

# DIVERSITY AND FLORAL PREFERENCE OF BUTTERFLIES IN MAIJOGMAI, ILAM, NEPAL



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## **Submitted to:**

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June, 2023

## DECLARATION

I hereby declare that the work presented in this thesis has been done by myself and has not been submitted elsewhere for the award of any degree. All the sources of information have been specifically acknowledged by reference to the authors or institutions.

Date: 2080/04/04

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## RECOMMENDATION

This is to recommend that the thesis entitled “**Diversity and Floral Preference of Butterflies in Maijogmai, Ilam, Nepal**” has been carried out by **Ms. Anju Helmu** for partial fulfilment of the requirement for a Master’s Degree in Zoology with a special on Entomology under my supervision. This is her original work and has been carried out under my supervision. To the best of my knowledge, this thesis work has not been submitted for any other degree in any institution.

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## LETTER OF APPROVAL

On the recommendation of the supervisor, **Mr. Bimal Raj Shrestha** this thesis submitted by **Ms. Anju Helmu** entitled “**Diversity and Floral Preference of Butterflies in Maijogmai, Ilam, Nepal**” is approved for the examination and submitted to the Amrit Campus in partial fulfilment of the requirement for Master’s Degree of Science in Zoology with special paper Entomology.

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## CERTIFICATE OF ACCEPTANCE

This thesis work submitted by Ms. Anju Helmu entitled “**Diversity and Floral Preference of Butterflies in Maijogmai, Ilam, Nepal**” has been accepted as a partial fulfilment for the requirement of a Master’s Degree of Science in Zoology with a special paper in Entomology.

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## LIST OF ABBREVIATIONS

<b>Abbreviated form</b>	<b>Detail of Abbreviations</b>
GPS	Global Positioning System
GLM	Generalized Linear Model
PCA	Principal Correspondence Analysis

## ABSTRACT

This study was carried out in the Maijogmai, Ilam. The goal of the present study was to investigate butterfly diversity and floral preferences of butterflies. A comprehensive survey of butterflies was done in 2022 from April and September covering altitudinal ranges from 1300 m a.s.l to 1900 m a.s.l. Altogether, seven line transects were established. A total of 22 species from 20 genera and four families were identified. The Nymphalidae family contributed the greatest species number (60.9%) whereas the family Papilionidae had the least species number (8.7%). Based on Jaccard's similarity index, butterfly species similarity was highest at heights of 1400m ( $J=0.667$ ). The lowest value of the butterfly species similarity index (0.0667) was found at altitudes of 1900m. Generalized Linear Model (GLM) with Poisson distribution and log link function was used to find factors affecting the diversity of butterfly species. Monotonic decline of species richness with increasing elevation was obtained and also showed a significant negative relation. For other environmental variables, none of them were found significant to the species richness of butterflies. Principal Correspondence Analysis (PCA) was used to find the relationship between plants and butterfly species. It was noticed that different butterfly species preferred herbs more frequently than shrubs, cultivated plants, and tree plants.

**Keywords:** *Butterflies, environmental variables, plant species*

# 1. INTRODUCTION

## 1.1. Background

Butterflies belong to the Lepidoptera order, which is the second largest in the Phylum Arthropoda. Butterflies are commonly referred to as “insects of the sun” because of their bright colours and delicate appeal (Arya *et al.* 2014). They have been admired for centuries for their natural beauty and behavioural exposure. Butterflies are diurnal and can be identified by their brightly coloured wings, clubbed antennae, and spirally coiled proboscis; females are frequently larger than males. The wings of butterflies are decorated with bright colour patterns that have been shown to function in species identification, mate selection, camouflage, warning, and in the deflection of predator attack (Brakefield 1999). Butterfly study in Nepal began in 1826 (Khanal and Smith 1997). There are 19,238 butterfly species in the world (Weiss *et al.* 1988). From Nepal, 660 species of butterflies belonging to 263 genera have been recorded (Smith 2010).

Butterfly species composition varies according to abiotic variables and environmental gradients (Khanal and Bhandary 1982). They are extremely sensitive to temperature, humidity, and light changes. Furthermore, the availability of flora, as well as terrain and climate, have a significant impact on butterfly ranges, variety, and abundance (Saikia 2014). These variables are also critical for butterfly reproduction and survival. Recent global warming trends, as well as local environmental conditions, have resulted in the elevational movement of certain species including butterflies (Luoto *et al.* 2006).

Butterflies are one of the best-known pollinators and bioindicators (Dhurairaj and Sinha 2015). They are effective pollinator insects because they are active during the day, visit a variety of flowers, and feed on the nectar and pollen of both wild and domesticated plant species (Simonson *et al.* 2001). Butterfly pollinators are important in the local ecosystem since they pollinate more than 50 commercially significant crops and are the second most specialized insects after bees in terms of their food plant (Geiger *et al.* 2010). Butterflies are strongly associated with the plant's species. Floral components and density are important factors in butterfly diversity and dispersal (Khanal *et al.* 2012). Many butterflies have species-specific connections with plant species that provide larval feeding. Many species rely on particular plants for food or reproduction (Bernays and Graham 1988). Butterflies and their caterpillars rely on specific host plants for foliage and nectar as food. Because of the difference in feeding behaviour between adults and larvae, butterfly habitat

selection is directly related to the availability of preferred host plants (Grossmueller and Lederhouse 1985). Butterfly diversity is highest in areas with a large number of host plants (Ghorai and Sengupta 2014) and lowest in shrub, grass, and open areas.

Butterfly species composition varies according to vegetation type (Sawchik *et al.* 2005), indicating a positive link between butterfly diversity and plant variety (Leps and Spitzer 1990). Butterfly diversity increases as habitat scale and vegetation structure complex increase (Shrestha *et al.* 2020). At higher altitudes, species richness, and diversity are minimal (Ghorai and Sengupta 2014). The conservation of butterflies is a major concern because some butterfly species have undergone significant declines over the past few decades due to habitat loss and fragmentation, a lack of native hosts and nectar plants, and insecticide use (Kremen 1992; Smith 1994). Additionally, because butterflies are sensitive to climate change and urbanization, it is crucial to learn about their status at the local level to support their conservation.

In Nepal, studies on species richness and diversity have been conducted (Bhusal and Khanal 2008; Khanal 2008; Prajapati *et al.* 2000; Shrestha *et al.* 2018). However, there have been few investigations on the relationship between vegetation and butterfly assemblages. (Shrestha *et al.* 2020; Subedi *et al.* 2021). Study of butterfly species and plant species has not been done in Maijogmai till now. So, that the main aim of this study is to assess butterfly diversity and its relationship with plants in Maijogmai, Ilam.

## **1.2. Objectives**

### **1.2.1. General Objective**

To determine the diversity and the floral preferences of butterflies in Maijogmai, Ilam, Nepal.

### **1.2.2. Specific Objectives**

1. To determine the pattern of butterfly species richness along the environmental variables in the study sites.
2. To find the relationship between butterfly species and plant species.

### **1.3. Significance**

Detail study of butterfly species has not been done in Maijogmai till now. The relationship between vegetation and butterflies is still not studied in this area. It will be more effective for future researchers. This study will find the current status of butterflies and their relation with plant species for future conservation.

### **1.4. Limitation of study**

1. It was difficult to identify some species of butterfly through direct observation.
2. Difficult to identify the plant species during survey.
3. Limited time for survey in field.
4. Short range of elevation was taken for study.

## 2. LITERATURE REVIEW

### 2.1. In context of Nepal

In 1826, General Thomson Hardwick began studying butterflies in Nepal. During the period 1852-1867, Maj. Gen. Ramsey, a British resident stationed in Kathmandu, recorded 44 species of Nepalese butterflies (Khanal and Smith 1997). Smith (1981) released a book named "Field Guide to Nepal's Butterflies" that had a list of 480 butterfly species that belonged to 200 genera and 11 families.

