Diversity of Butterflies and their Relationship with Visiting Plant Species in the Manang Region, Central Nepal

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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 sources of information have been specifically acknowledged by reference to the authors.

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RECOMMENDATION

This is to recommend that the thesis entitled "**Diversity of Butterflies and their Relationship with Visiting Plant Species in the Manang region, Central Nepal**" has been carried out by Mr. Bimal Raj Shrestha for partial fulfillment of the requirement for Master's Degree in Zoology with the special paper of Entomology under our supervision. This is his original work and has been carried out under our supervision. To the best of my knowledge, this work has not been submitted for any other degree in any institutions.

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LETTER OF APPROVAL

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ABSTRACTS

A detailed survey of butterflies was conducted during June and August, 2014 in 15 different sites ranging altitude from 1600 m above sea level (asl) to 3600 m asl. Total of 57 species belonging to 8 families and 39 genera were recorded. The Nymphalidae and Satyridae were the predominant families of the study sites contributing 12 (20.69% of each) species where the families Hesperiidae and Acreidae were the least observed families contributing 1 (1.72 % of each) butterfly species. The butterflies that showed higher occurrences were *Pieris canidia, Aglais cashmerensis, Issoria issaea, Vanessa indica, V. caurdi, Colias fieldii, Aulocera brahaminis, Celastrina huegeli, Lampides boeticus, Albulina galathea and Polyommatus stoliczkana.* Among them *Pieris canidia* was the most dominant species recorded at all sites. Also, 17 butterfly species were recorded new addition for this region. In addition to diversity of butterflies, the altitudinal changes of butterfly species of present data were compared to historical data from 1982. Generalized Linear Model (GLM) with Poisson distribution and log link function was used to find factors affecting diversity of butterfly species. Principle Correspondence Analysis (PCA) was applied to generate the relationship between plants and butterfly species. It was found that shrubby land, open land, distance from the water bodies, slope, time of sampling and human settlement significantly affect butterfly species richness ($P<0.05$). However, there was independent of altitude ($P=0.36141$) and agricultural land ($P=0.498$). Most of the butterfly species were observed preferring the herbs, shrubs plants and few species were found at cultivated vegetation and garden. Only the species *Gonepteryx aspasia* was recorded preferring tree vegetation. The result also showed the 15 species of butterfly had altitudinal changed at least by 100 meters over the 30 years' time period. Due to the habitat loss by different developmental activities butterfly species are subjected to in great risk disappearance. Hence proper management should be brought about to save them.

Key words: Manang Region, Butterflies, Plant Species, Environmental Variables

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LIST OF ABBREVIATIONS

Abbreviated Form	Detail of Abbreviations
%	Percentage
ACA	Annapurna Conservation Area
ACAP	Annapurna Conservation Area Project
Asl	Above sea level
DHM	Department of Hydrology and Meteorology
DNPWC	Department of National Park and Wildlife Conservation
et al.	and others
GLM	Generalized Linear Model
GoN	Government of Nepal
GPS	Global Positioning System
ie	That is
M	Meters
Mm	Millimeters
^{o} C	Degree Celsius
PCA	Principle Correspondence Analysis
Prof.	Professor
SN	Serial Number
spp.	Species
UK	United Kingdom
UNEP	United Nations Environment Programme
USA	United States of America
viz.	namely

1. INTRODUCTION

1.1 Background

Insect comprises approximately half of the Earth's diversity (May 1992) and Lepidoptera is the most widespread order of insect in the world (Perveen 2012). They occupy the vital position in ecosystem (Kunte 2000, Mohagan 2011) which is extensively considered as the valuable ecological indicators (Erhardt 1985, Brown 1997, Kremen 1992). They are highly sensitive towards different environmental factors such as temperature, humidity, light level and the type of habitat (Spitzer 1997, Balmer and Erhardt 2000). Moreover, the availability of vegetation, even topography and climates are also the major influences on butterfly distributions, diversity and abundance (Khanal 1982, Saikia 2014). Also these factors are very important for reproduction and survival for butterfly (Sharp *et al.* 1974). Butterflies are sensitive insect to change the environmental conditions such as solar radiation, vegetation structure, climate change and weather events (Wood and Samways 1991, Parmesan 1996, Luoto *et al.* 2006). Like the local environmental factors, the recent global warming trends have led to the poleward or elevational shift of different species (Parmesan and Yohe 2003, Hickling *et al.* 2006) including butterflies (Parmesan *et al*. 1999, Wilson *et al.* 2007). Thus, the proper maintenance and management of environment is necessary to conserve biodiversity (Kumar *et al.* 2009).

Butterflies (Phylum; Arthropoda, Class; Insecta and Order; Lepidoptera) are diverse (Shapiro 1996), diurnal, easily recognizable (Pollard 1977, Perveen 2012), ubiquitous, taxonomically well studied (Khanal and Bhandary 1982, Ghazoul 2002, Sundufu and Dumbuya, 2008). They are considered a model organism for fragmentation studies (Rosin *et al*. 2012) and occur in all part of the world (Bonebrake *et al.* 2010). They are the most beautiful, conspicuous, colourful, have the great aesthetic (Kunte 2000, Joshi and Dhyani 2014) and greatly appreciated in ecotourism (Thomas *et al.*1992).

Butterflies are strongly associated with the plants species (Khanal and Bhandary 1982, Dennis 1992, Kerman *et al.* 1993). The diversity and distribution of plants species are the important determinants to measure the diversity of butterfly species (Ricketts 2001, Fleishman *et al.* 2005). Moreover plants are utilized as diet by both in larval and adult stages of butterfly (Kitahara 2004), oviposition behaviour and nesting (Ballabeni *et al.*

2003). There is a diverse range of diet, habitat requirements and dispersal abilities for butterflies (Lopez-Villalta 2010). Since there is a close association with different plant species and play significant role in plant pollination (Khanal and Bhandary 1982, Qureshi *et al.* 2013). Therefore butterfly species richness is high in the maximum availability of host plants (Kunte 2000) are localized to specific habitat types (Sudufu and Dumbuya 2008). The butterfly responds quickly to the habitat change (Bourn and Thomas 2002) and are highly associated with the size of habitat they preferred (Rosin *et al.*) so known to be the indicators of habitat quality (Thomas *et al.* 2004). So greater habitat size represents the greater size and higher colonization rates of butterfly (Nowicki *et al.* 2008). The diversity of butterfly is potentially sustains as an increased range of natural resources (Erhardt 1985) and has the negative correlation with the decreasing plant diversity (Illan *et al.* 2010, Stefanescu *et al.*2011).

The distribution of butterflies involves both expanding and contracting ranges (Abbas *et al.* 2002). In Nepal, the patterns of distribution of butterflies are varied (Bhusal and Khanal 2008). Their distribution ranges from sub-tropical to the Himalayan regions up to an altitude of 18000 feet (Khanal and Bhandary 1982). In context of Nepal different species of butterfly are found along different altitudes as the Palearctic butterflies are found above 3000 m above sea level (asl) while the temperate, subtropical and tropical are sequentially distributed below this altitude (Khanal *et al.* 2013b). Approximately, the world contributed 19,238 butterfly species (Happner 1998) although there are many species hide being named. Nepal hosts 660 butterfly species which belong to 11 families out of 15 families found worldwide (Smith 2011a).

There are studies related to diversity and species richness in Nepal (Shrestha and Smith 1977, Smith 1977a, 1977b, 1977c, Subba 1978, Khanal 1982, Khanal 1984, Khanal 1985, Khanal 1987, Bhusal 2001, Khanal 2001, Khanal 2008, Thapa 2008, Khanal *et al.* 2012 and Khanal *et al.* 2013). However, the detail studies of butterflies in a specific region and exploring the factors affecting the diversity and distribution is lacking in Nepal. Thus, present study focusing on diversity, distribution, range shift and also the relationship between butterflies and plants was carried out in ACAP areas of Manang, Central Nepal.

1.2 Rationale

1.2.1 Justification of study

Despite being important part of an ecosystem such studies on butterfly are scanty at global level (Fleishman *et al.* 1998) and also in the Himalayas regions of Nepal (Smith 2011c). Hence, documentation and also exploring factors influencing the distribution of butterflies is important. It is also important to highlight the relationship between butterflies and plant species and also find out the range shift of butterfly species over the period of time which is new research of butterfly species in Nepal.

1.2.2 Limitation of study

- Due to time constrains, physical difficulty, harsh climatic conditions study could not conduct systematically up to the higher altitude.
- The study was also constrained by steep and rugged terrain.

1.3 Objectives

The major objective of study was to find out the diversity and distribution of butterflies and the specific objectives were:

- To study the diversity and distribution patterns of butterflies.
- To find various environmental factors affecting diversity of butterflies in Manang regions.
- To find the relationship between different butterflies and their visiting plant species.
- To find the altitudinal differences between present and historical upper elevational limits of the species.

2. LITERATURE REVIEW

2.1 In context of world

The study of butterflies has been done systematically since the early 18th century (Happner 1998). The series of paper had been published by Wordmason and de Niceville in various issues of the Journal of Asiatic Society of Bengel for the year 1880-82 and listed 133 species of butterflies of the Andamans and Nocobar (Ferrar 1948). Furthermore, Ferrar (1948) also recorded 268 species of Butterflies from the same area.

