Studies on threat status and food habits of butterflies (Lepidoptera) of Shimla Water Catchment Wildlife Sanctuary, Himachal Pradesh, India

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ABSTRACT. The current study gives more information on Lepidoptera (butterfly) diversity and their food plant resources in the conifer woods of Shimla Water Catchment Wildlife Sanctuary, Himachal Pradesh. The study was carried out during the three distinct seasons; summer, monsoon, and autumn from March 2019–April 2022. A total of 1650 butterflies, representing 68 species and 6 families were recorded. The Nymphalidae comprised the greatest number of species (28 species), followed by the Lycaenidae (15), Pieridae (13), Papilionidae (7), Hesperiidae (4) and Riodinidae (1). Species abundance and richness were more in mixed forest type which owing water and grass-cover availability supported most unique butterfly assemblages as compared to pure conifers and oak forest. The months from April to November harbor the greatest abundance of species. An overall reduction in species abundance was seen from December through January and until the end of March. This study provides an understanding of butterflies and has inspired additional investigation for the restoration of forest habitats in this protected area. The current study on diversity shows the importance of preserving biodiversity and monitoring climate change. It offers a basic identification, gathers data from a comparative viewpoint, allows synthesis, and develops and stimulates ideas and hypotheses that are applicable to other fields.

Key words: Climate, conservation, diversity, environment, pollinators

INTRODUCTION

Insects constitute the majority of species on the globe (May, 1992). An essential component of ecosystem functions is played by insects. They help in maintain soil structure and fertility by cycling nutrients, pollinating plants, dispersing seeds, regulates the populations of other species, and serve as a key food

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source for other taxa (Kaundil & Mattu, 2017). Butterfly species are regarded as charismatic creatures with a variety of useful functions, which a large number are recognized as ecosystem services for human well-being (Kurtz et al., 2001; Nelson, 2007; Guiney & Oberhauser, 2008). Butterflies depend on plants for food and to complete their life cycle, many economically important plants species are pollinated by butterflies. Fruit and seed production reduce as a result of a lack of suitable pollinators (Partap et al., 2001). Rotten fruit, carrion, urine, and animal feces also attract some butterflies (Ehrlich & Raven, 1964). Over 28,000 species of butterflies have been identified worldwide, with tropical areas home to 80% of them. Additionally, the Indian subcontinent is home to 1,504 different species of butterflies which has a varied landscape, climate, and vegetation (Tiple, 2011). A study has been shown that the Indian Himalayan Region (IHR) is a major hotspot area for biological diversity (Myer et al., 2000; Kumar & Mattu, 2014).

The interaction between plants and butterflies is extremely complex and co-evolved (Ehrlich & Raven, 1964). The majority of butterflies are strictly seasonal, and prefer only one kind of habitat, and visit only a small number of flowering plants. The preference of the butterflies is influenced by the colour and shape of the flowers (Hirot et al., 2012; Cepero et al., 2015). Due to their poikilothermic characteristics, insects are highly sensitive to temperature, and because of their high mobility, they quickly adjust to changing thermal circumstances and migrate (Kiritani & Yukawa, 2010). In general, the presence of vegetation in gardens or woodlands, both in semi-natural and natural environments, enhances the conservation of butterflies (van Halder et al., 2008). The range of the plants that serve as hosts for butterflies, as well as the type of vegetation that was assessed and may have an effect on the butterfly community composition, are expected to be included in butterfly distributions, even at small scales (Beccaloni, 1997). Butterflies are strong biological markers of general environmental health and habitat quality (Larsen, 1988). The relative amount of resources for plants and butterflies was a key factor in establishing the pattern of the butterfly community (Yamamoto et al., 2007). The ecosystem structure and functions alter as a result of a decline in the vegetation pattern, which also affects the abundance of the ecosystem's constituent biota. For butterflies, many such events support the decline in species richness and consequently, the quality of the associated habit (Stefanescu et al., 2004). Deforestation, habitat loss due to urbanization, and industrialization are the main factors contributing to the fall of butterfly populations. Since butterflies are exothermic creatures, the surrounding temperature has a significant impact on their activity. Therefore, changes in the range, phenology, voltinism, and activity patterns will be reflected by equivalent changes in climate. Thus, butterflies are suitable bioindicators, and over the past few decades, there has been a steady buildup of evidence that changes in their distribution and abundance are being driven by the climate. Due to their amazing capacity for environmental adaptation, they are often regarded as the flagship species for conservation (Thomas, 2005). Butterflies offer an excellent subject for studying environmental quality due to their taxonomy, distribution, short lifespan, and day-flying activity. The butterfly was also considered by several researchers and biologists as a useful bio-indicator as its contribution towards the conservation of the forest community (Bhardwaj et al., 2012).

