c-a0c1-b8d5fb69f85a

Sagwe, R.N., Muya, S.M. and Maranga, R., 2015. Effects of land use patterns on the diversity and conservation status of butterflies in Kisii Highlands, Kenya. *Journal of Insect Conservation*, 19(6), pp.1197–1207. [DOI]

Samraj, J.M. and Agnihotri, M., 2021. Impact of land use pattern and seasonality on butterfly diversity in a sub-tropical Terai Arc Landscape (TAL), Pantnagar, Uttarakhand, India. *Tropical Ecology*, 62(2), pp.301–310. [DOI]

Sarma, K., Kumar, A., Devi, A., Mazumdar, K., Krishna, M., Mu[DOI], P. and Das, N., 2012. Diversity and habitat association of butterfly species in foothills of Itanagar, Arunachal Pradesh, India. *Cibtech Journal of Zoology*, 1(2), pp.67–77.

Sengupta, P., Banerjee, K.K. and Ghorai, N., 2014. Seasonal diversity of butterflies and their larval food plants in the surroundings of Upper

Neora Valley National Park, a sub-tropical broad-leaved hill forest in the Eastern Himalayan landscape, West Bengal, India. *Journal of Threatened Taxa*, 6(1), pp.5327–5342. [DOI]

Shannon, C.E. and Weaver, W., 1949. *The Mathematical Theory of Communication*. The University of Illinois Press, Illinois, pp.144.

Simpson, E., 1949. Measurement of diversity. *Nature*, 163(4148), p.688. [DOI]

Singh, A.P. and Bhandari, R.S., 2003. Butterfly diversity in tropical moist deciduous sal (*Shorea robusta*) forests of Dehradun Valley: The lower Western Himalayas. *The Indian Forester*, 129(10), pp.1257–1269.

Singh, A.P. and Bhandari, R.S., 2006. New additions to the butterflies of Dehradun Valley, the lower Western Himalayas. *The Indian Forester*, 132(6), pp.767–769.

Singh, A., Brar, J.S. and Sarari, P., 2017. Habitat preference of butterflies and moths (Insecta: Lepidoptera) in Talwandi Sabo, Punjab. *Bulletin of Environment, Pharmacology and Life Sciences*, 6(12), pp.67–71.

Smetacek, P., 2002. The genus *Pontia* (Lepidoptera: Pieridae) in the Kumaun Himalaya. *Journal of the Bombay Natural History Society*, 99(2), pp.224–231.

Smetacek, P., 2010. *Ypthima kedarnathensis* Singh, 2007 (Lepidoptera: Nymphalidae: Satyrinae) from the Kumaon Himalaya, India. *Journal of Threatened Taxa*, 2(13), pp.1390–1391. [DOI]

Smetacek, P., 2011a. Detrimental effects of low atmospheric humidity and forest fire on a community of Western Himalayan butterflies. *Journal of Threatened Taxa*, 3(4), pp.1694–1701. [DOI]

Smetacek, P., 2011b. Four new Lycaenid butterfly records from the Kumaon Himalaya, India. *Journal of Threatened Taxa*, 3(2), pp.1555–1558. [DOI]

Smetacek, P., 2011c. On the anomalous altitudinal distribution of West Himalayan Troidini and Papilionini (Papilionidae). *Journal of the Lepidopterists' Society*, 65(2), pp.126–132. [DOI]

Smetacek, P. and Smetacek, R., 2011. Additions to the known larval host plants of Indian Lepidoptera. *Journal of Threatened Taxa*, 3(12), pp.2272–2276. [DOI]

Smetacek, P., 2012a. Butterflies (Lepidoptera: Papilionoidea and Hesperoidea) and other protected fauna of Jones Estate, a dying watershed in the Kumaon Himalaya, Uttarakhand, India. *Journal of Threatened Taxa*, 4(9), pp.2857–2874. [DOI]

Smetacek, P., 2012b. Preimaginal stages of *Graphium (Pazala) eurous caschmirensis* (Rothschild, 1895) (Lepidoptera: Papilionidae) in the Kumaon Himalaya, India. *Nachrichten des Entomologischen Vereins Apollo (News of the Entomological Society Apollo)*, 32(3–4), pp.109–112.

Sondhi, S. and Kunte, K., 2018. *Butterflies of Uttarakhand – A Field Guide*. In: B. Singh and M.P. Singh (eds.). Titli Trust, Dehradun and National Centre for Biological Sciences, Bengaluru, pp.384.

Sondhi, S., 2017. First records of butterflies *Anthene emolus emolus* (Godart, [1824]) (Lepidoptera: Lycaenidae: Polyommatinae) and *Gandaca harina assamica* Moore, [1906] (Lepidoptera: Pieridae: Coliadinae) from Kumaon, Uttarakhand, India. *Journal of Threatened Taxa*, 9(6), pp.10355–10357. [DOI]

Tews, J., Brose, U., Grimm, V., Tielborger, K., Wichmann, M.C., Schwager, M. and Jeltsch, F., 2004. Animal species diversity driven by habitat heterogeneity: The importance of keystone structures. *Journal of Biogeography*, 31(1), pp.79–92. [DOI]

Tyagi, R., Joshi, P.C. and Joshi, N.C., 2011. Butterfly diversity of District Nainital, Uttarakhand, India. *Journal of Environment and Bio-Sciences*, 25(2), pp.273–278.

Uniyal, V.P., 2007. Butterflies in the Great Himalayan Conservation Landscape in Himachal Pradesh, Western Himalaya. *Entomon*, 32(2), pp.119–127.

Veenakumari, K., Mohanraj, P. and Sreekumar, P.V., 1997. Host plant utilization by butterfly larvae in the Andaman and Nicobar Islands (Indian Ocean). *Journal of Insect Conservation*, 1(4), pp.235–246. [DOI]

Verma, A. and Arya, M.K., 2018. A preliminary study on the status and distribution of butterfly fauna in and around the valley of Reetha Sahib, Champawat, Kumaon Himalaya, India. *Journal of Insect Conservation*, 10(1), pp.43–51.

Verma, A. and Arya, M.K., 2022. Butterfly diversity and abundance in a sub-tropical wetland environment of Shyamlatal, Western Himalaya. *Asian Journal of Conservation Biology*, 11(1), pp.26–40. [DOI]

Weißhuhn, P., 2019. Indexing the vulnerability of biotopes to landscape changes. *Ecological Indicators*, 102, pp.316–327. [DOI]

Wynter-Blyth, M.A., 1957. *Butterflies of the Indian Region*. Bombay Natural History Society, Bombay, pp.523.