Parsons and Cantlie (1948) listed 273 species of butterflies from Khasi and Jaintia Hills, Assam. They also described the habitat, distribution and status of the listed species. And, again in the year 1952, they added 210 more species of butterflies from the same area. Similarly Menesse (1950) studied on the butterfly diversity of Sind.

Ehrlich and Raven (1964) studied on the relationship between different families of butterfly species and their food plants and found that butterfly are the phytohagous groups of organism affecting the plant evolution.

Donahue (1967) explored the butterfly fauna of Delhi, India and reported 77 species and among them 32 species were recorded new for Delhi.

Emmel and Leck (1969) made a remarkable study on butterflies of Barro Colorado Island, Panama. They studied on seasonal fluctuation of butterfly in size and species diversity. They found considerable fluctuation in butterfly size from wet season to dry season and species diversity in the forest were comparatively less than that in the clearing fauna in both wet and dry season because of long time expose of sunlight in the clearing fauna which help the species for activity. They also made a census of 92 species of butterflies.

Spitzer *et al.* (1993) described the butterfly community in Tam Dao montane rain forest in Northern Vietnam, ecologically and biogeographically. They found the negative correlation between the size of species geographic ranges and maturity of the succession stages of its habitat preferred.

Sanchez-Rodriguez *et al.* (1995) studied on the altitudinal changes in butterfly communities in the Sierra de Javalambre of central Spain and obtained the result of less abundance of butterfly species at higher elevation then lower elevation.

Pullin (1996) studied about the status of butterflies of Britain. He found that butterflies in Britain were declined rapidly in both distribution and abundance and he found the reason was due to unsuitability of habitat.

Bonvanno *et al.* (2000) recorded 147 species of butterfly belonging 77 genera under 9 families at Ton Nga-Chang Wildlife Sanctuary, Songkhla Province, Southern Thailand. They found Nymphalidae and Lycaenidae were the most dominant families.

Kunte (2001) studied the butterfly diversity in and around the Pune city where he recorded 104 species of butterfly. Likewise in the same year Sreekumar and Balakrishna recorded 71 species of butterfly in the Aralam Wildlife Sanctuary, Kerala, India.

Yog (2002) studied the influence of abundance of plant species with the butterfly species on Upland Prairies of the Willamette Valley, Oregon and also studied the juvenile and adult food resource use and spatial patterns associated with resource use by locally uncommon butterfly species.

Konvicka *et al.* (2003) observed the 15 butterfly species shifted uphill elevation in Czech Republic with the maximum shift of 148 m by the species *Melitaea diamina*.

Wilson *et al.* (2005) found the significant uphill shift in elevation by 23 grassland butterfly species over 30 years with an average elevation of 120-200 m in the Sierra de Guadarrama mountain range, Spain.

Kitahara *et al*. (2008) examined the relationships between the diversities of vegetation, adult nectar plants, and butterflies in and around the Aokigahara primary woodland on the northwestern foot slopes of Mount Fuji, central Japan where they detected the strongest correlation between butterfly species richness and nectars plant species richness. Also they found nectars feeding butterfly species were significantly biased to herbaceous and perennials plants.

Tiple and Khurad (2009) recorded 145 species of Butterfly in and around the Nagpur city, India. They recorded 62 new species of butterfly for the Nagpur city. The highest number of butterflies was recorded belonging to the Nymphalidae (51 species) with 17 new records, followed by Lycaenidae (46 species) with 29 new records, Hesperiidae (22 species) with 14 new records, Pieridae (17 species) with 4 new records and Papilionidae (9 species).

Ramesh *et al*. (2010) studied on diversity pattern, abundance and habitat of butterfly of department of atomic energy campus, Kalpakkam, India. They recorded 55 species of butterflies under 5 families and found Nymphalidae was the dominant family whereas Hesperiidae came to least concern. They observed the maximum number of butterflies preferred the scrub jungle and garden area habitat.

Gowda, *et al.* (2011) recorded 54 species of butterfly in Lakkavalli Range of Bhadra Wildlife Sanctury, Karnatak, India.

Smetacek (2011) focused his research on Western Himalyan Neptini (Nymphalidae) in India between 1986 and 2008 and recorded a new subspecies *Neptis clinia praedicta.* Further he proposed two new combinations *N. nata yerburii* and *N. capnodes pandoces*.

Kumar (2012) studied the foraging activity and abundance of butterflies in Jhasi, India and recorded 27 species belonging 5 families.

Khan *et al.* (2011) conducted the detail survey of butterfly diversity and their different altitudinal distribution in Kashmir Himalayas. They provided the list of 68 butterflies belonging to 38 genera under 7 families with 36 new species of butterflies for this region.

Padhye, Shelke and Dahanukar (2012) recorded 58 species of butterfly in all latitudinal zones in Western Ghats, India. They also reported maximum number of species in the evergreen forest habitats with 78%.

Perveen (2012) recorded 21 species of butterflies from Kohat, Khyber Pakhtunkhwa, Pakistan. He recorded butterflies of only three families that are Nymphalidae, Papilionidae and Pieridae.

Rosin *et al.* (2012) studied on the relative effects of habitat patch, patch size, wind shelter, vegetation size, human settlement and landscape characteristics on butterflies inhabiting calcareous grasslands in southern Poland. They concluded, butterfly species richness and abundance were positively affected by patch size, wind shelter and plant species richness whereas the negative effect of human settlement.

Roy *et al.* (2012) studied the butterfly diversity in three different types of habitats that included vegetation assemblages with closed canopy cover, edges of forest and areas of human intervention and reported 30 species of butterflies. They recorded highest butterfly diversity and abundance from the edges of the forest.

Shobana *et al* (2012) did research in diversity and abundance of butterflies in Villupuram, Tamil Nadu, South India. They recorded 56 species of butterfly.

Singh (2012) studied on lowland forest butterflies of the Sankosh River catchment, Bhutan and recorded 213 species of butterflies.

Sharma and Ahamed (2013) recorded 67 species of butterflies belonging to 4 families and 41 genera from Gir Protected Area, Gujarat, India. They recorded 23 new species for the Protected Area.

Ghorai and Sengupta (2014) made a research in Altitudinal Distribution of Papilionidae Butterflies along with their Larval Food Plants in the Eastern Himalayan Landscape of the West Bengal, India. They found 26 species of Papilione Butterflies across 11 altitudinal belts and 35 species of plants belonging to 6 families serve as the larval food plants of these Butterflies.

Patel and Pandya (2014) studied the relationship of local butterflies with host plant species they preferred around the Maharaja Sayajirao University of Baroda, Sayajigaunj, Gujarat, India. They recorded 21 host plant species distributed in 13 families and maximum number of butterflies preferred plants of Asteraceae family.

Saikia (2014) studied the diversity of butterfly in Gauhati University Campus, Jaulapuri, Assam, India from 2003 to 2010. He recorded 140 species of butterfly under 5 familis. He found that the monsoon season had the maximum diversity than the pre-monsoon, winter, post- monsoon and retreating monsoon.

Sonay *et al.* (2014) investigated the relationship between species richness, composition and biotic and abiotic environment in different groups of butterflies that share ecological characteristics. They concluded that climatic variables were the main determinants of

butterfly species richness and composition for generalists, whereas habitat diversity and plant richness were also important for specialists.

2.2 In context of Nepal

Nepal is one of the hot spot in the world for butterfly watchers. In Nepal, study of butterfly was started from 1826 by well-known butterfly collector General Thomson Hardwick and then after, during 1852-67, Maj. Gen. Ramsey, a British resident while being deputed in Kathmandu, recorded 44 species of butterfly of Nepal (Khanal and Smith, 1997).

Shrestha and Smith (1977) studied on different types of variation shown by Nepal's Butterflies. They studied sexual dimorphism, regional variation, polymorphism, seasonal variation and continuous variation of butterflies of Nepal.

Smith (1977a, 1977b, 1977c) recorded the 8 new species of butterflies from Godavari, Lalitpur. Out of them he recorded 4 new species for Nepal. In the same year Smith made a remarkable research in the East Nepal and recorded 26 new species of butterflies for Nepal. And, again in the following year Smith recorded 28 spring butterflies from west Nepal of Mahakali and Seti zone. Among them, he found six species of butterflies (*Neope pulaha, Lasiomata schakra, colias erate, Lycaena pavana, L. phlaeas* and *Heliophorus sena*) were flying at lower altitudes whereas three species (*Lethe kansa, Eurchrysops pandava*, and *Gonepteryx aspasia*) were found flying at high altitude.

Smith (1978) did remarkable work in the research field of butterflies of Nepal. He published scientific list of Nepal's butterflies where he listed 565 species of butterflies.

Smith (1980) recorded 47 species of butterflies from westernmost districts Mahakali, Seti, and Karnali. This research was the continuation of the research done in 1977 by Smith in west Nepal.

Smith (1981) published a book ‘Field Guide to Nepal’s Butterflies’ where he listed the 480 species of butterflies under 200 genera and 11 families and also described their characteristics and mentioned the status of the listed butterflies in Nepal.

Khanal and Bhandary (1982) studied on the food plants preferred by the butterfly larvae and the economic important of the plants and their distribution.