All over the world, habitat loss and fragmentation are two primary threats to biodiversity. Habitat fragmentation is made up of five distinct phenomena: 1. Decrease in the habitat's overall size, 2. Reduction in the interior-to-edge ratio, 3. Disconnection of one habitat fragment from other habitat regions, 4. Splitting a single habitat patch into multiple smaller ones, and 5. Reduction in the average size of each habitat patch (Didham, 2010). Population fragmentation and ecological deterioration are both caused by the emergence of discontinuities in an organism's preferred habitat. Geological processes change the topography of the physical environment, which splits habitats. Additionally, human actions like land conversion can change the ecology and result in the eradication of numerous species. The fossil record contains evidence of habitat degradation brought on by natural phenomena like volcanism, fire, and climate change. For example, the destruction of the tropical rainforest habitat in Europe 300 million years ago led to a large loss in the diversity of amphibians, but the drier environment
at the same time led to an increase in the diversity of reptiles (Sahney et al., 2010). The fragmentation of habitat is usually the cause of a species near-threatened or threatened status. The ability of a species to survive depends on the environment that is currently accessible. By preserving or establishing native plant corridors, it is possible to connect habitat fragments, which is a solution to the issue of habitat fragmentation. Figure 1 Illustrates a schematic representation of the habitat fragmentation process. This is a process by which a huge habitat area is split up into a number of smaller patches, each with a reduced overall area and being separated from the others by a different matrix of habitats from the original. White patches signify matrix, while green areas signify habitat.

Lots of studies on the diversity of butterflies in different parts of Himachal Pradesh have been conducted by various researchers. The purpose of the current study was to examine the diversity, habitat preferences, food/host plant resources, and to demonstrate how plant species assemblages at study area influence the diversity of butterfly species and their abundance in the coniferous wood of the Water Catchment Wildlife Sanctuary, Shimla, Himachal Pradesh. Understanding the mutualistic interactions between plants and butterflies would help us in better understand the basic principles behind community formation and stability (Wisz et al., 2013). The empirical study provides a significant amount of information that is used in conservation planning and management about the variety and behaviour of butterflies from different terrestrial ecosystems (see Opler, 1995; New, 1999; Barranco-León et al., 2016).

**MATERIAL AND METHODS**

**Study area.** Water Catchment Wildlife Sanctuary is located between latitude 31°05′12″N–31°07′11″N and longitudes 77°12′54″E–77°16′04″E in Shimla District of Himachal Pradesh (Fig. 2). The sanctuary covers a total area of 10.25 square Kilometers. The temperature fluctuates from -5.4°C to 32°C, while the altitude ranges from 1,518–2,637 m amsl. The Sanctuary receives about 1600 mm of rain annually, and the majority of that falls during the bitterly cold winter months (Prakash & Pathak, 2019). The sanctuary is divided into four beats (Churat, Chharabra, Seog, Kufri). The region has a wide variety of flora and wildlife. Himalayan Cedar (Deodar) predominates in this area’s vegetation, which is also dotted with White Oak, patches of Chir Pine, and Blue Pine at higher elevations. The majority of the ground vegetation, which makes up around 50% of the total, is made up of grasses, while there are also several ferns and vascular herbs (Prakash & Pathak, 2019).

**Sampling.** The sampling and monitoring of butterflies were carried out in 4 beats of Water Catchment Wildlife Sanctuary Shimla, Himachal Pradesh from March 2019 to April 2022 to assess the butterflies and their host/food plant diversity. The sanctuary experiences four seasons during the year; summer, monsoon, autumn and winter. The survey was done during summer, monsoon, and autumn. Because of low temperature and excessive snowfall within the sanctuary, the sanctuary remains closed during winter. The Pollard walks method (Pollard & Yates, 1994) was used to assess the butterfly fauna. In each of the four study sites, a fixed transect was laid. Transect dimensions were set at 1000 × 20 metres respectively and with the help of an insect net and sweeping technique, the specimens were collected. Additionally, photographic documentation was completed using a zoom lens for the Nikon D5600 Camera that has an EF range of 75 to 300 mm. Butterflies are most active during bright sunlight, so transects were walked mostly from 10:00 AM to 02:00 PM (flight period). During the study period, every location was visited twice a month. All the butterflies at sampling sites were recorded with the number of individuals seen. Also, other parameters such as weather conditions, nectar plants, and geographic characteristics were recorded. Only one or two specimens were brought to the lab for identification. Insect species were identified with the use of relevant literature; Evans (1932), Wynter-Blyth (1957), Kunte (2000), Kehimker (2008) and Singh (2010). Some adult specimens were identified through comparison to a reference collection maintained at national museum at Forest Research Institute (F.R.I.), Dehradun, Uttarakhand, India.
Figure 1. A schematic representation of the habitat fragmentation process, which is the process by which a big habitat area gets divided into a number of smaller patches, each with a smaller total area and being segregated from the others by a matrix of habitats that is different from the original. White patches signify matrix, while green areas signify habitat.

Figure 2. Map of Shimla district, showing Water Catchment Wildlife Sanctuary, Himachal Pradesh, India.
This locality has abundant flowering plants surrounded by trees, shrubs and herbs. Flowers visiting by butterflies were recorded for every plant that adult butterflies visited, although it was not quantified. The butterflies were classified into six categories based on relative abundance estimations Rajasekhar (1991, 1992 and 1995): 1. Abundant: >30%; 2. Very Common: 20–30%; 3. Common: 10–20%; 4. Frequent: 5–10%; 5. Occasional: 1–5%; 6. Rare: < 1%.