Khanal and Bhandary (1982) investigated the food plants preferred by butterfly larvae, as well as the economic importance and distribution of the plants. Smith (1989) released a book titled "Butterflies of Nepal," in which he mentioned 614 butterfly species from seven families.

Prajapati *et al.* (2000) investigated seasonal and altitudinal variations of butterfly species in Makawanpur district, Central Nepal. They discovered 65 butterfly species from 48 genera and 8 families, with Nymphalidae and Lycaenidae being the most common families and Acraeidae being the least common. They conclude that the diversity of species was greater in autumn than in spring.

Khanal (2001) identified 114 butterfly species in the Jhapa area of East Nepal, categorizing them into nine families. He found 27 rare butterflies, 11 unusual butterflies, and 76 common butterflies. He also concentrated on the conservation of butterflies and other plants and animals that were in danger due to habitat destruction and deforestation due to a lack of conservation education and awareness efforts.

According to Ghimire (2001), 43 species of butterflies were recorded from Champadevi, District Kathmandu, with Nymphalidae having the most and Acreidae having the fewest.

In total, Subba (2005) counted 41 species of butterflies from Gujurmukhi Village Development Committee, Ilam, which were divided into 31 genera and 7 families.

Khanal (2006) brought a list of 54 late-season butterflies from the Koshi Tappu Wildlife Reserve in Eastern Nepal, which were classified into seven of the 14 families found in Nepal.

Khanal (2008) identified 85 species in 64 genera and 10 families based on their altitudinal distribution in four western Terai districts (Dangdeukhuri, Banke, Bardia, and Surkhet). As a result of habitat deterioration brought on by urbanization, it was also noted that Banke and Dangdeukhuri were losing their butterfly diversity.

Bhusal and Khanal (2008) identified 40 butterfly species from 28 genera and 8 families in the Churiya mountains of eastern Nepal during the winter and spring seasons with the Nymphalidae being the most commonly recorded family.

Smith (2010) found 263 genera and 660 species of butterflies in Nepal. Butterflies of Nepal, Butterflies of ACA, and Illustrated Checklists of Nepal's Butterflies are three reference volumes written by Smith (2011a, 2011b, 2011c). He listed 278 species, 347 species, and 600 species in these works, respectively.

Khanal *et al.* (2012) conducted a study on butterflies in Langtang National Park between the altitudes of 1500 m and 4300 m and recorded 126 species. They discovered the most species at elevations between 1500 and 2900 meters.

In the Godavari Forest in Lalitpur, Central Nepal, Khanal *et al.* (2013a) counted 11 species. They also discovered the causes of the butterfly decline, with the main reasons being the area's rapid population increase, lack of host plants, and the establishment of a marble quarry nearby.

Khanal *et al.* (2013b) studied the endangered butterflies of central Nepal. They discovered 18 butterfly species in 5 families. Four species of butterflies, *Teinopalpus imperialis*, *Papilio krishna*, *Meandrusa lachinus*, and *Euripus consimilis*, were determined to be at high risk, 12 species of butterflies were discovered to be indigenous to central Nepal, and *Diagora nicevillei*, an endangered species, was also discovered.

Subba and Tumbahangfe (2015) found 31 butterfly species from Biratnagar, Nepal, belonging to 26 genera and six families. In 2015, they gathered specimens from March to June.

Khanal (2015) discovered 34 different species of Nymphalid Butterflies in the Godavari Pulchowki Mountain Forest in Central Nepal. They also discovered *Phaedyma aspasia kathmandia*, an endangered and endemic Nepalese Nymphalid species.

Pandey *et al.* (2017) conducted an extensive investigation of the elevational distribution of butterflies in the Langtang region of the Himalayas, where they recorded 28 butterfly species from five different families and demonstrated how some species decline at higher elevational gradients.

Dahal (2017) identified 31 species from 27 genera and nine families. Grassland has the largest diversity of butterflies, followed by agricultural land and forest. The post-monsoon season had higher butterfly diversity than the pre-monsoon season, and there was little seasonal overlap.

Rai (2017) recorded 1664 individuals representing 37 species, 30 genera, and seven families. Cropland had the highest diversity and evenness of species, followed by forest and human settlement areas. In terms of seasonal variation, more species were recorded during the autumn season, followed by the spring season, and fewer species were recorded during the winter season. The low altitude was discovered to have more diversity than the higher altitude.

Nepali *et al.* (2018) discovered 84 butterfly species belonging to 56 genera and 6 families, as well as their relationships with various plant species, in the National Botanical Garden (NBG), and discovered that the garden has a high diversity of butterflies that are interrelated to one another.

Shrestha *et al.* (2018) discovered 77 butterfly species divided into 56 genera and 6 families. The Nymphalidae family had the greatest number and diversity of butterflies, and it dominated the entire sacred forest. *Pieris canidia* was the most prevalent species throughout the research period. SSF had the most butterfly species, with four uncommon, 19 rare, 21 quite common, and 18 common. The main risks they reported in the SWSF and PSF were unmanaged pollution, a high level of human interference, the quantity of open-access tracks, and so on.

Sah (2019) discovered 23 species belonging to 19 genera and 8 families. The most common families were Nymphalidae and Pieridae, which contributed 39.13% and 21.74% of the species, respectively, while Satyridae, Nemeobidae, Amathusidae, and Papilionidae contributed 4.35% of each. They discovered that butterflies have a larger diversity in non-cultivated areas than in cultivated land.

Khanal (2020) identified 114 butterfly species from three distinct northern destinations: Melamchi, Timbu (central-northern), Helambu (northern), Nakote (north-western), Panch Pokhari, and the surrounding region (north-eastern). They discovered that the diversity of butterflies fell significantly beyond 3500 meters as they approached Panch Pokhari, but species richness was observed high at 900-2700 meters along the Melamchi-Helambu route, which included Nakote, Shermathan, and Tarkyghyang.

Shrestha *et al.* (2020) examined butterfly-plant interactions and body size patterns over an elevational gradient in central Nepal's Manang region, recording 57 species of butterflies

from 39 genera and 8 families. Only 67 of the 127 plant species identified in the study region were visited by butterflies as nectar sources.

Miya *et al.* (2021) discovered 1,753 individuals of 149 butterfly species from 92 genera and six families in Byas municipality-6 of the Tanahun, Nepal. The most species were observed in March (106), whereas the most species abundance was found in June (268) individuals.

Neupane and Miya (2021) identified 180 butterfly species belonging to 108 genera and six families in Putalibazar Municipality, Syangja, Gandaki, Nepal. The Nymphalidae has the most diversity, with 67 species ( $H=3.79$ ). The forest area had the most butterfly diversity and species abundance (147 species, 1199 individuals;  $H=4.47$ ). The monsoon season has the highest species richness (109 species).

Subedi *et al.* (2021) documented 298 individuals from 31 different butterfly species visiting 28 different nectar plant species from Rupa Wetland. The most abundant butterflies were *Zemeros flegyas* (92 individuals) and *Junonia atlites* (80 individuals).

## **2.2. In context of World**

Butterflies have been studied since the 18<sup>th</sup> century (Heppner 1998). Spitzer *et al.* (1993) ecologically and biogeographically described the butterfly community in the Tam Dao montane rain forest in Northern Vietnam. They discovered a relationship between the size of a species, geographical range, and the maturity of its preferred habitat's succeeding phases. Pullin (1996) investigated the status of butterflies in Britain and discovered that the distribution and the number of butterflies were quickly declining due to unsuitable habitats. Boonvanno *et al.* (2000) discovered 147 butterfly species from 77 genera and 9 families at Ton Nga-Chang Wildlife Sanctuary in Songkhla Province, Southern Thailand. They discovered that the Nymphalidae and Lycaenidae were the most dominating families. Collinge *et al.* (2003) conducted a study on the effects of local habitat variables and landscape on butterfly communities and discovered that host plant heterogeneity and habitat quality had a substantial effect on butterfly diversity while landscape type had a minor effect.