Khanal (1982) recorded 97 butterfly species belonging 9 families under 61 genera from different altitudinal levels of Lamjung and Manang including Papilionidae (13 species), Pieridae (15 species), Lycaenidae (17 species), Nemeobiidae (2 species), Acraeidae (1 species), Nymphalidae (23 species), Satyridae (14 species), Danaidae (8 species) and Hesperiide (4 pecies). Again in another study Khanal (1984) recorded 20 new species of butterflies from Lamjung and Manang belonging to 5 families under 19 genera including Papilionidae (2 species), Pieridae (2 species), Lycaenidae (6 species), Satyridae (4 species) and Hesperiidae (6 species). He recorded 54 butterfly species only from the Manang during two times of his research.

Khanal (1985a, 1985b) reported a total of 52 species of butterflies under 8 families and 42 genera from Gorkha and Trisuli regions and in the same year he recorded 39 species of butterflies from Piper, Kaski. In 1987 Khanal recorded 50 species of butterflies spread over 9 families and 39 genera from Pokhara- Mukthinath trekking route.

Smith (1989) published a book “Butterflies of Nepal’’ where he mentioned 614 species of butterfly belonging to 7 families. He listed highest number of species of Lycaenidae with 173 species and only 2 species of Labytheidae.

Giri (1991) recorded 117 species of butterflies under 8 families and 68 genera from Sankhuwasabha district.

Thapa (1998) mentioned 656 butterfly species of 286 genera in his book "An Inventory List of Nepal’s insects Lepidoptera volume II" and found *Orinoma gray* (1846) and one of its sub species as endemic to Nepal.

Khanal (1999) listed 71 species of butterflies spread over 50 genera and 8 families from Kanchanpur and Kailali districts of Far western Nepal. He recorded Nymphalidae and Lycaenidae had the highest number of species diversity where Nemeobiidae had the least number with a single species. He also observed hundreds of *Catopsilia pomana* (Family: Pieridae) migrating to north-east side of Kanchanpur district.

Ghimire (2001) made a checklist of 43 species of butterflies belonging 29 genera from Champadevi, Kathmandu.

Khanal (2001) reported 114 species of butterflies under 9 famlies from Jhapa district, East Nepal. Among these butterflies he found, 27 species were rare, 11 were uncommon and remaining 76 species were common. He also focused on conservation of butterflies and other flora and fauna which was in threat by deforestation and habitat loss by the lack implementation of conservation education and awareness programme.

Subba (2005) recorded a total of 41 species of butterflies spread over 31 genera and 7 families from Gujurmukhi Village Development Committee, Illam, Eastern Nepal. He reported Nymphalidae as the dominant family and Danaidae as scarce one.

Khanal (2006) brought out the lists of late season butterflies of Koshi Tappu Wldlife Reserve, Eastern Nepal. He recorded 54 species of butterflies belonging seven families.

Bhusal and Khanal (2008) studied on the butterfly diversity at Churiya range of eastern Nepal in winter and spring season and recorded 40 species of butterflies under 28 genera and 8 families.

Khanal (2008) studied the diversity of butterfly in four districts ((Dangdeukhuri, Banke, Bardia and Surkhet) of western Terai and recorded 85 species under 64 genera and 10 families according to their altitudinal distribution. Also observed the loss of butterfly richness due to degradation of habitat by increase urbanisation in Dangdeukhuri and Banke.

Thapa (2008) recorded 43 species of butterflies from Thankot and Syuchatar VDCs, Kathmandu. Also she recorded most of butterfly species in bushes and forest habitat.

Smith (2011a, 2011b, 2011c) published three guide books namely; Butterflies of Nepal, Butterflies of ACA and Illustrated checklists of Nepal's Butterflies of butterflies. In his books he listed 278, 347 and 600 species of butterflies respectively.

Khanal *et al.* (2012) made remarkable research of butterfly in Langtang National Park within the altitudinal ranges of 1500 m to 4300 m and recorded 126 species of butterflies. They observed maximum number of species within the altitude varies from 1500 - 2900 m and also found the population declination of *Parnassius epaphus epaphus* and *Parnassius hardwickei* due to habitat loss and human interferences.

Khanal, *et al.* (2013a, 2013b) assess the population status and prevailing threats of an endangered and endemic subspecies of butterfly, *Phaedyma aspasia kathmandia* (Great Hockey Stick Sailor, Family: Nymphalidae) in Godavari forest of Lalitpur district, Central Nepal. They recorded only 11 individuals of this species. They found that the establishment of marble quarry around the butterfly habitat was the main reason of decline of the butterfly fauna from that area. In the following year they studied on the threatened butterflies of central Nepal. They recorded 18 species of butterflies under 5 families. Out of them, they found four species of butterflies namely *Teinopalpus imperialis, Papilio krishna, Meandrusa lachinus and Euripus consimilis* were at high risk, 12 species of butterflies were found endemic to central Nepal and *Diagora nicevillei*, an endangered species was also recorded. An effort had also been done to document the reason of butterfly declination and they found the main reasons were due to rapid growth of human interference, rapid loss of their habitat and host plants and establishment of marble quarry nearby.

Khanal, *et al.* (2015) reported the 34 species of Nymphalid Butterflies at different altitudinal Ranges in Godavari- Phulchowki Moutain Forest, Central Nepal. They also recorded *Phaedyma aspasia kathmandia*, an endangered and endemic Nymphalid species of Nepal. And in the same year Khanal recorded 26 Lycaenidae butterfly species within the altitude ranges 1400 – 2700 m at Shivapuri mountain forest.

3. MATERIALS AND METHOD

3.1 Study Area

Manang district is located in the Central Himalayas Nepal (Bhattarai *et al.* 2006) at 28°27′ to 28°54′ N latitudes and 83°50′ to 84°34′ E longitudes with an area of 2246 sq. km which is equal to 1.53% of the total area of the entire nation and occupies about 25% of the total area of Annapurna Conservation Area (ACA). The district is bordered to the east by Manaslu Himal, west by Damodar Himal and Muktinath Himal and the south by Annapurna Himal and Lamjung Himal while north Peri, Himlung Cheo Himal. This district is the part of trans- Himalayan zone of Nepal. The altitudes of the district vary from 1600 m (Taal) to 8156 m (Mount Manaslu) above sea level (a.s.l).

The district is mostly covered by high mountains and hills i.e. almost 83.56% of the total areas of the district and forest and shrubs cover 4.58% of the total area whereas pasture and cultivated land cover 10.92% and 0.62% respectively.

0.29% of the total area of Manang is covered by rivers and lakes. Marsyangdi River along with their tributaries Narkhola, Dhudkhola, Jharkhola drain from north to south forming longitudinal valleys. The district is divided into three ecozones (valleys): Gyasumdo valley, located at the southern region of the district, Nar- phoo valley, located at the northern region of the district whereas Nyeshang valley is located at western region of Manang.

3.2 Vegetation of the study area

Vegetation of Manang contains highly diversified floras ranging from tropical, sub-tropical and temperate in lower Manang to sub-alpine and alpine meadows in upper Manang (Khanal 1982). Tropical, Sub tropical and temperate type of vegetation are found from 1600 to 3000 m asl which occupy 4% of the total area of Manang whereas Subalpine and alpine vegetation are found from 3000 m to 5000 m asl occupying 28.5% of the total area of Manang. The dominant tropical, sub-tropical and temperate plants include *Schima wallichi, Acacia catechu, Bombax ceiba, hordeum vulgare, Phascolus munga, Daphne bholua, Rheum*

emodi, Juglen regia, Arundinaria intermedia etc and dominant Sub-alpine and alpine plant species area are *Pinus wallichi, Rhododendran* spp*., Juniperous recurve, Astragalus spp, Corydalis govamans, Potentilla fruticosa, Iris* spp. etc (Khanal 1982). Manang is highly rich in medicinal plants which exhibit 91 such plants species belonging to 40 families under 73 genera (Bhattarai *et al.* 2006). Enthnomedicinal plants species of Manang district includes *Cicerbita macrorhiza, Rosa sericea, R. macrophylla, Rumex nepalensis, Rubus foliolosus, Rhododendran lepidotum, Cynoglossum zeylanicum* etc.

3.3 Climate of the study area

In general Manang comprises temperate, cool temperate and alpine type of climate. Due to the great variation in altitude aspects and slopes with different landscape, there is the great variation in the climate. Manang receives much of its rain fall from the south- west monsoon, hence June to October are generally wettest season. On the basis of meteorological record, the average annual rainfall on the Manang is 90 mm, with the maximum rainfall recorded of 385.6 mm in the month of June, 2008 (Figure 2). The average annual maximum temperature of Manang ranges between 17.05°C to 19.08°C whereas the winter is cold and severe with the average annual minimum temperature ranges between 2.7°C to 7.25°C (DHM 2013). January is the coldest month with an average of -3.31°C (Figure 1).