Data analysis. Species diversity was calculated using the Shannon Wiener diversity index ($H$) (Shannon-Wiener, 1940). Microsoft excel (ver. 2019) is used to calculate species diversity, evenness, richness.

$$H = -\sum p_i \ln p_i$$

Where $p_i$ is the proportion of individuals found in the ith species. In a sample the true value of $p_i$ is unknown but is estimated as $n_i/N$; $n_i=$ number of specimens of i-species per sample, $N=$ total number of individuals of all the species. The Simpson's index was also used to determine the species diversity measurement; higher values indicate greater diversity. This index is less sensitive to rare species compared to the Shannon-Wiener Index ($H'$). Simpson's index always has a value between 0 and 1 (Simpson, 1949).

$$D = \sum p_i^2$$

Where $p_i =$ the proportion of individuals in the ith species. In order to calculate the index the form appropriate to a finite community is used (Magurran, 1998):

$$p_i = \frac{n_i (n_i - 1)}{N(N - 1)}$$

Where $n_i =$ the number of individuals in the ith species and $N =$ the total number of individuals. As D increases, diversity decreases and Simpson's index is therefore usually expressed as 1-D or 1/D. The Berger-Parker index was calculated as a simple measure of the numerical importance of the most abundant species (Magurran, 1998):

$$d = \frac{N_{\text{max}}}{N}$$

Where $N_{\text{max}}$ is the number of individuals in the most abundant species, and $N$ is the total number of individuals in the sample. The Evenness index was calculated utilising (Hill, 1973):

$$E = \frac{H}{\ln S}$$

Where $S$ denotes the overall number of species, $E$ is constrained between 0 and 1.0 with 1.0 representing a situation in which all species are equally abundant. As with $H$ this evenness measure assumes that all species in the community are accounted for in the sample. The Margalef index served as a straightforward indicator of species richness (Margalef, 1958) in which

$$D = \frac{(S - 1)}{\ln N}$$

Where $S =$ Total number of species, $N =$ Total number of individual in sample, $\ln =$ Natural logarithm.
RESULTS

The current study set out to investigate the diversity, evenness, and habitats preference of butterflies. In the current study, 68 species of butterflies from 52 genera and six families were recorded from various beats of the Water Catchment Wildlife Sanctuary. The family Nymphalidae contributed the most species to the overall number of observed species (28 species), followed by the Lycaenidae (15 species), Pieridae (13 species), the Papilionidae (7 species), the Hesperidae (4 species), and the Riodinidae (1 species) had minor representation. The list of identified butterflies is given in (Appendix 1).

According to the percentage composition of each family (Fig. 3) the Nymphalidae made up roughly (41%) of the overall butterfly fauna, followed by Lycaenidae (22%), Pieridae (19%), Papilionidae (10%), Hesperidae (6%), and Riodinidae (2%). The Riodinidae had the lowest species diversity (0%), while the Nymphalidae had the highest (2.91). The values of the diversity indices are shown in Table 1. Evenness was highest in family Nymphalidae (0.874) and lowest in Riodinidae (0). The Nymphalidae had the highest species richness (3.90) while the Hesperidae had the lowest (3.60) only one species were represented by the Riodinidae, which made up only 0.36% of all the species in the study area. The most widespread family was Nymphalidae. Simpson’s diversity index (SDI) measures community diversity. The range is from 0 to 1, where high scores (close to 1) indicate low diversity. Low scores (close to 0) indicate high diversity. Nymphalidae had the highest diversity (0.06), followed by Lycaenidae (0.09), Pieridae (0.12), Papilionidae (0.20), Hesperidae (0.32), and Riodinidae (1.00) with lowest diversity. Berger-Parker Dominance Index of Nymphalidae was (0.13), Lycaenidae (0.18), Pieridae (0.15), Papilionidae (0.30), Hesperidae (0.43), and Riodinidae (0). Among all the sampling sites, it was found that Chharabra beat had the highest number of species followed by Kufri and chirat beat having same species richness. The least number of species were found at Seog beat. Based upon sighting frequency, Chharabra beat was found to be the most favorable place for butterfly fauna due to the presence of suitable host/food plants.

Based on the number of sightings throughout the duration of the whole study period, each species was given a relative abundance (Fig. 4). By using the number count method to determine relative abundance, it was found that out of the 68 butterfly species recorded in Water Catchment wildlife sanctuary, 4 species are abundant, 5 species are very common, 11 species are Common, 16 species are Frequent, 19 species are Occasional and 12 species are Rare. The Wildlife Protection Act of 1972's provisions applies to 3 of the 68 butterfly species that were recorded, giving them legal protection in India (Anonymous, 1997).

Out of these, 1 species is protected under Schedule II (Papilio machon) and 2 species (Athyma Jian, Callerabia ananda) are protected under Schedule IV of the Wildlife Protection Act, 1972 (Anonymous, 1997). Among different vegetation types sampled in study area, butterfly abundance was maximum in scrub habitats, followed by herbs and then trees.

Table 1. The calculated diversity indices for the butterfly communities at Water Catchment Wildlife Sanctuary, Shimla, Himachal Pradesh.