Kitahara *et al.* (2008) discovered the strongest correlation between butterfly species richness and nectar plant species richness in and around the Aokigahara primary woodland on the northwestern foot slopes of Mount Fuji in central Japan. They also discovered that

nectar-feeding butterfly species were significantly biased toward herbaceous and perennial plants.

Sundufu and Dumbuya (2008) identified 290 butterfly species and studied their habitat preferences in the Bunbuna Forest Reserve in Northern Sierra Leone. 75.5% of them preferred forest habitats, while 47.6% chose disturbed areas, and 23.1% preferred savannah habitats.

Tiple and Khurad (2009) discovered 145 butterfly species in Nagpur, India. In Nagpur, they discovered 62 new kinds of butterflies. The Nymphalidae (51 species) had the newest records, with 17, followed by the Lycaenidae (46 species) with 29 new records, the Hesperidae (22 species) with 14 new records, the Pieridae (17 species) with 4 new records, and the Papilionidae (9 species).

Ramesh *et al.* (2010) studied butterfly diversity patterns, abundance, and habitat at the Department of Atomic Energy Campus in Kalpakkam, India. They collected 55 butterfly species from 5 families and discovered that the Nymphalidae were the dominant family, with the Hesperidae being the least concerned. They discovered that the scrub jungle and garden area habitats were favoured by the greatest number of butterflies.

Khan *et al.* (2011) discovered 68 butterfly species belonging to 38 genera and 7 families while studying the altitudinal distribution pattern of butterflies in the Kashmir Himalayas.

Bhardwaj *et al.* (2012) identified 79 butterfly species while examining butterfly communities along an elevational gradient in Tons Valley, Western Himalayas. They also discovered that diversity was greatest in varied ecosystems and reduced in homogeneous habitats. The richness and abundance of butterfly species were significantly correlated with altitude, temperature, and relative humidity.

Sarma *et al.* (2012) studied the diversity and habitat relationship of butterfly species in the Itanagar foothills of Arunachal Pradesh, India, and discovered 63 species, with the Nymphalidae accounting for 44%, the Lycaenidae 17%, the Pieridae 16%, the Papilionidae 14%, and the Hesperidae 8%. They also discovered that the forest had the greatest diversity of butterflies, followed by roadside plantings.

Ferrer- Paris *et al.* (2013), 44,148 butterflies from 5,152 species of butterflies (28.6% of all Papilionidae species globally) and 1,193 genera (66.3%) were counted. Angiosperm plants serve as hosts for the majority of butterflies. Qureshi and Bhagat (2013) documented a total of 90 host plants divided into 66 genera and 28 families, with 21 new records from Kashmir Valley.

Ghorai and Sengupta (2014) investigated the altitudinal distribution of Papilionidae butterflies and their larval feeding plants in West Bengal, India's Eastern Himalayan Landscape. They found 26 butterfly species across 11 altitudinal belts, as well as 35 plant species from 6 families that serve as larval food plants for these butterflies.

Mali *et al.* (2014) discovered 43 butterfly species from five families while studying the biotic interrelationship of plants and butterflies in Gandhinagar, Gujarat.

Saikia (2014) discovered 140 species of butterflies classified into 5 families while studying butterfly diversity at Gauhati University College in Jaulapuri, Assam, India, between 2003 and 2010. The monsoon season, he discovered, has the maximum diversity, followed by the pre-monsoon, winter, and post-monsoon seasons.

Patel and Pandya (2014) investigated the relationship between local butterflies and the host plant species that they preferred in the proximity of the Maharaja Sayajirao University of Baroda in Sayajigaunj, Gujarat, India. They discovered 21 host plant species distributed across 13 families, with the Asteraceae family attracting the greatest number of butterflies.

Acharya and Vijayan (2015) studied butterflies in Sikkim along an elevational gradient and found a decrease in species richness as elevation increased.

Alarape *et al.* (2015) published a checklist of 57 butterfly species from 9 families surveyed at the Ibadan Botanical Garden in Nigeria. They found a relationship between temperature and the diversity and abundance of butterfly species, but not between physical variables (relative humidity and temperature) and the overall number of species and families.

Ghosh and Saha (2016) discovered 51 species of butterflies belonging to 5 genera while examining the seasonal diversity of butterflies in Taki, North 24 Parganas, West Bengal, India, in terms of habitat heterogeneity, larval host plants, and nectar plants. They also discovered an increase in butterfly species richness and abundance during the post-monsoon season

Kumar *et al.* (2016) reported 29 species of butterflies from Shimla's Chanshal Valley, belonging to 22 genera and 4 families, where butterfly diversity was higher in autumn than in than in summer due to host plant availability and suitable environmental conditions such as temperature and humidity.

Alleppa and Shrivastava (2016) discovered 45 species from five families. The Nymphalidae family dominated their study, accounting for 37.77% of the butterflies surveyed, followed by Pieridae (22.22%), Papilionidae (20%), Lycaenidae (11.11%), and Hesperidae (8.88%).

Arya *et al.* (2020) recorded 497 individuals from several puddling places in NWS, 85.92% males and 14.08% females of 22 species from four families. The majority of butterfly species and individuals were observed puddling during the summer season, followed by the rainy and winter seasons, respectively.

Uwizelimana *et al.* (2022) collected 1215 individuals from 56 species, with the Charaxinae and Satyrinae groupings dominating. 77% of the reported species are found between 1700 and 2100 meters above sea level. They discovered that species richness and abundance were higher during the dry season and declined as elevation increased.

Vieira *et al.* (2022) collected data at three different elevation levels using both active (nets) and passive (bait trap) methods. A total of 622 Lepidoptera individuals were collected, representing 154 different species. They identified that the family Nymphalidae has the most diversity and abundance, followed by the families Hesperidae, Pieridae, Papilionidae, Lycaenidae, and Riodinidae. They also discovered that the middle elevation zone had the most richness, abundance, and diversity, whereas the high elevation zone had the most specialized species.

During the two-year survey period, (Chandra *et al.* 2023) discovered 89 butterfly species from the families Nymphalidae (43 species), Pieridae (15 species), Lycaenidae (13 species), Hesperidae (8 species), Papilionidae (7 species), and Riodinidae (3 species), 46 of which were new to the Nandhour Landscape. Butterfly diversity and richness were found to be greatest in dense moist riverine forests, and lowest in human settlements and agricultural land.