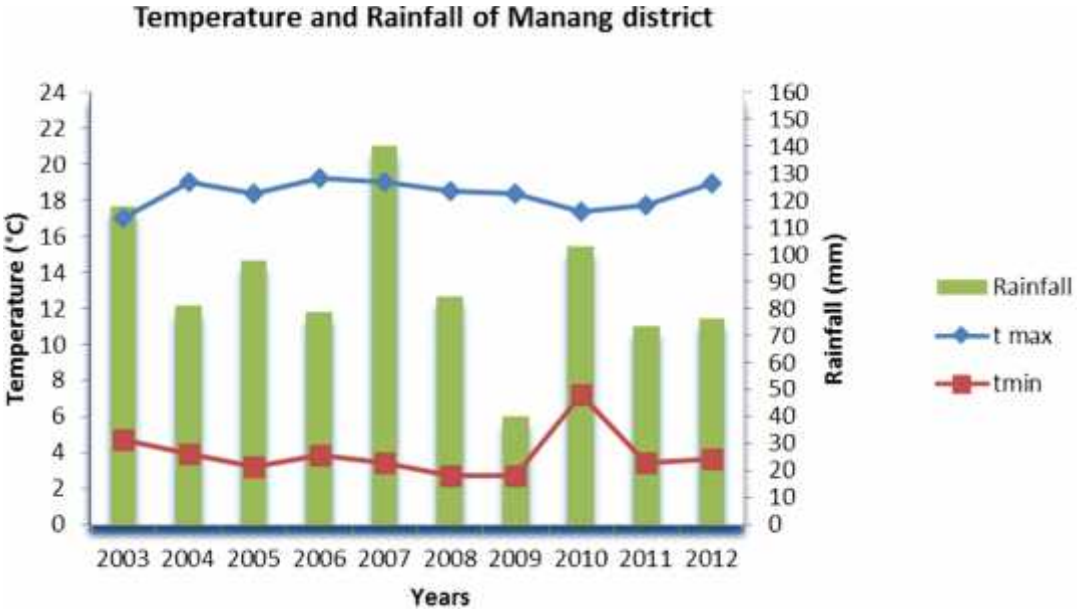

Figure 1: Average Annual Rainfall (mm) and Average Annual Temperature (° C) (Maximum and Minimum) of Chame, Manang (2002-2012).

3.4 Field survey, butterfly collection, preservation and identification

The study was conducted at 15 sampling plots of study sites from Taal (1600 m asl) to Manang Village (3600 m asl) of Manang district (Figure 1, Table 1). The study was done during June and August, 2014. Random surveys had been done to collect the data of butterfly by all out search method, when butterflies were more active. The butterfly species were collected by using the butterfly net. The butterflies were adopted capture and release method for confirmation (Khanal *et al.* 2013b) to the same species. Photographs of each captured species were taken in the field for identification and released. Further, the confused captured butterfly species were kept in the envelope and put in the box with naphthalene ball for preservation. Also recorded coordinates (latitudes and longitudes) and elevation with the help of Garmin Global Positioning System (GPS) device, slope and aspect using clinometers, host plants, presence/absence of forest, shrubs, grassland, agricultural fields, distance from water and settlement in meters and time (Time 1 as June data, Time 2 as August data). Later, photos were sorted and the species were identified using standard literature (Smith 2011a and Smith 2011c). Further, identification of species was confirmed by the well-known taxonomist, Prof. Dr. B. Khanal at Natural History Museum, Swayambhu, Kathmandu.

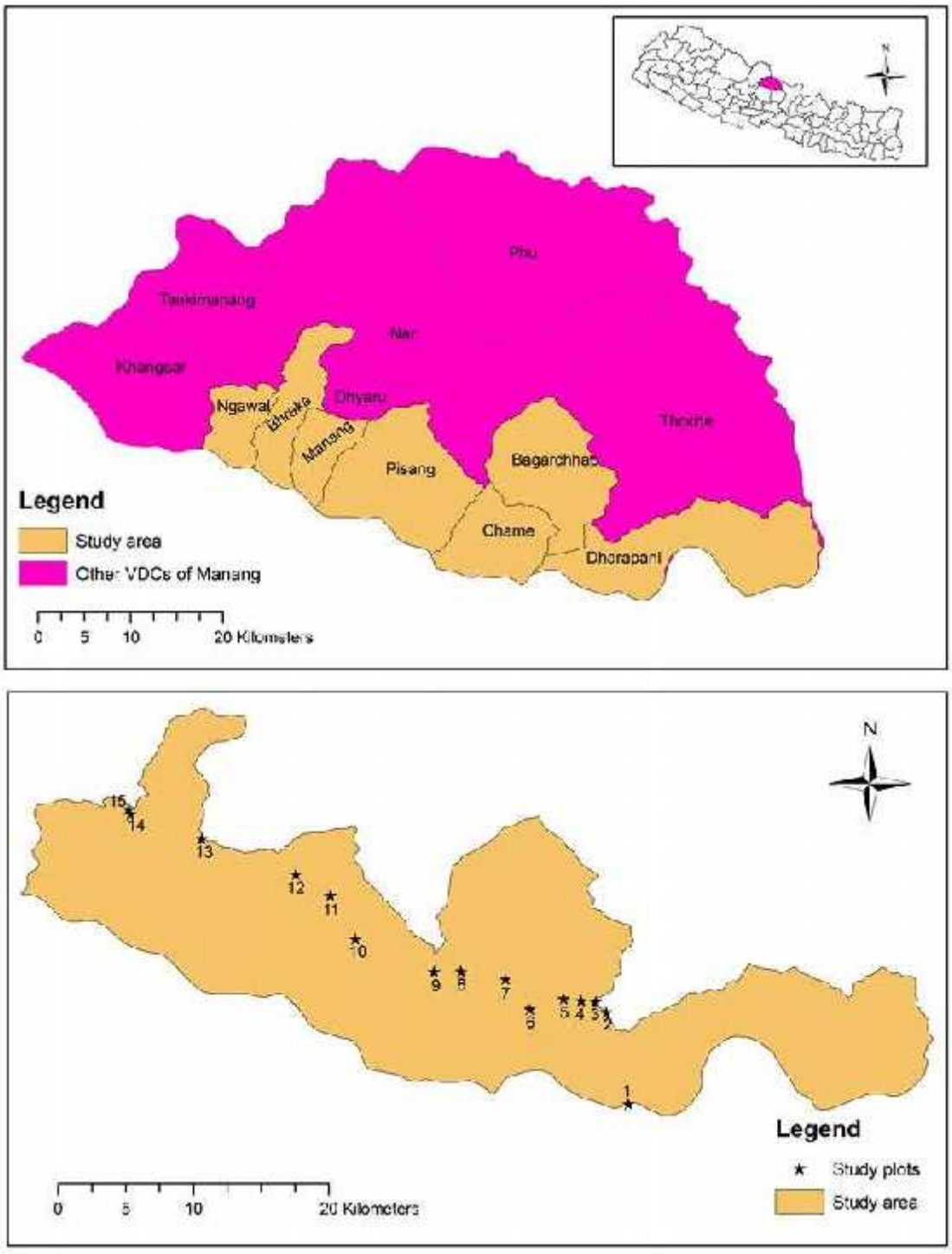

Figure 2: Map of Study Area, showing the sampling plots

Table 1: Locations of the study sites

Locations in Manang		GPS Reading		
S.N	Study sites	Latitudes (N)	Longitudes (E)	Altitudes (m)
1	Taal	28°46'19.48"	84°37’26.99"	1660
2	Dharapani	28°30'58.90"	84°21'27.42"	1860
3	Quiche	28°31'56.24"	84°20'55.06"	2000
4	Bagarchap	28°31'58.93"	84°19'39.12"	2160
5	Danakyu	28°32'04.37"	84°19'39.12"	2300
6	Timang	28°32'13.95"	84°15'05.78"	2600
7	Thanchowk	28°32'51.14"	84°17'17.96"	2700
8	Chame	28°33'03.73"	84°14'28.67"	2710
9	Talekhu	28°33'26.80"	84°13'33.15"	2780
10	Bratang	28°34'25.03"	84°11'17.12"	3000
11	Dhikurpokhari	28°35'43.23"	84°08'13.33"	3100
12	Pisang	28°36'53.78"	84°08'09.44"	3200
13	Humde	28°38'21.34"	84°05'25.27"	3300
14	Braga	28°39'16.22"	84°02'12.27"	3400
15	Manang	28°39'36.05"	84°02'19.49"	3500

3.5 Plant identification

In the field butterflies were observed while visiting different host plant species. All the plant species were identified with the help of plant ecologist Dr Maan Rokaya.

3.6 Data processing and statistical analyses

To find out the determinants (slope, aspect, presence/absence of forest, shrubs, grassland, agricultural fields, distance from water and settlement and time of sampling) of butterfly species richness, generalized linear model (GLM) with Poisson distribution and log link function was used. The analyses were carried out using S-Plus (2000). The figures were drawn using STATISTICA (Inc 2004).

The relationship between different butterfly species and plants generated by Principle Correspondence Analysis (PCA) diagram showed that the butterfly species were significantly associated with the plants in Canoco 5.01 (Ter Braak and Smilauer 2012).

Altitudinal differences between present and historical upper elevational limits were recorded to document the change of altitudinal changes by butterfly species. Altitudinal migration rate was computed as Telwala *et al.* (2013) which was originally used for plant species shift in India:

$$Es = \frac{OR - OH}{DH}$$

Where,

Es = elevational shift per decade.

OR = present uppermost elevation limit of species.

OH = historical uppermost elevation limit of species.

DH = number of decades since historical investigation (i.e., 3 decades for present study).

ES values obtained for each species was then averaged over the entire dataset to obtain mean upward species displacement rates/decade. The historic data were taken from Khanal 1982 and 1984.