<table>
<thead>
<tr>
<th>Family</th>
<th>Shannon-Wiener Index ($H'$)</th>
<th>Species evenness</th>
<th>Species richness (S)</th>
<th>Simpson’s Index (λ)</th>
<th>Berger-Parker Dominance Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nymphalidae</td>
<td>2.91</td>
<td>0.87</td>
<td>3.76</td>
<td>0.06</td>
<td>0.13</td>
</tr>
<tr>
<td>Lycaenidae</td>
<td>2.46</td>
<td>0.90</td>
<td>2.14</td>
<td>0.09</td>
<td>0.18</td>
</tr>
<tr>
<td>Pieridae</td>
<td>2.25</td>
<td>0.87</td>
<td>1.74</td>
<td>0.12</td>
<td>0.15</td>
</tr>
<tr>
<td>Papilionidae</td>
<td>1.67</td>
<td>0.86</td>
<td>1.33</td>
<td>0.20</td>
<td>0.30</td>
</tr>
<tr>
<td>Hesperidae</td>
<td>1.14</td>
<td>0.82</td>
<td>0.97</td>
<td>0.32</td>
<td>0.43</td>
</tr>
<tr>
<td>Riodinidae</td>
<td>0.00</td>
<td>0.00</td>
<td>0.36</td>
<td>1.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>
Host and nectar plant species. The diversity, abundance, and richness of butterfly species were significantly influenced by the local environment characteristics. Every plant in the study area visited by adult butterflies was also recorded. The most common plants visited by adult butterfly were *Berberis lycium*, *Prinsepia utilis*, *Bidens pilosa*, *Rosa moschata*. Most butterflies were observed visiting a limited number of plant species; *Kaniska canace* visits only on *Smilax* sp. In addition, some butterflies species were observed on the ground or on rubbish; *Leptotes plinius* which was found on the ground.
DISCUSSION

Biodiversity is rapidly and drastically changing on a global scale. In addition to the geographic regions and the movement of the species diversity are influenced by its ecological needs (Khan et al., 2011). Only a few species are confined to the Himalayan climate, in the altitude above 4000 m a.s.l. (Khanal et al., 2012). Numerous studies on species diversity and habitat preferences have been conducted all over the world, while addressing the issue of habitat fragmentation. Many institutions began focusing on Rhopaloceran studies at the start of the twenty-first century, which gave India access to a large range of literary materials (Gay et al., 1992). The objective of this study was to better understand the status of butterfly diversity in the Water Catchment WLS as well as how local habitat factors affect the variety, abundance, and richness of butterfly species and the assessment of endangered and protected species of butterflies in this area. Across the range of habitat types, there were very few differences in butterfly diversity and richness. The present butterfly study has much more specimens than earlier publications from this area. In their study (Gangotia & Kumar, 2019) used the same methods to collect butterflies over a period of 1-year from 2017 to 2018. They recorded 31 species of butterflies, which were divided into five groups. These species are nearly two times less common than what was observed in the current study. In 2008 The Zoological Survey of India issued a venerable reference on common butterflies of Uttarakhand (Kumar, 2008). ZSI released a guide on the butterflies of Himachal Pradesh, a year later (Arora et al., 2009). After a short period of time, the Kerala Forest Research Institute produced a thorough report on the Nilgiri Biosphere Reserve's butterflies (Mathew, 2011).

The study area is primarily covered in a variety of plant types with dense vegetation that supports butterfly populations (Rana & Kapoor, 2015) reported 476 different species of Vascular plants. Out of the total number of species, 36 were pteridophytes, 39 were trees, 81 were shrubs, and 320 were herbs. The largest families were Asteraceae (45 species), Lamiaceae (31 species), and Poaceae (32 species) 39 families exhibited monotypy. Temperature fluctuations were found to have an impact on the seasonal distribution of many butterfly species which is the most significant environmental factor determining behaviour, distribution, population size, development, survival, reproduction as well as phenology (Petzoldt & Seaman, 1992).

The temperature within the ideal range increases metabolism, which in turn accelerates the rate of development. The temperature influences each stage of the life cycle because it affects the metabolism (Gullan & Cranston, 2014). According to (Muralirangan et al., 1993), excessive humidity encourages fungal attack whereas high temperatures reduce the number of insects. From June to July, when the monsoon season begins, species abundance climbs and peaks. From August to November and December to February, however, there is a decline in species abundance this decline lasted throughout March. Butterfly populations increased during the monsoon. It might be due to enough host plants and the climate being suitable for the growth and development of butterflies. The least amount of butterflies were gathered in the winter due to inadequate host plants and adverse weather conditions. In windy weather, butterfly variety is generally lower. While many species of Lycaenids and some Papilionids are completely missing from windy areas, other Nymphalids, such as Vanessa cardui and Issoria issaea, can withstand strong wind pressure. The high abundance observed in our study during specific months was mostly caused by the overlap of seasonal peaks of numerous butterfly species with high abundance. The presence of many abundant species implies the succession of generations, which is only possible if the species can withstand more extreme climate variations and make better use of local resources over longer time periods (Wolda, 1978). Similar data was recorded by various researchers in different districts of Himachal Pradesh as in Balh valley of District Mandi 40 species of butterflies were recorded by (Kumar & Mattu, 2014). 50 species of butterflies were recorded from Pong Lake of District Kangra by (Mehta et al., 2002). According to Singh & Banyal (2014) 49 species are recorded in District Chamba. In 2021 Six rhopaloceran species of the Nymphalidae, Pieridae, Lycaenidae, and Satyridae families were recorded from the Chandertal Wetland by Singh & Thakur (2021).
Due to distinct dry and wet seasons and increased climatic variability, the extremely unequal distribution of butterfly species in the communities raises the possibility that the diversity of butterflies in a subtropical region may differ from the tropics. It is well known that richness and abundance increase with relative humidity (Muralirangan et al., 1993). The months of July and August have the greatest average relative humidity measurements, while November has the lowest average readings. Additionally, our results agreed with (Lee et al., 2014, Montero-Munoz et al., 2013, Valtonen et al., 2013, Camero & Calderon, 2007, Clark et al., 2007). They come to the conclusion that environmental gradients either directly or indirectly affect butterfly diversity and abundance. The butterfly assemblage in our study displayed significant seasonal variations in richness and abundance are mentioned in Fig. 2 and in Table 1. A good diversity of butterfly species is supported in the research area. Species of two butterfly families, Nymphalidae and Pieridae were found in more numbers than others, which are reflecting the availability of larval food plants of butterflies in this Sanctuary and a similar pattern was observed from the Chanshal valley of district Shimla (Kumar et al., 2016). Athyma jina, Atrophaneura polyeuctes, Celastrina lavandularis, Junonia iphita, Melantis lida, Pontia daplidice, Vagrans egista were found to be rare species in the study area. During the transect walk, they just seen occasionally particular with just one or two specimens. Similar result was shown in the watershed’s catchment region and the nearby forests yielded a total of 64 species and 45 genera from six butterfly families. Nymphalidae, which included 28 species and 45.84% of all butterflies, was the most prevalent taxonomic group of butterflies.