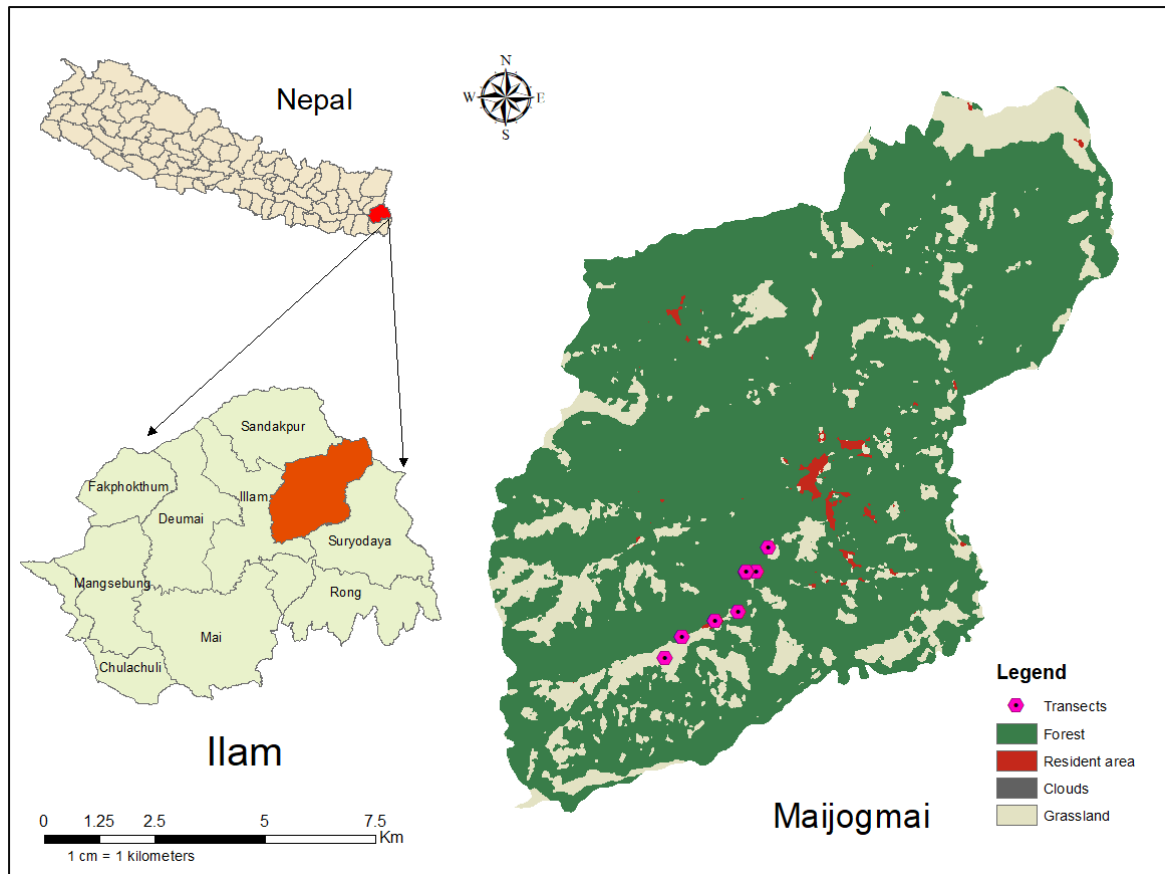
### 3. MATERIALS AND METHODS

#### 3.1. Study area

The study was conducted in Maijogmai, Ilam, Nepal. It has an area of 172.41 square kilometres. The study site lies within the elevation ranges from 1300m to 1900m within the geographical stands with latitude 26°54' 38.6" N and longitude 88°0'21.7" E. Most of the study site were grassland and open areas. Geographically, it lies in the Mahabharat range. Maijogmai's vegetation includes a wide range of floras from subtropical and temperate zones. The dominant plant species of Maijogmai include *Rubus ellipticus*, *Alnus nepalensis*, *Schima wallichii*, *Bambusa nutans*, *Citrus reticulata*, *Amomum subulatum*, *Thysanolaena maxima* and *Leucosceptrum canum*, *Schima wallichii*, *Castanopsis indica*, *Bidens pilosa*, *Pinus roxburghii* and *Pinus wallichii*. Flowering plants in this area include *Rhododendron*, *Malvaviscus arboreus*, *Erigeron karvinskianus*, *Tagetes erecta*, *Rhododendron*, *Rosa rosa*, and medicinal plants are *Zingiber officinale*, *Artemisia indica*, and *Phyllanthus emblica* (Parajuli 2013).

The Maijogmai area comprises a sub-tropical and temperate type of climate. Maijogmai,s climate varies from cold and freezing in the winter, mild warm in summer, and gloomy during the monsoon. The temperatures are highest on average in April and lowest in January. The average annual temperature of Maijogmai is 20.5°C. In a year, the average rainfall is 2500mm (Bhattarai 2018). The temperatures are highest on average in June and lowest in January.

Maijogmai is also famous for its natural scenery and landscapes as well as its diverse agricultural economy which specializes in horticultural crop production. People of this area agriculture and animal husbandry have been the main sources of income.



**Figure 1:** Map of Maijogmai, Ilam (Source: Arc GIS)

### 3.2. Materials

During fieldwork, the following materials were used:

- i. Sweeping net
- ii. GPS (Garmin extra 10)
- iii. Field guide book: An Illustrated Checklist of Butterflies of Nepal, By Colin Smith, 2011.
- iv. Vials
- v. Triangular paper envelopes

### 3.3. Field survey, butterfly collection, preservation, and identification

The sampling was done during April and September 2022. The line transect approach was followed for butterfly sampling (Pollard 1977). Altogether, seven line transects with 100m were established. The altitudinal distance between two consecutive transects was made at 100m. All butterfly species observed along the transects within a range of 2m from the transects were identified and recorded. Butterflies were observed between 9:00 AM to 2:00 PM. Each transect was visited twice a month. A sweeping net was used to collect butterfly

(Martínez-Sánchez *et al.* 2020). The butterflies adopted the capture and release method for confirmation of the same species (Shrestha *et al.* 2020). Each trapped butterfly species was photographed as many times as possible from various angles to obtain enough photos to allow accurate species identification and then released. The unidentified butterfly species were kept in paper envelopes and were kept in a box with naphthalene balls for preservation. Also recorded coordinates (latitudes and longitudes) and elevation with the help of the Gramin Global Positioning System (GPS).

Later, photos were sorted and the species were identified using standard (Smith 2011a) literature. Some species were identified with direct observation during the field periods. In the case of some unidentified species, they were captured and later identified by tallying their photograph with the preserved species of the Natural History Museum, Swoyambhu, Kathmandu, and books (Smith 2011a, 2011b).

### **3.4. Plant Identification**

Plant species that were visited by butterfly was recorded and identified with the help of different books (Polunin and Stainton 1984) and websites.

### **3.5. Data analysis**

#### **3.5.1. Diversity and Similarity Index**

The data were analysed by using MS – EXCEL 2021. The diversity of butterfly species was calculated using the Shannon-Wiener diversity index (H), given by the equation,

$$H = - \sum P_i \times \ln (P_i).$$

Where, H= Shannon-Weiner diversity index.

ln = the natural log

$\Sigma$  = the sum of the calculations

n= the abundance of each species.

N= Total number of individuals in the sample.

$P_i = n/N$  = Relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community.

To compare the similarity of species composition with elevations Jaccard similarity index was used. The formula for the Jaccard similarity index is:

$$J = |A \cap B| / |A \cup B|$$

Where,

$J$  represents the Jaccard similarity between sets A and B.

$|A \cap B|$  denotes the number of elements that are common to both sets.

$|A \cup B|$  denotes the total number of distinct elements in both sets.

### **3.5.2. Relation Between butterfly richness and environmental variables**

Firstly, we modelled the response of butterfly richness with elevation using generalized linear modelling with the Poisson family and identity link function. We also tested for the models (linear, quadratic, and cubic) terms to check for other dominant trends of species richness along elevation gradients. All the models we then compared using Akaike Information Criterion. Burnham and Anderson (1998), and the most parsimonious model ( $\Delta AICc=0$ ) was selected for the inference.

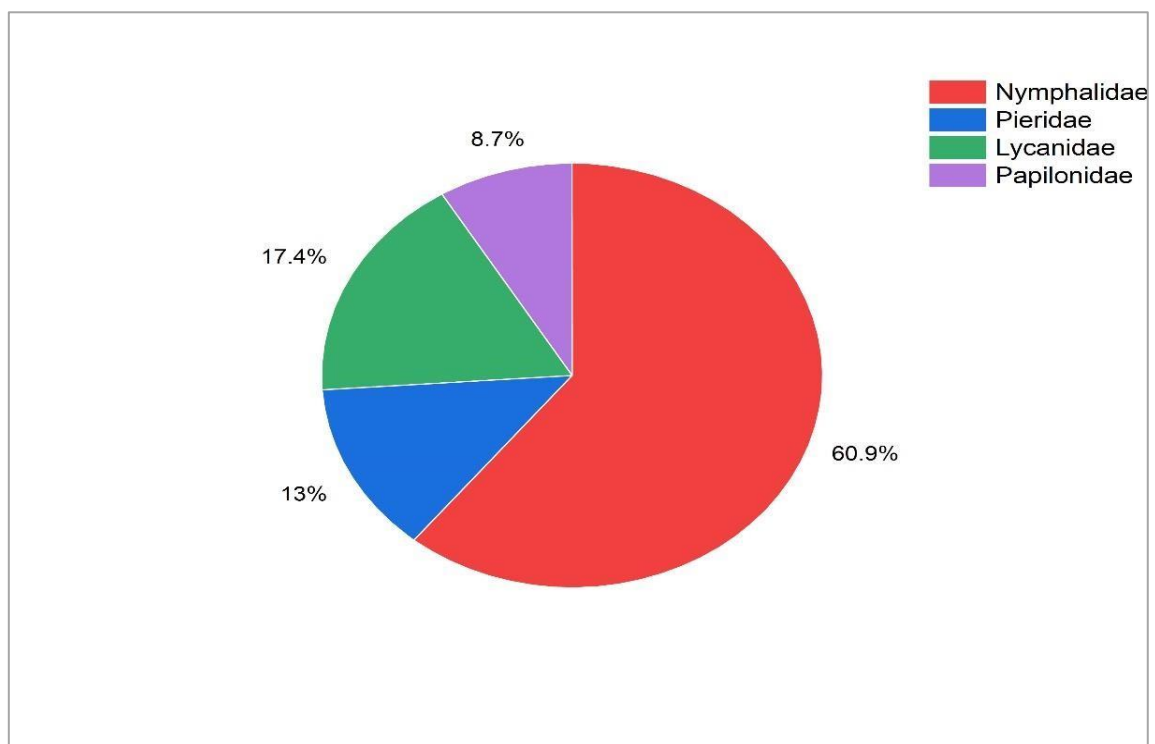
To model the response of the selected environmental variables, we used the same family and link as the elevational gradient but performed a dredging function in the “MuMin” package in R (Barton 2019) where all the possible linear combinations of the environmental variables were run and the model selected by using the criteria of  $\Delta AICc < 2$  for multimodel inference.