4. RESULT

4.1 Diversity and Distribution

A total of 57 species of butterfly belonging to 8 families and 39 genera were recorded so far during the study period at 15 study sites. Family Satyridae and Nymphaliddae contributed maximum number of butterfly (12 of each) followed by Lycaenidae (11), Papilionidae (9), Pieridae (7), Danaidae (4) and a single species from the family Acreidae and Heseriidae. In family wise distribution of all butterfly species of families Nymphalidae, Lycaenidae, Papilionidae, Satyridae and Pieridae were recorded distributed throughout the sites whereas the families Danidae, Aceridae and Hesperiidae were seen at the less sites of the study area (Figure 3, Appendix III). Among the total, 17 butterfly species were found new addition for the Manang (Appendix IV) and 1 butterfly species (*Crebeta lahmani*) was found endemic to Nepal.

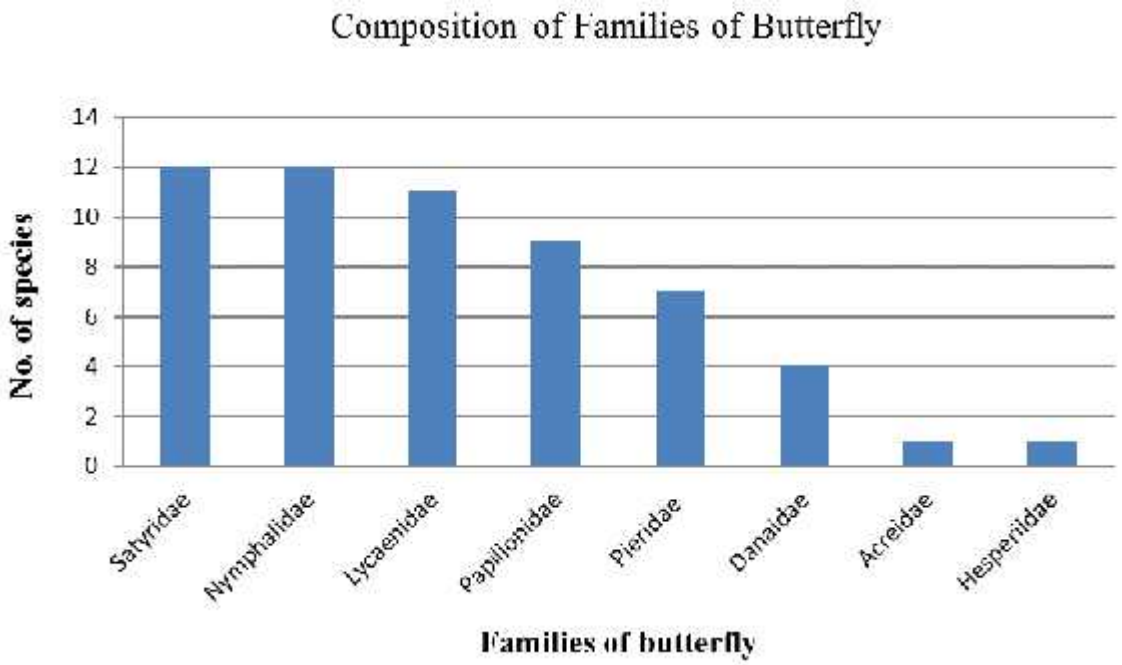

Figure 3: Family wise distribution of butterfly species recorded in the study sites.

4.2 The Effect of different environmental factors on species richness of butterfly

Out of many environmental variables, shrub land, open land, distance from the water bodies, slope and time significantly affected the species richness in Manang ($P<0.05$) (Table 3). The butterfly species richness significantly increases near the shrub land, open land, with increasing the distance from the water, during second field sampling and decrease with increasing slope ($P<0.05$) (Table 3). The relationship between species richness and altitude was not significant ($P= 0.36141$), nor with the agricultural land ($P= 0.498$). There was insignificant increase of species richness with increase the distance from the human settlement ($P= 0.062305$).

Table 3: Showing the effect of different environmental factors on butterfly species richness.

Environmental variables	**DF**	**Deviance**	**Resid, DF**	**Resid DV**	**P**	**R^2**
Altitude	1	0.83299	30	74.98917	0.36141	-
Forest	1	0.45844	29	74.53073	0.4983538	-
Shrub	1	25.80667	28	48.72406	0.0000004	0.340358
Open land	1	4.72425	27	43.9998	0.0297401	0.062307
Agricultural land	1	0.54293	26	43.45687	0.4612201	-
Distance from settlement	1	3.47494	25	39.98193	0.062305	0.04583
Distance to water	1	5.72035	24	34.26158	0.0167694	0.075444
Slope	8	24.62671	16	9.63487	0.0017978	0.324796
Time	1	6.13366	15	3.50121	0.0132632	0.080895

4.4 Relationship between different Butterfly Species and their visiting plants

A total of 55 species of plant belonging 39 genera and 21 families were recorded to be associated with butterfly species (Appendix I).

The PCA diagram displayed the butterfly species such as *Pieris canidia* and *Vanessa cardui* showed the highly visited toward the plant species like *Rosa serice, Berberis angulosa, Aster himalalica, Thalictrum cultratum, Rumex nepalensis, Thymus linearis, Morina polyphylla* and *Sarccoea hookeriana* whereas the butterfly species like *Issoria issaea, Ypthima parasakra, Vanessa indica, Colias fieldii,* and *Polymmatus stocliczkanus* were frequently observed visiting toward the plant species *viz. Urtica dioica, Salvia nubicula, Arisaema concinnum, Swertia chiriyata, Geranium donianum, Rumex nepalensis, Thymus linearis,* and *Aster himalalica*. Butterfly species *Papilio polytes, Aglais cashmerensis, Atrophaneura polyeuctes, Callereba scandal, Celatrina lavendularis, Raphicera satricus, Danaus genuita, Argyreus hyperbius, Gonepteryx aspasi, Atrophaneura lattivata, Lampides boeticus, Heliophorus tamu, Acraea ossoria* were mostly preferring similar type of plant species such as *Innolu cappa, Fagopyrum dibotrys, Fagopyrum esculentum, Cynoglossum zylenicum, Persicaria nepalensis* and *Geranium pretense* (Figure 4).

Relationship between Butterfly Species and their Visiting Plant Species

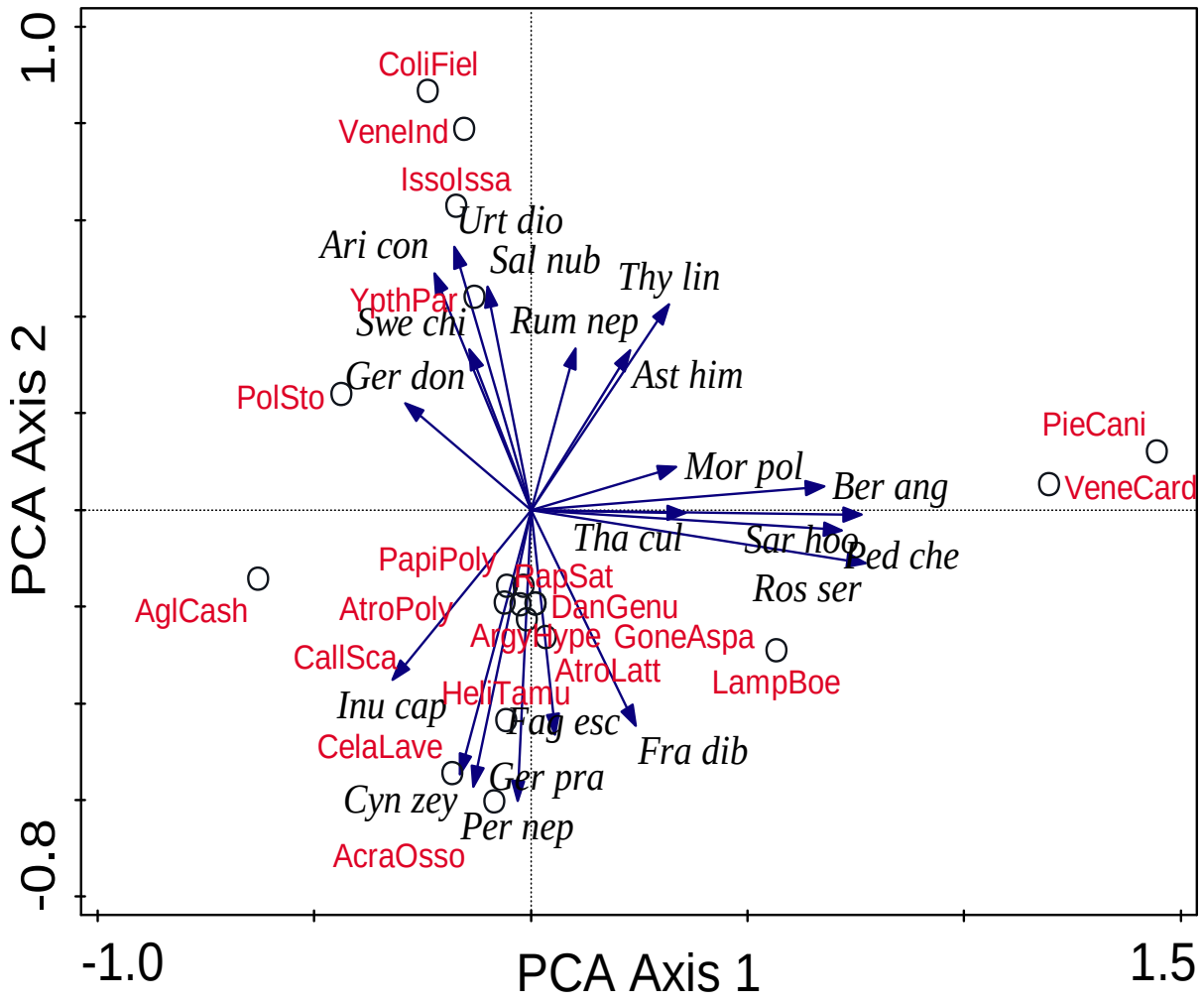

Figure 4: Principle Components Analysis (PCA) ordination diagrams, showing the relationship between butterfly species (open circles) and their visiting plants species (thin arrow), explained by the two canonical axes (Axis 1= 0.092% and Axis 2= 0.023%) and counted as the 0.115%. For the detail of abbreviated species of plants see Appendix I and butterfly Appendix III.