The Himalayan butterflies, which included rare (17.18% species), habitat-specific (18.75% species), legally protected (7.81% species), and endemic (20.31% species) butterflies, were among the species with the highest conservation priority (Verma & Arya, 2022). Similar result was shown in the study area Aglais cashmirensis, Ethene embolus, and Papilio demoleus was very common in the study area (Verma & Arya, 2022). Habitat preference varies species-wise. It has also been observed that the occurrence and abundance of butterflies was more in grassland and mixed tree forests but their occurrence was very few in pure conifers forests and Oak forests. Aporia agathion, Kaniska canace and some Papilo sp. were found only in pure conifers forests in the study areas. Butterflies visited flowers with tubular corollas more frequently than those without, as well as those with colours purple, blue, yellow, and red rather than pink and white, and those that were available throughout the year. There is a minimum threshold level determined by each environmental component below which an organism cannot exist. The largest population density is produced by the influencing variables at their best levels, and beyond a certain point again, existence is lost (Mani, 1968). As per the current study, butterflies can find favourable ecological conditions and habitats in the studied locations. It might be because there are enough host plants and the climate is ideal for the growth and development of butterflies.

The current research on biodiversity contributes to the conservation and climate change monitoring requirements. As butterflies are excellent bio-indicators of ecosystem disturbances (Thomas, 2005). They are also recognised as ecological indicators that respond quickly to climatic and ecological changes and the stratification of the vegetation in terms of temperature wind, light, and humidity (Dar et al., 2021) so, studies on their diversity status, etc. Will be very useful in tracking changes in an ecosystem, particularly those caused by habitat loss, deforestation, organic and inorganic pollution which will help in the better management and conservation of butterfly fauna. Our study on diversity shows the importance of preserving biodiversity and monitoring climate change. It offers a basic identification, gathers data from a comparative viewpoint, allows synthesis, and develops and stimulates ideas and hypotheses that are applicable to other fields. Additionally, the planning of programs for eco-restoration and the development of butterfly parks or gardens would be benefited from this information. Recently Ecotourism has been promoted is an effort to enhance awareness of the significance of biodiversity, mainly the variety of butterflies. In developing and planning butterfly parks, the study on plant-butterfly interactions given in the paper gains significance. Furthermore, while suggesting the establishment of new parks and protected areas, conservation efforts must take into account the significant value of beta variety.
AUTHOR’S CONTRIBUTION

The authors confirm their contribution in the paper as follows: P. Kumar: Conceptualization of the study, Identification of the specimens, review; A. Verma: Collecting the specimens, Identification of the specimens, data analysis and preparation of the manuscript; R. Gangotia: Collecting the specimens; P. Kumar-Thakur: GIS-Mapping. All authors read and approved the final version of the manuscript.

FUNDING

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AVAILABILITY OF DATA AND MATERIAL

The specimens listed in this study are deposited in reference collection maintained at Himalayan Forest Research Institute (H.F.R.I.), Shimla and are available from the curator, upon request.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

Not applicable.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest regarding the publication of this paper.

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REFERENCES


Appendix 1. The list of butterflies (Rhopalocera) species with their relative abundance and Food/host plants specie recorded during study period from Water Catchment Wildlife Sanctuary.