The relationship between different butterfly species and plants generated by Principal Correspondence Analysis (PCA) diagrams showed that the butterfly species were significantly associated with the plants.

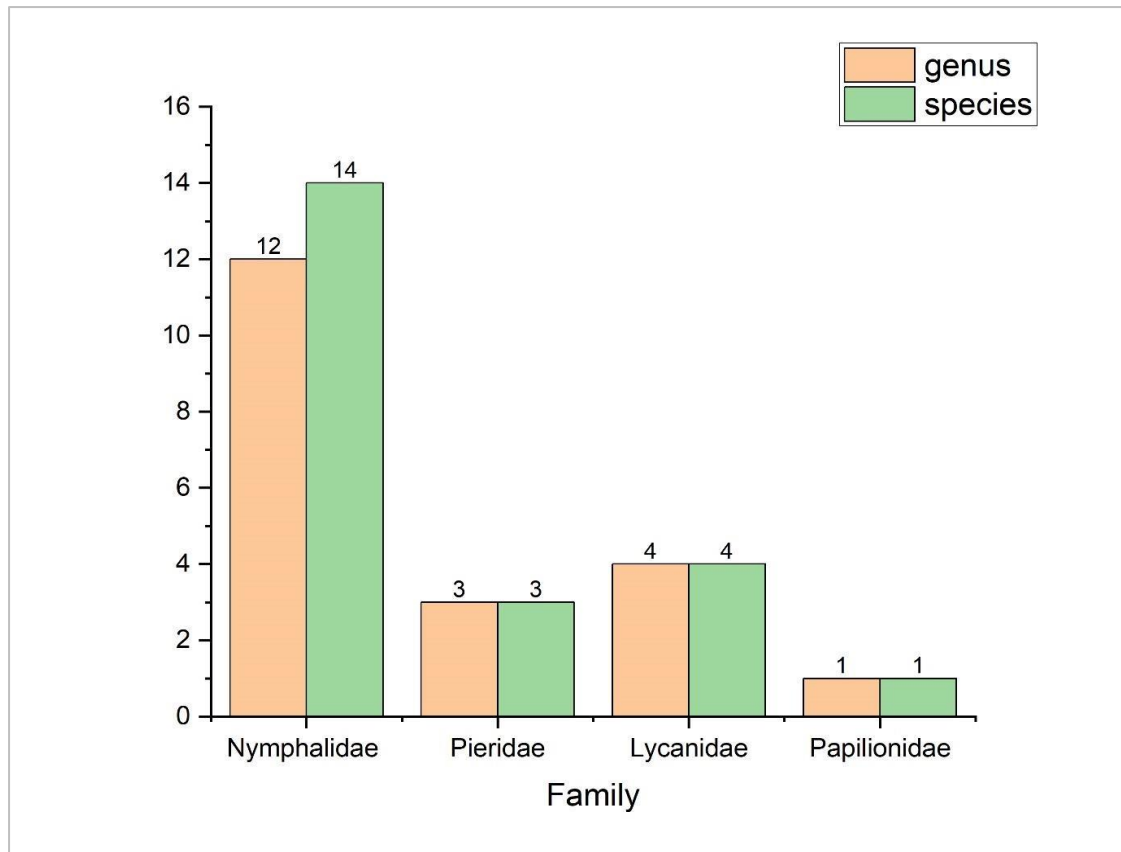
## 4. RESULTS

### 4.1. Diversity and Distribution

A total of 235 individuals of 22 species of butterflies belonging to 20 genera and four families were observed at different sites during the entire study period (Appendix I). Of these, the family Nymphalidae was largest represented by 14 species (60.9%) followed by Lycaenidae with four species (17.4%), Pieridae with three species (13%), and Papilionidae was the lowest with one species (8.7%) (Fig 2; Fig. 3). Nymphalidae represented the greater number of genera (12) and then Lycaenidae (4), Pieridae (3), and Papilionidae (1) (Fig: 3).



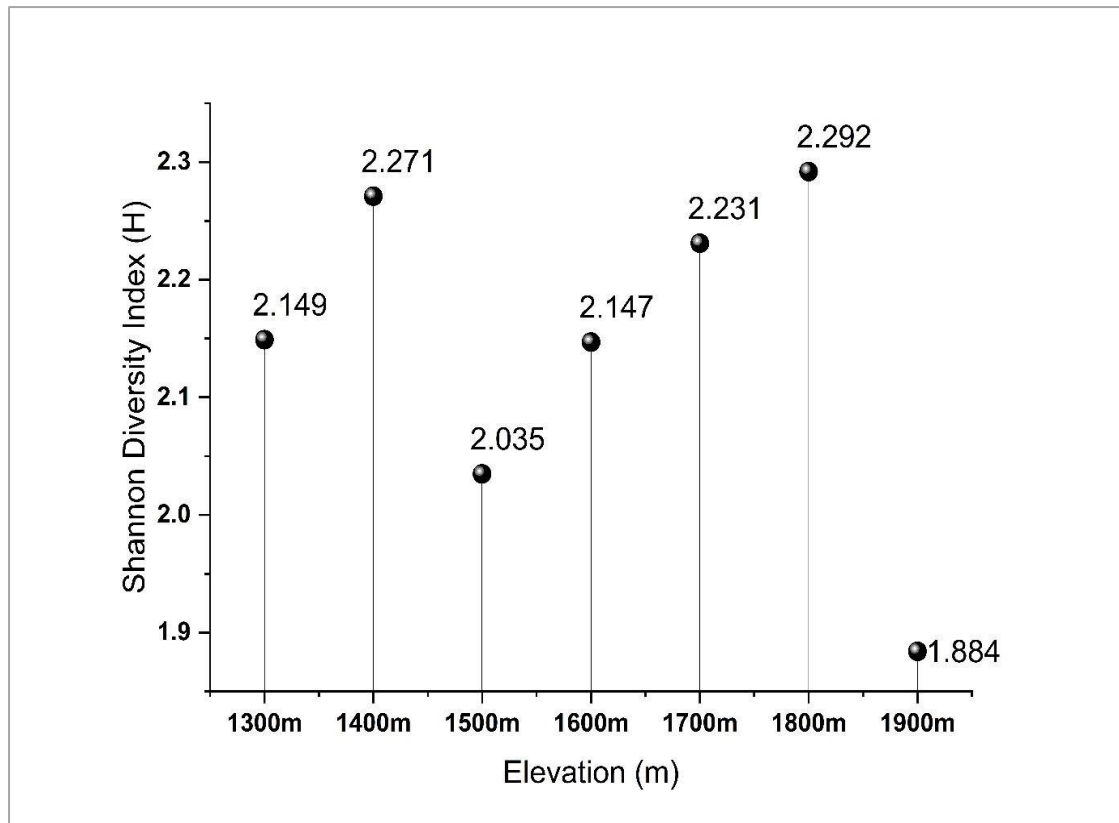
**Figure 2:** Family-wise distribution of butterfly species recorded in the study area



**Figure 3:** Family-wise number of genus and species recorded in the study area

#### **4.1.2. Butterfly Diversity and Similarity index**

The Shannon-Wiener diversity index ( $H'$ ) was 2.795. The diversity index was highest ( $H' = 2.292$ ) at 1800 m and lowest at 1900 m ( $H' = 1.884$ ) (Fig 4). Based on Jaccard's similarity index, butterfly species similarity was highest at heights of 1400m ( $J=0.667$ ). The lowest value of the butterfly species similarity index (0.0667) was found at altitudes of 1900m (Table 1). The similarities index values in butterfly communities along elevation gradients (Jaccard's similarity index) are provided in Table 1.