4.5 Altitudinal differences between present and historical upper elevational limits of the species

In comparison between the historic data (Khanal 1982, Khanal 1984) and the recent data (2014), the results showed that 15 species of butterflies displayed the different rate of altitudinal changes over 30 years period. The species Glassy Blue Bottle (*Graphium cloanthus*) showed the highest elevational changes in comparison to their historical position (i.e. 741 m per decade) whereas the minimum elevational change of 100 m per decade was observed in the species Eastern Blue Sapphire (*Helioporus oda*) (Figure 5, Appendix II).

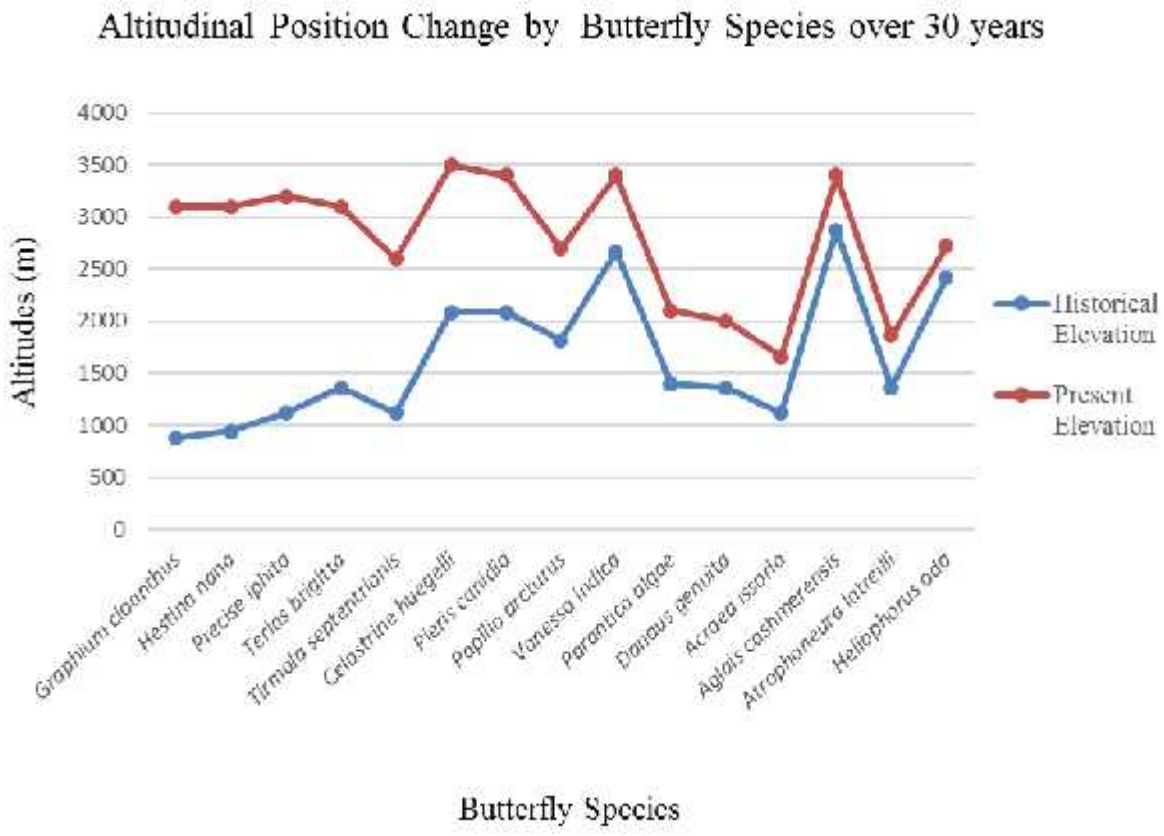

Figure 5: Altitudinal comparison of historical data with present recoded sampling data.

5. DISCUSSION

5.1 Diversity and Distribution

A total of 57 species of butterflies were recorded. In this study, species of Satyridae and Nymphalidae contributed the highest species number (20.69% of each) whereas the Hesperiidae and Acridae had the least species number (1.72% of each). Thapa (2008) had also obtained the similar result that Nymphalidae and Acreidae contributed the highest and least species number respectively at Thankot and Syuchatar, Kathmandu. In compilation with secondary information on the diversity of butterfly species by Khanal (1982 and 1984) recorded the 54 butterfly species with Nymphalidae and Satyridae were the dominant families in the same region where Bhusal and Khanal (2008) observed Nymphalidae as highest family and Hesperiidae as least in the Eastern Siwalik of Nepal. Out of 57 species recorded, the 39 species have been already reported (Khanal 1982, Khanal 1984, Smith 2011b) where 17 butterfly species were the new additional species of the study sites. The butterfly diversity increase with of high regional habitat heterogeneity, climate energy, altitudinal shift (Kerr 2001, Wilson *et al.* 2007*)* and availability of nectars plants (Shields *et al.* 1969, York 2002, Kitahara *et al.* 2004). However, 65 species of butterflies which were recorded earlier couldn't be found during the study period. This might be the intensive sampled of butterfly species above 3600 m by previous research (Khanal 1982, 1984 and Smith 2011b) and time of sampling. So far as distribution pattern of butterfly from the present location is concerned the species like *Pieris canidia* was recorded in every study sites. On other hand, species like *Aglais cashmerensis, Issoria issaea, Vanessa indica, V. caurdi, Colias fieldii, Aulocera brahaminis, Celastrina huegeli, Lampides boeticus, Albulina galathea* and *Polyommatus stoliczkana* were the dominated butterfly species seen in most of the study sites and found at maximum number. Other species like *Gonepteryx rhamni. G. aspsia, Terias brigitta, Colias electo, Childena children, Hestina nama, Apatura ambica, Aglais ladakensis, Precis ihita, Kuekuenthaliella mackinnoni, Argyreus hyperbius, Crebeta lehmanni, Ypthima parasakra, Callerebia scandal, Dallacha hyagriva, Raphicera satricus, Zophoessa nicetas, Z. maityra, Prannasius epaphus, P. acdestis, Papilio machaon, P. arcturus, P. paris, P. polytes, Grapium cloanthus, Atrophaneura polyeuctes, A. latreillei, Helioporus tamu, H. oda, Oreolyce vardhana, Celastrina lavendularis, Polymmatus astrarche, Tirmala septentrionis, Parantica tytia, Danaus genuita, Acraea issoria, Lethe*

baladeve and *Coladenia agnioides* were observed very rarely and found in minimum number (Appendix III). Khanal (1982 and 1984) and Smith (2011b) also obtained similar results from the same region only the few exception the new recorded of butterfly contradict their result.

The rarely occurrence of these butterfly species in the study sites provide useful information on biodiversity conservation. During the study period the butterfly species like *Kuekuenthaliella mackinnoni, Argyreus hyperbius, Crebeta lehmanni, Aglais ladakensis, Albulina orbitulus, Heliophorus tamu, Oreolyce vardhana, Athyma opalina, Childrena childreni, Hestina nana, Apatura ambica, Atrophaneura latreillei, A. polyeuctes, Papilio machaon, P. paris, P. arcturus, Gonepteryx aspasia, G. rhamni, Callerebia scandal, Dallacha hygriva, Lethe baladeva, L. serbonis, Raphicera satricus, Ypthima newara* and *Zophoessa maitrya* were observed only with single individual number. Increment of human settlement, loss of habitat, habitat sizes and host plants by developmental activities, grazing pressure, influx of tourists and transportation disturbance has great risk for these species of this area. The previous studies Thapa (2008), Khanal *et al.* (2013a, 2013b), Khanal *et al.* (2015) found the similar external challenges to threat the butterfly species of different parts of Nepal. Khanal (2008) also observed the loss of butterfly diversity due to increment of human settlement in Dangdeukhuri, and Banke of western Nepal.