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Families</th>
<th>RV*</th>
<th>Food / host plants specie</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Papilionidae</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Potanthus daru Kollar, 1842</td>
<td>Himalayan Dart</td>
<td>Hesperidae</td>
<td>A</td>
<td>Rosa moschata, Grasses</td>
</tr>
<tr>
<td>2 Calanthis aurivitatta Moore, 1978</td>
<td>Dark yellow banded flat</td>
<td>Hesperidae</td>
<td>R</td>
<td>Rosa moschata, Grasses</td>
</tr>
<tr>
<td>3 Pelopidas subochracea Moore, 1784</td>
<td>Large branded swift</td>
<td>Hesperidae</td>
<td>A</td>
<td>Taraxacum officinale, Fragaria rubiocola</td>
</tr>
<tr>
<td>4 Pseudocallonia danae Fabricius, 1778</td>
<td>Vulvous pied flat</td>
<td>Hesperidae</td>
<td>VC</td>
<td>Berberis sp., Prinsepia utilis</td>
</tr>
<tr>
<td>5 Neozephyrus dana Hewitson, 1869</td>
<td>Metallic Green Hair streak</td>
<td>Lycaenidae</td>
<td>F</td>
<td>Bidentis pilosa, Taraxacum officinale</td>
</tr>
<tr>
<td>6 Lycaena phlaeas Linnaeus, 1761</td>
<td>Common Copper</td>
<td>Lycaenidae</td>
<td>C</td>
<td>Taraxacum officinale, Fragaria rubiocola</td>
</tr>
<tr>
<td>7 Heliopanthera epicles Frutshorfer, 1918</td>
<td>Purple Sapphire</td>
<td>Lycaenidae</td>
<td>O</td>
<td>Taraxacum officinale, Bidentis pilosa</td>
</tr>
<tr>
<td>8 Aethene enolus Godart, 1823</td>
<td>The Ciliate Blue</td>
<td>Lycaenidae</td>
<td>VC</td>
<td>Prinsepia utilis, Indigofora sp.</td>
</tr>
<tr>
<td>9 Zizyzeria karsandra Moore, 1865</td>
<td>Dark Glass Blue</td>
<td>Lycaenidae</td>
<td>C</td>
<td>Bidentis pilosa, Berberis sp., Erigeron bellidiioides, Potentilla nepalensis</td>
</tr>
<tr>
<td>10 Polyommatus icarus Rottentburg, 1775</td>
<td>Common Blue</td>
<td>Lycaenidae</td>
<td>O</td>
<td>Prinsepia utilis, Indigofora sp.</td>
</tr>
<tr>
<td>11 Celastrina lancaudarios Moore, 1877</td>
<td>The Plain Hedge Blue</td>
<td>Lycaenidae</td>
<td>R</td>
<td>Prinsepia utilis, Berberis sp.</td>
</tr>
<tr>
<td>12 Arcia estradie Denis &amp; Schiffermüller, 1775</td>
<td>Brown Argus</td>
<td>Lycaenidae</td>
<td>O</td>
<td>Othali corniculata</td>
</tr>
<tr>
<td>13 Leptotes plinius Fabricius, 1793</td>
<td>Zebra blue</td>
<td>Lycaenidae</td>
<td>O</td>
<td>Ground, Grasses</td>
</tr>
<tr>
<td>14 Celastrina lucillii Moore, 1882</td>
<td>Large hedge blue</td>
<td>Lycaenidae</td>
<td>F</td>
<td>Prinsepia utilis, Indigofora sp.</td>
</tr>
<tr>
<td>15 Celastrina marginata de Nicéville, 1884</td>
<td>Margined hedge blue</td>
<td>Lycaenidae</td>
<td>O</td>
<td>Prinsepia utilis, Indigofora sp.</td>
</tr>
<tr>
<td>16 Deudorix epiphora Moore, 1857</td>
<td>Hairy line blue</td>
<td>Lycaenidae</td>
<td>F</td>
<td>Prinsepia utilis</td>
</tr>
<tr>
<td>17 Heliopanthera androche Westwood, 1851</td>
<td>The green sapphire</td>
<td>Lycaenidae</td>
<td>F</td>
<td>Trifolium repens, Taraxacum officinale</td>
</tr>
<tr>
<td>18 Lycaena phila Linnaeus, 1761</td>
<td>White-banded cornered</td>
<td>Lycaenidae</td>
<td>C</td>
<td>Taraxacum officinale</td>
</tr>
<tr>
<td>19 Prostata bulea de Nicéville, 1884</td>
<td>Bhuja lineblue</td>
<td>Lycaenidae</td>
<td>F</td>
<td>Bidentis pilosa, Prinsepia utilis</td>
</tr>
<tr>
<td>20 Argynus hyperbius Linnaeus, 1763</td>
<td>The Indian Fritillary</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Bidentis pilosa, Rubus ellipticus, Viola sp.</td>
</tr>
<tr>
<td>21 Phalanthe phalanthe Drury, 1773</td>
<td>The Common Leopard</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Taraxacum officinale, Bidentis pilosa</td>
</tr>
<tr>
<td>22 Issoria lathoria Linnaeus, 1758</td>
<td>Queen of Spain Fritillary</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Bidentis pilosa, Loniceria quisquilocularis</td>
</tr>
<tr>
<td>23 Callenara ananda Moore, 1858</td>
<td>Ringed Argus</td>
<td>Nymphalidae</td>
<td>R</td>
<td>Cymathula tomentosa, grasses</td>
</tr>
<tr>
<td>24 Ailagis cashmirensis Kollar, 1848</td>
<td>Small Tortoise Shell</td>
<td>Nymphalidae</td>
<td>VC</td>
<td>Utica sp., Anaphalis sp.</td>
</tr>
<tr>
<td>25 Lassionata schlara Kollar, 1844</td>
<td>Common Wall</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Prinsepia utilis, Rubus sp., Berberis sp.</td>
</tr>
<tr>
<td>26 Vanessa carduii Linnaeus, 1758</td>
<td>Painted Lady</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Trifolium repens, Taraxacum officinale</td>
</tr>
<tr>
<td>27 Fabriciana adpene Denis &amp; Schiffermüller, 1775</td>
<td>High Brown Fritillary</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Taraxacum officinale, Rumex hastatuslusi, Viola sp.</td>
</tr>
<tr>
<td>28 Athyma jini Moore, 1858</td>
<td>Bhitian Sergeant</td>
<td>Nymphalidae</td>
<td>R</td>
<td>Prinsepia utilis, rocks, Grasses</td>
</tr>
<tr>
<td>29 Lethe perna Kollar, 1844</td>
<td>Straight-banded tree brown</td>
<td>Nymphalidae</td>
<td>C</td>
<td>Cedrus deodara, Grasses</td>
</tr>
<tr>
<td>30 Kaniska canace Linnaeus, 1763</td>
<td>Blue admiral</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Smilax sp.</td>
</tr>
<tr>
<td>31 Yathima nareda Hewitson, 1864</td>
<td>Large three ring</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Prinsepia utilis, Chaerophyllum reflexum,</td>
</tr>
<tr>
<td>32 Yathima sacra Moore, 1857</td>
<td>Himalayan five-ring</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Prinsepia utilis</td>
</tr>
<tr>
<td>33 Vanessa indica Herbst, 1794</td>
<td>Indian red admiral</td>
<td>Nymphalidae</td>
<td>R</td>
<td>Trifolium repens</td>
</tr>
<tr>
<td>34 Acraea isoria Hubner, 1819</td>
<td>Yellow Coster</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Debregensia bicolor</td>
</tr>
<tr>
<td>35 Athyma perius Linnaeus, 1758</td>
<td>Common sergeant</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Cedrus deodara, Taraxacum officinale, Trifolium repens</td>
</tr>
<tr>
<td>36 Junonia titha Cramer, 1779</td>
<td>Chocolate pansy</td>
<td>Nymphalidae</td>
<td>R</td>
<td>Trifolium repens</td>
</tr>
<tr>
<td>37 Aclocera suhla Kollar, 1844</td>
<td>Common satyr</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Bistorta affinis</td>
</tr>
<tr>
<td>38 Danusa chrysippus Linnaeus, 1758</td>
<td>Plain tiger</td>
<td>Nymphalidae</td>
<td>C</td>
<td>Asclepis curassavica, Cynanchum sp.</td>
</tr>
<tr>
<td>39 Elymnias undularis Linnaeus, 1763</td>
<td>The palmflies</td>
<td>Nymphalidae</td>
<td>C</td>
<td>Taraxacum officinale, Rumex hastatuslusi, Viola sp.</td>
</tr>
<tr>
<td>40 Hyponephelle fulcilla Grum-Grimminal, 1890</td>
<td>Tawny Meadow brown</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Rumex hastatuslusi, Viola sp.</td>
</tr>
<tr>
<td>41 Junonia limonias Linnaeus, 1758</td>
<td>Lemon pansy</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Barleria sp., Hygrophi a auriculata</td>
</tr>
<tr>
<td>42 Lethe naga Doherty, 1889</td>
<td>Naga tree brown</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Capillipedium sp., Imperata cylindrical</td>
</tr>
<tr>
<td>43 Lethe rohria Fabricius, 1877</td>
<td>Common tree brown</td>
<td>Nymphalidae</td>
<td>O</td>
<td>Aplada sp.</td>
</tr>
<tr>
<td>44 Melanitis lida Linnaeus, 1758</td>
<td>Common evening brown</td>
<td>Nymphalidae</td>
<td>R</td>
<td>Bistorta affinis</td>
</tr>
<tr>
<td>45 Neptis yerburi Butler, 1886</td>
<td>Yerbury's sailer</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Prinsepia utilis, Rubus ellipticus</td>
</tr>
<tr>
<td>46 Sephis dactras Kollar, 1844</td>
<td>Western costier</td>
<td>Nymphalidae</td>
<td>F</td>
<td>Prinsepia utilis, Rubus ellipticus, Trifolium repens</td>
</tr>
<tr>
<td>47 Vogros egista Cramer, 1780</td>
<td>Race Sinha</td>
<td>Nymphalidae</td>
<td>R</td>
<td>Rosa moschata, Cedrus deodara</td>
</tr>
<tr>
<td>48 Atrophaneura polyxenes Doubleday, 1842</td>
<td>Common windmill</td>
<td>Papilionidae</td>
<td>R</td>
<td>Rosa moschata</td>
</tr>
<tr>
<td>49 Papilio macchon W.H. Edwards, 1876</td>
<td>Common yellow Swallowtail</td>
<td>Papilionidae</td>
<td>R</td>
<td>Rosa moschata, Cedrus deodara</td>
</tr>
<tr>
<td>50 Papilio chlyta Linnaeus, 1758</td>
<td>Common mime</td>
<td>Papilionidae</td>
<td>F</td>
<td>Alseodaphe semicarpofila, Cinnamonomum varum</td>
</tr>
<tr>
<td>51 Papilio demoleus Linnaeus, 1758</td>
<td>Lime butterfly</td>
<td>Papilionidae</td>
<td>VC</td>
<td>Brassica conopetris, Zanthoxylum armatum</td>
</tr>
<tr>
<td>52 Papilio paris Linnaeus, 1758</td>
<td>Paris peacock</td>
<td>Papilionidae</td>
<td>C</td>
<td>Citrus sp., Eucodia roxburghiana</td>
</tr>
<tr>
<td>53 Papilio polyctor Boisdulval, 1836</td>
<td>Common peacock</td>
<td>Papilionidae</td>
<td>O</td>
<td>Prinsepia utilis, Rubus ellipticus, Trifolium repens</td>
</tr>
<tr>
<td>54 Papilio protenor Cramer, 1775</td>
<td>The spangle</td>
<td>Papilionidae</td>
<td>A</td>
<td>Trifolium repens, Taraxacum officinale</td>
</tr>
</tbody>
</table>