**Figure 4:** Shannon Diversity Index

**Table 1:** Elevation-wise Jaccard Similarity Index

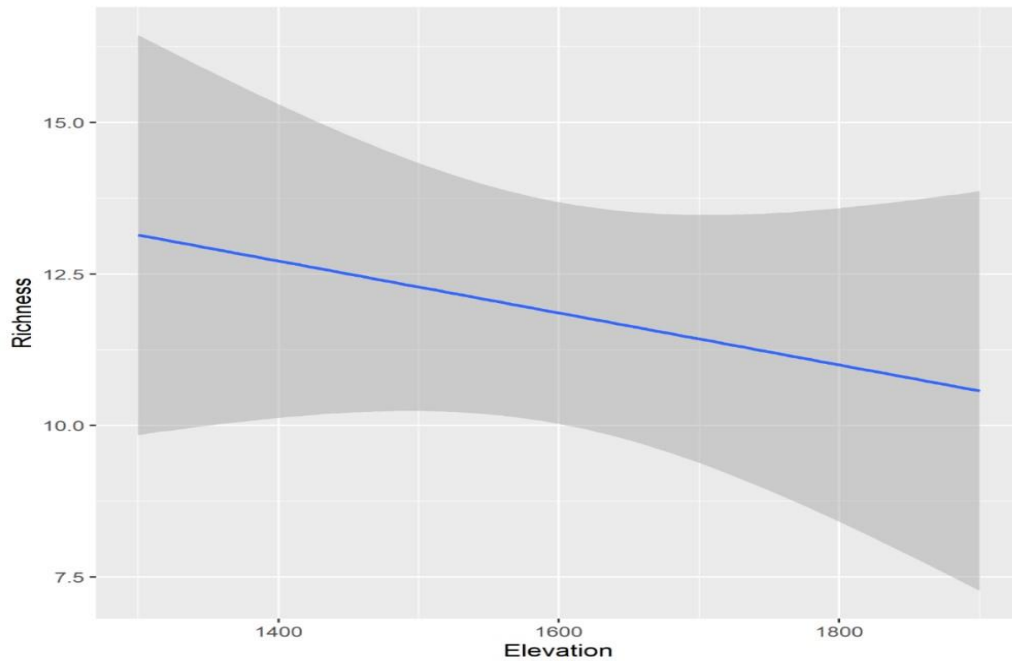
<b>Elevation</b>	1300m	1400m	1500m	1600m	1700m	1800m	1900m
1300m	1	0.667	0.214	0.2	0.117	0.176	0.0667
1400m	0.667	1	0.2667	0.333	0.235	0.294	0.125
1500m	0.214	0.2667	1	0.545	0.5	0.357	0.364
1600m	0.2	0.333	0.545	1	0.583	0.428	0.333
1700m	0.117	0.235	0.5	0.583	1	0.615	0.416
1800m	0.176	0.294	0.357	0.428	0.615	1	0.5
1900m	0.0667	0.125	0.364	0.333	0.416	0.5	1

## 4.2. Relation of Butterfly with environmental parameters

### 4.2.1. Relationship between Richness and environmental variables

Butterflies were observed in different altitudinal ranges. The monotonic decline of richness with increasing elevation was obtained and also showed a significant negative relation ( $P < 0.001$ ) (Fig 5; Table 2). AICc values represent the difference in Akaike Information

Criterion Corrected for small sample sizes between each model and best fitting model. In this case cubic model and quadratic has highest AICc values suggesting that linear model is the most appropriate for describing the relationship between the species richness and elevation (Table 2). For other environmental variables, none of them were found significant to the species richness of butterflies (Appendix II).



**Figure 5:** Species richness of butterflies from different elevations of the study site

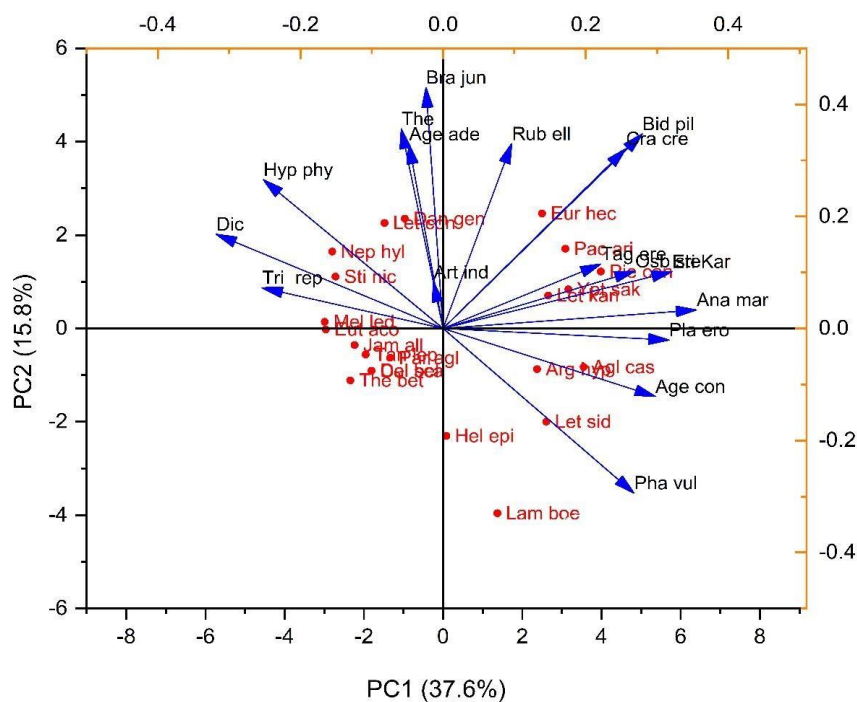
**Table 2:** Generalized Linear Models of species richness overall and family-wise species richness considering response variables as a function of elevation. Linear, quadratic, and Cubic models are tested to determine best-suited models and ranked by  $\Delta$ AICc values. (SE). Significant values of model coefficients: \*\*\*,  $P < 0.001$ ; \*\*,  $P < 0.01$ ; \*  $P < 0.05$

Family	Models	$\Delta$ AICc	Intercept	Coefficient Linear	Coefficient Quadratic	Coefficient Cubic
Species Richness	Cubic	20.10	6.774e+01 (2.002e-08)	-1.263e-01	8.092e-05	-1.717e-08
	Quadratic	6.84	-1.734e01 (3.208e-06)	3.744e-03	-1.288e-06	
	Linear	0	3.0492573 (0.0005497)	<b>-0.000362</b> ***		

### 4.3. Butterflies' association with plant species

The study sites reported a total of 28 plant species from 27 genera and 17 families. The PCA ordination diagrams show the relationship between butterfly species and plant species

explained by two canonical axes. The 1<sup>st</sup> canonical axis explained (37.6%) and the 2<sup>nd</sup> (15.8%) (Fig 6). The PCA diagram displayed the butterfly species such as *Pieris canidia*, *Eurema hacabe*, *Lethe kansa*, *yptima sakra* and *Parantica aglea* showed the highly preferred plant species like *Biden pilosa*, *Tagetes erecta*, *Osbeckia stellata*, *Anaphalis margaritacea*, and *Plantago erosa*. whereas the butterfly species like *Lethe confusa*, *Neptis hylas*, *Stibochiona nicea*, and *Danaus genutia* preferred the plant species like *Trifolium repens*, *Hypoestes phyllostachya*, *Dicliptera juss*, and *Thelypteridaceae*. Butterfly species *Aglais cashmerensis*, *Lampides boeticus*, were mostly preferring similar types of plant species such as, *Phaseolus vulgaris*, *Ageratum conyzoides*. However, *Melanitis leda*, *Jamides alecto*, *Euthalia aconthea* *Thecla betulae*, *Delias belladonna* butterfly species were found to prefer selective few plant species like *Trifolium repens*, *Dicliptera juss*, and *Ageratina adenophora*. Among all plant species, *Ageratina adenophora* was found most dominant species (Fig 6).