5.2 The Effect of different environmental factors on species richness of butterfly

Total butterfly species richness correlated positively with shrub, open land, Distance to water bodies, slope, distance from the settlement and time of sampling whereas the negative correlation with the altitude, forest area and agricultural land. It was observed that most of the butterfly species preferred open/ grassland, shrub land and very few butterflies (e.g. *Pieris canidia* and *Aglais cashmerensis*) preferred agricultural land and the species like *Terias brigitta* and *Ypthima parasakra* preferred forest area. The results of this study had similarity with the finding of Thapa (2008), Rosin *et al.* (2012), Acharya and Vijayan (2015), Serrat *et al.* (2015), where there finding also revealed most of the butterfly species were significantly associated in such habitat but Mihoci *et al.* (2011) contradict the result and showed the species richness was maximum in the agricultural land rather than other habitat where Khanal *et al.* (2012), Roy *et al*. (2012) observed these

most of the species on forest areas at Langtang National Park, Nepal and Neora Valley National Park, West Bengal, India. Another component of environment – altitude has no significant effect in the species richness. This may interpreted as a result of similar habitat sizes within the different altitudinal sites and altitudinal ranges of study were not varied. It was the similar result obtained by Guiterrez and Memendez (1995) whereas Sanchez-Rodriguez *et al.* (1995) obtained significant negative relationship and Khan *et al.* (2011) deny the result showing the significant correlation between butterfly species and altitudes. Human activities are the reason of environmental destruction (Wenzel *et al.* 2006, Niell 2007) hence species richness, abundance and diversity of the butterfly are negatively related to the human settlement (Kitahara 2004, Stefanescu *et al.* 2004, Rosin *et al.* 2012). Like Blair and Launer (1997), Kitahara (2004), Stefanescu *et al.* (2004), Rosin *et al.* (2012) found to be appeared most of the butterfly species decreases with the increase in human settlement and few near it; which coincided the result obtained and a few individual species (e.g *Aglais cashmerensis, Pieris canidia,* and *Vanessa cardui)* had higher occupancy near the human settlement. The species found near the human settlement probably the possessing of the flower- rich gardens. Thus, nectars of flower might be the nutritive source of food for butterflies (Dunning *et al.* 1992, Ouin *et al.* 2004). Results from other studies (Kitahara and Fujii 1994, Clark *et al.* 2007, Sundufu and Dumbuya 2008) showed a significant negative effect of human activity on butterfly populations while Collinge *et al.* (2003) did not find an effect, which was as the result obtained in the research.

5.4 Relationship between different Butterfly Species and their visiting plants

Vegetation has the effective role in distribution of butterfly (Ehrlich and Gilbert 1973, Khanal and Bhandary 1982, Hardy and Dennis 1999). The present study also determined the high presence of butterfly species toward the diversified plant area. Such results had been observed by several previous researchers (Kitahara 2000, Tiple *et al.* 2006, Kitahara *et al.* 2008). The preference of different butterfly species maximally visited towards herbs rather than shrubs or cultivated plants and tree plants was observed in the study sites. The present findings are consistent with the previous studies done by Khanal and Bhandary (1982) in various regions of Nepal, Qureshi *et al.* (2013) at Kashmir, Kitahara *et al.* (2008) at Aokigahara Primary Woodland of Mount Fuji, Central Nepal; however, studies in Langtang National Park by Khanal *et al.* (2012) reverse the obtained result where

recorded most of these species in the forest area. These results suggest that herbaceous plant species richness in a habitat were the important factor governing and supporting its adult butterfly species richness.

5.5 Altitudinal differences between present and historical upper elevational limits of the species

In recent study, the altitudinal changes of butterfly species in Manang with the species recorded in the same region by Khanal (1982 and 1984) over the last 30 years were documented. Comparison of the 1982 and 1984 recorded species with the randomly sampled 2014 data, 15 species showed changes their historical position and were non uniform across the elevation. Seven out of 15 species of butterfly displayed the highest altitudinal change with an average of 400-750 m per decade and other eight butterflies showed lower with ann average increases of 100-400 m per decade (Appndix II). Konvicka *et al.* (2003) also recorded the 15 butterfly species change their position in Czech Republic, Wilson *et al.* (2005) had the result of changing the position by 23 grassland species along altitudinal gradient and Wilson *et al.* (2007) also revealed the significant uphill shift of butterfly species at Sierra de Guadarrama, Spain, which was the similar result of this study.

The result clearly showed the more declination of species at low elevations which are possibly the effect of climate change (Parmesan *et al.* 1999, Wilson *et al.* 2005, Wilson *et al.* 2007), habitat degradation (Sala *et al.* 2000, Warren *et al.* 2001, Van Swaay *et al.* 2006), increment of human settlement (Wenzel *et al.* 2006, Rosin *et al.* 2012), availability of moisture at high elevations (Wilson *et al.* 2005) and developmental work like transportation, hydro-electrical project etc. Also, the habitat sizes are comparatively smaller at lower regions than at the higher regions of the study sites. Hence, it might be the cause of the change of position by butterfly species.

6. CONCLUSION AND RCOMMENDATION

From the present study, the following conclusions were derived:

- The butterfly of the families Nymphalidae and Satyridae were the most abundant species observed during the study and the families Hesperiidae and Acreidae contributed least number of species. Also 17 species of butterfly were recorded new additional species for this region.
- The abundance and diversity of butterfly species were significantly correlated with both the physical (i.e. Slope, Time of sampling and Distance to water) as well as biological (i.e. Open/shrub land) factors.
- Plant species richness affects the richness and diversity of specialist butterflies. Most of the butterfly species were observed preferring herbaceous rather than the shrub and trees.
- Altitudinal shifts in the distribution of butterflies did not show any consistent patterns. Habitat loss in lowlands by different developmental activities, insufficient sunlight available and increment of human settlement were responsible for the change of position of individual species over 30 years.

Based upon the study, I have recommendations for further studies and they are as follows;

- Although there is high diversity of butterfly species in the study area, in depth research should be designed to cover more seasons within a year and in between year. Moreover, continuous monitoring of the butterfly fauna is necessary so that any changes in the environment which may occur in future can be identified and unappropriated measures can be taken to counter them.
- Though 58 species of butterfly were identified, concerning bodies Department of National Parks and Wildlife Conservation, (DNPWC) and Annapurna Conservation Area Project (ACAP) responsible for issuing permit should see the importance of field studies and should readily issue permits especially for trapping or collection of study material as always there may remain a risk of having quite a large numbers of butterflies left behind and never would be discovered.
- Being a tourist hub, it was observed that the people of Manang built restaurants and hotels for earning concept by destroying the habitat, habitat sizes and even the host plants of butterfly species which may lead to the extinction of local butterflies. Hence that should be controlled and managed.
- During field time I found the local people were unknown about biodiversity and their conservation. Hence conducting awareness programme at local level might

be a very good option for the conservation of the species in human dominated landscape.

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Appendices

Appendix I: Plants Preferred by Butterflies in Manang.

S.N.	Scientific Names	Abbreviations	Family
1	*Anemone rupicola* Cambess.	Ane rup	Ranunculaceae
2	*Anemone obtusiloba* D. Don	Ane obt	Ranunculaceae
3	*Arisaema concinnum* Schott	Ari con	Araceae
4	*Berberis aristata* DC.	Ber ari	Berberidaceae
5	*Artemisia indica* Willd.	Art ind	Asteraceae
6	*Aster himalaicus* C. B. Clarke	Ast him	Asteraceae
7	*Aster molliusculus* (Lindl. ex DC.) C.B.Clarke	Ast moll	Asteraceae
8	*Berberis angulosa* Wall. ex Hook. f. & Thomson	Ber ang	Berberidaceae
9	*Caltha palustris* L.	Cal pal	Ranunculaceae
10	*Cynoglossum amabile* Stapf & Drumm.	Cyn ama	Boraginaceae
11	*Erysimum melicentae* Dunn	Ery meli	Brassicaceae
12	*Fragaria nubicola* Lindl. ex Lacaita	Fra nub	Rosaceae
13	*Galium aparine* L.	Gal asp	Rubiaceae
14	*Gentiana capitata* Buch.-Ham. ex D. Don	Gen cap	Gentianaceae
15	*Gentiana pedicellata* (D. Don) Griseb.	Gen ped	Gentianaceae
16	*Geranium donianum* Sweet	Ger don	Geraniaceae
17	*Cynoglossum zeylanicum* (Vahl ex Hornem.) Thunb. ex Lehm.	Cyn zey	Boraginaceae
18	*Inula cappa* (Buch.-Ham. ex D. Don) DC.	Inu cap	Asteraceae
19	*Nepeta erecta* (Royle ex Benth.) Benth.	Nep ere	Lamiaceae
20	*Ligularia amplexicaulis* DC.	Lig amp	Asteraceae
21	*Morina polyphylla* Wall. ex DC.	Mor pol	Dipsacaceae
22	*Medicago falcata* L.	Med fal	Fabaceae
23	*Nepeta leucophylla* Benth.	Nep leu	Lamiaceae
24	*Pedicularis cheilanthifolia* Schrenk	Ped che	Scrophulariaceae
25	*Pedicularis scullyana* Prain ex Maxim.	Ped scu	Scrophulariaceae
26	*Plantago erosa* Wall.	Pla ero	Plantaginaceae