*Note: RV* stands for relative abundance.
<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name</th>
<th>Families</th>
<th>RV*</th>
<th>Food / host plants specie</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eurema hecabe Linnaeus, 1758</td>
<td>Common Grass Yellow</td>
<td>Pieridae</td>
<td>C</td>
<td>Potentilla nepalensis, Frageria subicola</td>
</tr>
<tr>
<td>Genopteryx rhamni Linnaeus, 1758</td>
<td>Common Brimstone</td>
<td>Pieridae</td>
<td>F</td>
<td>Prunsepia utilis., Berberis sp.</td>
</tr>
<tr>
<td>Colias fieldii Menetries, 1855</td>
<td>Darl Clouded Yellow</td>
<td>Pieridae</td>
<td>F</td>
<td>Trifolium repens, Berberis sp.</td>
</tr>
<tr>
<td>Pieris rapae Linnaeus, 1758</td>
<td>Cabbage White</td>
<td>Pieridae</td>
<td>C</td>
<td>Berberis sp., grass</td>
</tr>
<tr>
<td>Pieris brassicae Linnaeus, 1758</td>
<td>Large Cabbage White</td>
<td>Pieridae</td>
<td>VC</td>
<td>Berberis sp., Arabis amplexicaulis</td>
</tr>
<tr>
<td>Pieris canidia Linnaeus, 1768</td>
<td>Indian Cabbage White</td>
<td>Pieridae</td>
<td>C</td>
<td>Berberis sp.</td>
</tr>
<tr>
<td>Belenois aerota Fabricius, 1793</td>
<td>Pioneer White</td>
<td>Pieridae</td>
<td>O</td>
<td>Hypericum perforatum, Cedrus deodara</td>
</tr>
<tr>
<td>Aporia agathion Gray, 1832</td>
<td>Great Black vein</td>
<td>Pieridae</td>
<td>O</td>
<td>Cedrus deodara, Hypericum perforatum, Berberis sp.</td>
</tr>
<tr>
<td>Aphrissa statira Cramer, 1777</td>
<td>Statira Sulphur</td>
<td>Pieridae</td>
<td>O</td>
<td>Hypericum perforatum, Grasses</td>
</tr>
<tr>
<td>Catopsilla Pomona Fabricius, 1775</td>
<td>Common emigrant</td>
<td>Pieridae</td>
<td>O</td>
<td>Trifolium repens Bistorta affinis, Impatiens sp.</td>
</tr>
<tr>
<td>Delias belladonna Fabricius, 1793</td>
<td>Plain tiger</td>
<td>Pieridae</td>
<td>C</td>
<td>Dentrophthoe sp., Bistorta affinis</td>
</tr>
<tr>
<td>Pieris napi Linnaeus, 1758</td>
<td>Green-veined white</td>
<td>Pieridae</td>
<td>O</td>
<td>Brassica campestris, Brassica oleracea</td>
</tr>
<tr>
<td>Pontia daplidice Linnaeus, 1758</td>
<td>Bath white</td>
<td>Pieridae</td>
<td>R</td>
<td>Lepidium virginicum</td>
</tr>
<tr>
<td>Dodona durgae Kollar &amp; Redtenbacher, 1844</td>
<td>Common punch</td>
<td>Riodinidae</td>
<td>C</td>
<td>Bidens pilosa</td>
</tr>
</tbody>
</table>