**Figure 6:** Principal Correspondence Analysis (PCA) ordination diagrams showing the relationship between butterfly species (Red colour) and plant species (Black colour) explained by two canonical axes. The 1<sup>st</sup> canonical axis explained (37.6%) and the 2<sup>nd</sup> (15.8%). For the details of all abbreviated species of Butterfly see Appendix I and Plant in Appendix III.

## 5. DISCUSSION

### 5.1. Diversity and Distribution

A total of 22 species of butterflies were identified. The Nymphalidae family contributed the highest species number (60.9%) whereas the family Papilionidae had the least species number (8.7%). Dar *et al.* (2022) also found a similar result that the Nymphalidae family contributed the highest species number and Papilionidae contributed the least species number at Jammu and Kashmir. According to Kumar *et al.* (2016), the Nymphalidae family contributed the highest species number where as Papilionidae contribute the least species number in the Subalpine area of Chanshal area of Chanshal Valley of District Shimla (Himachal Pradesh), supporting the current study. A similar result was drawn by different researchers from different parts of the world (Sharma and Paudel 2021; Subedi *et al.* 2021). However, Mukherjee *et al.* (2015) found that the family Lycaenidae had the highest butterfly diversity, followed by Nymphalidae, and that the Papilionidae had the lowest butterfly diversity. Similarly, Nymphalidae was shown as the most dominant family by (Narasimmarajan *et al.* 2014; Neupane and Miya 2021; Sarma *et al.* 2012; Shrestha *et al.* 2018), which may be due to the availability of their particular larval host plants Saikia, (2014) their ecological adaptation, diversification, and great dispersal ability Dudley and Adler (1996). Up to now the distribution pattern of butterflies from the current location is concerned with the species such as *Pieris canidia*, *Eurema hecabe* that were recorded in every study site. However, species like *Aglais cashmerensis*, *Ypthima sakra*, *Argynnis hyperbius*, *Neptis hylas*, *Lethe confusa*, *Danaus genutia* and *Callerebia scanda* were dominant butterfly species in the study sites and having the maximum number of species. Other species like *Stibochiona nicea*, *Lethe kanca*, *Lethe sidera*, *Melanitis leda*, *Tanaecia lepidea*, *Euthalia aconthea*, *Parantica aglea*, *Delias belladonna*, *Thecla betulae*, *Lampides boetius*, *Heliophonus epides*, *Jamides alecto*, *Pachliopta aristolochiae* were observed very rarely and found in minimum number. During the study period, one of the Papilionidae butterfly species, *Pachliopta aristolochiae*, was observed to be the species with the fewest numbers. Butterfly diversity and distribution decline as human disturbance, habitat fragmentation, and forest fires increase, and host plants are impacted by developmental activities (Khanal 2015; Kumar 2012). There may be a comparable reason for the butterfly species' population decline in this region. Additionally, it might be due to different seasons and geographical zones.

## **5.2. Relation of butterfly with environmental parameters**

This study reveals that a monotonic decline of species richness with increasing elevation was obtained. This result is similar to the results of (Acharya and Vijayan 2015; Ghorai and Sengupta 2014; Joshi and Arya 2007). In India's Kerala and Uttarakhand, respectively, (Sreekumar and Balakrishnan 2001) discovered a decline in species richness and abundance as altitude increased. The harshness of environmental and climatic conditions, area reduction, scarce vegetation, and scarcity of suitable habitats may all contribute to the ongoing decline in species numbers with elevation (Khanal *et al.* 2012; Lawton *et al.* 1987). This decline may also be a result of a decrease in resource diversity. But (Shrestha *et al.* 2020) found an unexpected pattern in butterfly diversity. i.e., species richness increases with increasing elevation. The study also shows that butterfly species richness models linearly rather than cubic and quadratic declined with increasing elevation. Which is similar to the results of (Leingärtner *et al.* 2014). In this study, none of the environmental variables (temperature, humidity, and canopy cover) were shown to be significant to the species richness of butterflies. This is consistent with the findings of (Alarape *et al.* 2015), who discovered no association between physical parameters (relative humidity and temperature). But it contrasts with other studies (Kati *et al.* 2012; Stefanescu *et al.* 2004) that reveal that species richness is correlated either positively or negatively with environmental variables. Bhardwaj *et al.* (2012) discovered that the richness and abundance of butterfly species were strongly related to altitude, temperature, relative humidity, fire signals, and animal abundance. This result is just the opposite of this study. It might be due to the small sample size and difference in the study locations' vegetation and landscape types. It could also be due to the short length of time and geographical zone.

## **5.3. Relationship between butterfly species and plant species**

According to Khanal and Bhandary (1982), vegetation plays a significant part in butterfly distribution. The study sites identified a total of 28 plant species from 27 genera and 17 families. Among 17 families Asteraceae family attracted the greatest number of butterflies. Patel and Pandya (2014) also obtained a similar result that discovered 21 host plant species distributed across 13 families, with the Asteraceae family attracting the greatest number of butterflies. The current study also found that there were many different butterfly species in the area with a variety of plants. Several earlier researchers (Kitahara *et al.* 2008; Tiple and Dennis 2005) noted similar outcomes. According to the results of the current study, it was

noticed that different butterfly species preferred herbs more frequently than shrubs, cultivated plants, and tree plants. Such findings have been reported from Lamjung-Manang, central Nepal (Khanal and Bhandary 1982). Nimbalkar *et al.* (2011) discovered that butterflies prefer the flowers of herbs and shrubs over the flowers of trees. These findings demonstrate the significance of herbaceous plant diversity in maintaining butterfly diversity.

## **6. CONCLUSION AND RECOMMENDATIONS**

### **6.1. Conclusion**

Altogether 20 genera and 22 species of butterfly were recorded which were categorized under four families (Nymphalidae, Pieridae, Lycaenidae, and Papilionidae.). This study concludes that the Nymphalidae family contributed the highest species number (60.9%) whereas, the family Papilionidae had the least species number (8.7%). This study reveals that monotonic decline of species richness with increasing elevation was obtained and also showed a significant negative relation. For other environmental variables, none of them were found significant to the species richness of butterflies. According to the current study, it was noticed that different butterfly species preferred herbs more frequently than shrubs, cultivated plants, and tree plants.

### **6.2. Recommendations**

The following recommendations have been made based on this research:

1. Further research should be conducted that covers all seasons to investigate more butterflies in that study location.
2. Further research should be conducted with wide range of elevation.