* Relative Abundance: A (Abundant: >30%), VC (Very Common: 20–30%), C (Common: 10–20%), F (Frequent: 5–10%), O (Occasional: 1–5%), R (Rare: < 1%).
 Threat status and food habits of Butterflies in Shimla (Lepidoptera) in the forests of Shimla.

چکیده: این تحقیق اطلاعات جدیدی را در خصوص تنوع پروردها (Lepidoptera) و منابع غذایی آنها در جنگل درختان سوزی برگ پنهانگه حیات و حش و حوضه آبی شیملا، هند، ارایه می‌دهد. این مطالعه در طول سه فصل مختلف، تابستان، پاییز و زمستان، از مارس 2019 تا آوریل 2022 انجام شد. کلیه پروردهای ثبت شده 68 گونه و 6 خانواده با جمعیت 1450 نمونه بودند. خانواده‌های Nymphalidae و 8 گونه (99 گونه) بیشتر شرکت داشتند. بعد از آن، در نوامبر 2021، گونه‌های Lycaenidae و 15 گونه (13 گونه) و Papilionidae و 7 گونه (8 گونه) کمتر می‌باشتند. پروردهای گونه‌هایی که در دسترس بودند، از نظر مکانی و فرم‌بندی، برای جمعیت پروردهای شرکت شده در درختان سوزی برگ و انواع مختلف از بی‌پروازی می‌توانند بودند. در نتیجه، این مطالعات بهبود در پژوهش‌های وابسته به رفتار و حیات پروردها در مناطق مختلف و از مطالعه بهبودی و پیشرفت در این زمینه کمک می‌کند.

واژگان کلیدی: اقلیم، حفاظت، تنوع، محیط زیست، گردآفشنگارها