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## APPENDICES

### Appendix I

Checklists of butterfly species recorded in the study

Family	S.N.	Scientific name	Common name	Abbreviations
Nymphalidae	1.	<i>Lethe confusa</i> Aurivillius, 1897	Banded tree brown	Let con
	2.	<i>Lethe kansa</i> Moore, 1857	Bamboo forester	Let kan
	3.	<i>Lethe siderea</i> Marshall, 1880	Scarce wood brown	Let sid
	4.	<i>Stibochiona nicea</i> Gray, 1846	Popinjay	Sti nic
	5.	<i>Neptis hylas</i> Linnaeus, 1758	Common sailor	Nep hyl
	6.	<i>Melanitis leda</i> Linnaeus, 1758	Common evening brown	Mel led
	7.	<i>Tanaecia lepidea</i> Butler, 1868	Grey count	Tan lep
	8.	<i>Danaus genutia</i> Cramer, 1779	Common tiger	Dan gen
	9.	<i>Aglais caschmirensis</i> Kollar, 1848	Indian tortoise shell	Agl cas
	10.	<i>Ypthima sakra</i> Moore, 1857	Himalayan five ring	Ypt sak
	11.	<i>Euthalia aconthea</i> Cramer, 1777	Common baron	Eut aco
	12.	<i>Parantica aglea</i> Stoll, 1782	Glassy tiger	Par agl
	13.	<i>Argynnis hyperbius</i> Linnaeus, 1763	Indian fitillary	Arg hyp
	14.	<i>Callerebia scanda</i> Kollar, 1844	Pallid argus	Cal sca
Pieridae	15.	<i>Pieris canidia</i> Sparrman, 1768	Cabbage white	Pie can
	16.	<i>Eurema hecabe</i> Linnaeus, 1758	Common grass yellow	Eur hec
	17.	<i>Delias belladonna</i> Fabricius, 1793	Hill jezebel	Del bel
Lycanidae	18.	<i>Thecla betulae</i> Linnaeus, 1758	Brown hairstreak	The bet
	19.	<i>Lampides boeticus</i> Linnaeus, 1767	Pea blue	Lam boe

	20.	<i>Heliophorus epicles</i> Godart, 1823	Purple sapphire	Hel epi
	21.	<i>Jamides alecto</i> Swinhoe, 1915	Metallic cerulean	Jam all
Papilionidae	22.	<i>Pachliopta aristolochiae</i> Fabricius, 1775	Common rose	Pac ari

## Appendix II

Showing the relationship between richness and environmental parameters through the generalized linear models with the Poisson distribution model.

Intercept	Canopy cover	Humidity	Temp.	df	logLik	AICc	Delta	weight
2.47293	NA	NA	NA	1	-16.1237	35.04732	0	0.651365
3.583742	NA	-0.02249	NA	2	-15.6551	38.31014	3.262814	0.127442
0.050099	NA	NA	0.115125	2	-15.6922	38.38433	3.337011	0.122801
2.566033	-0.00208	NA	NA	2	-16.0714	39.14276	4.09544	0.084045
-1.35291	-0.00736	NA	0.197406	3	-15.2406	44.48116	9.433839	0.005825
1.589791	NA	-0.01673	0.08121	3	-15.4804	44.96075	9.91343	0.004583
3.612237	-0.00134	-0.02185	NA	3	-15.6333	45.26667	10.21935	0.003933
-0.40961	-0.00637	-0.00837	0.170138	4	-15.1943	58.38867	23.34135	5.56E-06

### Appendix III

Plant species recorded in study area

S.N.	Scientific Names	Abbreviations	Family
1.	<i>Biden pilosa</i> Linnaeus ,1753	Bid pil	Asteraceae
2.	<i>Erigeron karvinskianus</i> DC	Eri kar	Asteraceae
3.	<i>Alnus nepalensis</i> D Don	Aln nep	Betulaceae
4.	<i>Trifolium repens</i> L.	Tri rep	Fabaceae
5.	<i>Crassocephalum crepidioides</i> S. Moore, 1912	Cra cre	Asteraceae
6.	<i>Hypoestes phyllostachya</i> Baker, 1887	Hyp phy	Acanthaceae
7.	<i>Tagetes erecta</i> L.	Tag ere	Asteraceae
8.	<i>Dicliptera</i> Juss.	Dic	Acanthaceae
9.	<i>Ageratina adenophora</i> King and H. Rob	Age ade	Asteraceae
10.	<i>Brassica juncea</i> L	Bra jun	Brassicaceae
11.	<i>Persicaria capitata</i> H. Gross, 1913	Per cap	Polygonaceae
12.	<i>Urena lobata</i> L.	Ure lob	Malvaceae
13.	<i>Lophatheum gracile</i> Brongn	Lop gra	Gramineae
14.	<i>Artemisia indica</i> L.	Art ind	Asteraceae
15.	<i>Rubus ellipticus</i> Sm, 1815	Rub ell	Rosaceae
16.	<i>Anaphalis margaritacea</i> L.	Ana mar	Asteraceae
17.	<i>Phaseolus vulgaris</i> L	Pha vul	fabaceae
18.	<i>Ageratum conyzoides</i> L 1753	Age con	Asteraceae
19.	<i>Thelypteridaceae</i> Ching	The	Thelypteridaceae
20.	<i>Osbeckia stellata</i> Buchanan Hamilton	Osb ste	Melastomataceae
21.	<i>Plantago erosa</i> L	Pla ero	Plantaginaceae
22.	<i>Persicaria chinensis</i> L	Per chi	Polygonaceae
23.	<i>Cestrum aurantiacum</i> Lindl	Ces aur	Solanaceae
24.	<i>Saurauia napaulensis</i> DC	Sau nap	Actinidiaceae
25.	<i>Hypericum perforatum</i> L	Hyp per	Hypericaceae
26.	<i>Isodon</i> Schrad	Iso	Lamiaceae
27.	<i>Boehmeria nivea</i> L	Boe niv	Urticaceae
28.	<i>Miconia crenata</i> Vahl	Mic cre	Melastomataceae

## Appendix IV

### Location of the study sites

Location	GPS reading		
Plot	Latitude	Longitude	Altitude
1	26°55'7.7"	87°59'16.9"	1300
2	26°55'22.9"	87°59'31.4"	1400
3	26°55'34.2"	87°59'59.0"	1500
4	26°55'41.4"	88°00'18.0"	1600
5	26°55'54.32"	88°00'25.53"	1700
6	26°56'10.5"	88°00'32.7"	1800
7	26°56'28.4"	88°00'42.7"	1900

Photo plates



*Lethe confusa*



*Aglais caschmirensis*



*Parantica aglea*



*Jamides allecto*



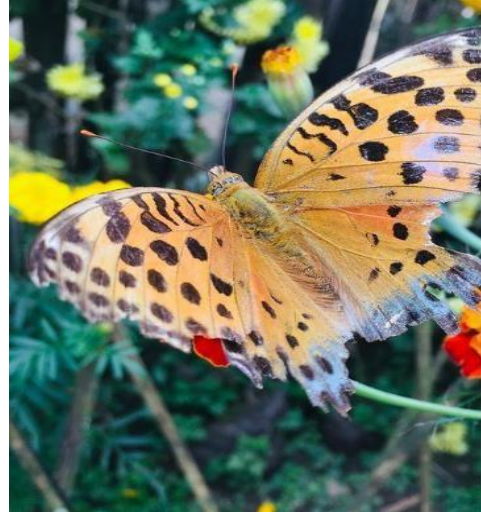
*Lampides boeticus*



*Melanitis leda*



*Lethe siderea*



*Argynnis hyperbius*



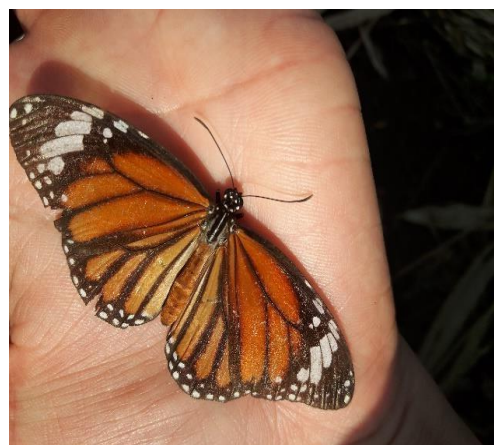
*Neptis hylas*



*Eurema hecabe*



*Pieris canidia*



*Danus genutia*