27	*Rosa sericea* Lindl.	Ros ser	Rosaceae
28	*Rumex nepalensis* Spreng.	Rum nep	Polygonaceae
29	*Salvia nubicola* Wall. ex Sweet	Sal nub	Lamiaceae
30	*Sarcococca hookeriana* Baill.	Sar hoo	Buxaceae
31	*Stellaria media* (L.) Vill.	Ste med	Caryophyllaceae
32	*Swertia chirayita* (Roxb. ex Fleming) Karsten	Swe chi	Gentianaceae
33	*Taraxacum eriopodum* DC.	Tar eri	Asteraceae
34	*Thymus linearis* Benth.	Thy lin	Lamiaceae
35	*Trifolium pratense* L.	Tri pra	Fabaceae
36	*Urtica dioica* L.	Urt dio	Urticaceae
37	*Verbascum thapsus* L.	Ver tha	Scrophulariaceae
38	*Thalictrum cultratum* Wall.	Tha cul	Ranunculaceae
39	*Anaphalis triplinervis* (Sims) C. B. Clarke	Ana tri	Asteraceae
40	*Dipsacus inermis* Wall.	Dip ine	Dipsacaceae
41	*Fragaria daltoniana* J. Gay	Fra dal	Rosaceae
42	*Phaseolus vulgaris* L.	Pha vul	Fabaceae
43	*Origanum vulgare* L.	Ori vul	Lamiaceae
44	*Prinsepia utilis* Royle	Pri uti	Rosaceae
45	*Persicaria nepalensis* (Meisn.) H. Gross	Per nep	Polygonaceae
46	*Geranium pratense* L.	Ger pra	Geraniaceae
47	*Fagopyrum dibotrys* (D. Don) H. Hara	Fra dib	Polygonaceae
48	*Swertia angustifolia* Buch.-Ham. ex D. Don	Swe ang	Gentianaceae
49	*Pedicularis pyramidata* Royle ex Benth.	Ped pyr	Scrophulariaceae
50	*Fagopyrum esculentum* Moench	Fag esc	Polygonaceae
51	*Strobilanthes lachenensis* C. B. Clarke	Str lac	Acanthaceae
52	*Chenopodium album* L.	Che alb	Chenopodiaceae
53	*Brassica oleracea* var. capitata L.	Bra ole	Brassicaceae
54	*Anemone vitifolia* Buch.-Ham. ex DC.	Ane vit	Ranunculaceae
55	*Arisaema tortuosum* (Wall.) Schott	Ari tor	Araceae

Appendix II: Altitudinal differences between present and historical upper elevational limits of the species.

SN	Scientific Name	Historic Record (m)	Present Record (m)	Range Shift Per Decade (m)
1	*Graphium cloanthus*	878	3100	741
2	*Hestin nana*	940	3100	720
3	*Precise iphita*	1121	3200	693
4	*Terias brigitta*	1363	3100	579
5	*Tirmala septentrionis*	1121	2600	493
6	*Celastrine huegelii*	2090	3500	470
7	*Pieris canidia*	2090	3400	437
8	*Papilio arcturus*	1818	2700	294
9	*Vanessa indica*	2666	3400	245
10	*Parantica algae*	1400	2100	233
11	*Danus genuita*	1363	2000	212
12	*Acraea issoria*	1121	1660	179
13	*Aglais cashmerensis*	2878	3400	174
14	*Atrophaneura latreilli*	1363	1860	166
15	*Heliophorus oda*	2418	2720	100

Appendix III: Butterflies recorded in Manang

SN	Scientific Name	Common Name	Abbreviation	Families	Frequency	Locality (Sites)
1	*Acraea issoria* Hubner 1819	Yellow Coaster	Aca-isso	Acreidae	2	1
2	*Danaus genutia* Cramer 1779	Common Tiger	Dan genu	Danidae	3	1,2,3
3	*Parantica aglea* Moore 1883	Glassy Tiger	Par agle	Danidae	3	1,2,3
4	*Parantica tytia* Gray 1833	Chestnut Tiger	Para tyt	Danidae	2	2,3
5	*Tirumala septentrionis* Butler 1874	Dark Blue Tiger	Tir sep	Danidae	2	5,6
6	*Coladenia agnioides* Elwes and Edwards 1897	Elwes' Pied Flat	Cla agn	Hesperidae	1	2
7	*Albulina galathea* Branchard 1844	Large Green Underwing	Albu gala	Lycaenidae	18	11,12,13,14
8	*Albulina lehana* Moore 1878	Common Mountain Blue	Alb leh	Lycaenidae	3	11,13,14
9	*Albulina orbitulus* Forster 1961	Greenish Mountain Blue	Albu orb	Lycaenidae	1	11
10	*Polyommatus astrarche* Bergstrasser 1779	Orange-Bordered Argus	Ari astr	Lycaenidae	3	12,13,14
11	*Celastrina huegeli* Evans 1925	Large Hedge Blue	Cel hue	Lycaenidae	22	1,2,3,13,14,15
12	*Celastrina lavendularis limbata* Moore 1879	Plain Hedge Blue	Cela lave	Lycaenidae	4	2,3,6
13	*Heliophorus oda* Hewitson 1865	Eastern Blue Sapphire	Heli oda	Lycaenidae	2	8
14	*Heliophorus tamu* Kollar 1848	Powdery Green Sapphire	Heli tamu	Lycaenidae	1	1
15	*Lampides boeticus* Linnaeus	Pea blue	Lamp boe	Lycaenidae	14	7,10,12,13,14

	1767					
16	*Oreolyce vardhana nepalica* Forster 1980	Dusky Hedge Blue	Ore var	Lycaenidae	1	5
17	*Polyommatus stoliczkanus* Felder 1865	Common Meadow Blue	Pol sto	Lycaenidae	18	12,13,14
18	*Aglais cashmerensis* Kollar 1844	Indian Tortoiseshell	Agl cash	Nymphalidae	11	1,5,6,7,11.13,14
19	*Aglasis ladakensis* Moore 1878	Ladakh Tortoiseshell	agla lada	Nymphalidae	3	6,7,12
20	*Argyreus hyperbius* Linnaeus 1763	Indian Fritillary	Argy hype	Nymphalidae	1	1
21	*Athyma opalina* Kollar 1844	Himalayan Sergent	Athy opa	Nymphalidae	1	4
22	*Childrena childreni* Gray 1831	Large Silverstrip	Chil chi	Nymphalidae	1	9
23	*Hestina nama* Doubleday 1845	Circe	Hes nan	Nymphalidae	1	11
24	*Issoria issaea* Doubleday 1846	Queen of Spain Fritillary	Isso issa	Nymphalidae	20	1,6,7,10,11
25	*Kuekuenthaliella mackinnoni* de Niceville 1891	Mackinnon's Silverspot	Kue mac	Nymphalidae	1	13
26	*Precis iphita* Cramer 1779	Chocolate Pansy	Pre iph	Nymphalidae	2	1,12
27	*Vanessa cardui* Linnaeus 1758	Painted lady	Vane card	Nymphalidae	7	1,7,11,13,14
28	*Vanessa indica* Herbst 1794	Indian Red Admiral	Vane ind	Nymphalidae	12	2,3,5,6,7,10,11,12,14
29	*Apatura ambica* Kollar 1844	Indian Purple Emperror	Aap ambi	Nymphalidae	1	2
30	*Atrophaneura latreillei* Donavan 1806	Rose Windmill	Atro latt	Papilionidae	1	2

31	*Atrophaneura polyeuctes letincius* Fruhstorfer 1908	Common Windmill	Atro poly	Papilionidae	1	3
32	*Graphium cloanthus* Cramer 1775	Glassy Blue Bottle	Grap cloa	Papilionidae	3	1,2,11
33	*Papilio arcturus* Weatwood 1842	Blue Peacock	Papi arc	Papilionidae	1	7
34	*Papilio machaon* Wyatt 1959	Common Yellow Swallowtail	Papi mac	Papilionidae	1	6
35	*Papilio paris* Fruhstorfer 1909	Paris Peacock	Papi pari	Papilionidae	1	1
36	*Papilio polytes* Linnaeus 1758	Common Mormon	Papi poly	Papilionidae	2	1,2
37	*Parnassius acdestis* Grm. Grsh 1891	Banded Apollo	Par acd	Papilionidae	2	10, 11
38	*Parnassius epaphus* Oberthur 1879	Common Red Apollo	Par epap	Papilionidae	2	11,12
39	*Colias stoliczkana* Epstein 1979	Orange Clouded Yellow	col stoli	Pieridae	2	6
40	*Colias erate* Esper 1805	Pale Clouded Yellow	Coli era	Pieridae	2	11,12
41	*Colias electo fieldii* Menetries 1855	Himalayan Dark clouded Yellow	Coli fiel	Pieridae	15	1,6,10,11,13,14
42	*Gonepteryx aspasia* Menetries 1859	Lesser Brimstone	Gone aspa	Pieridae	1	2
43	*Gonepteryx rhamni* Linnaeus 1758	Common Brimstone	Gon rhi	Pieridae	2	2,7
44	*Pieris canidia* Evans 1926	Indian Cabbage White	Pie cani	Pieridae	30	All 15 sites
45	*Terias brigitta* Cramer 1780	Small Grass Yellow	Teri bri	Pieridae	2	7,11

46	*Aulocera brahminus* Evans 1923	Narrow- Banded Satyre	Aulo bra	Satyridae	13	2,3,4,5,6,7,8,9,10,11,12
47	*Callerebia scanda* Watkins 1927	Pallid Argus	Call sca	Satyridae	1	1
48	*Crebeta lehmanni* Forster 1980	Nepal Wall	Cre lah	Satyridae	1	10
49	*Dallacha hyagriva* Moore 1857	Brown Argus	Dal hyg	Satyridae	1	11
50	*Lethe baladeva* Moore 1865	Treble Silverstripe	Leth bala	Satyridae	1	8
51	*Lethe serbonis* Talbot 1947	Brown Forester	Let ser	Satyridae	1	2
52	*Raphicera satricus* Doubleday 1849	Large Twany Wall	Rap sat	Satyridae	1	2
53	*Rhaphicera moorei* Butler 1867	Small Tawny Wall	Rhap moo	Satyridae	3	7,8,9
54	*Ypthima newara* Moore 1874	Newari Three Ring	Ypth new	Satyridae	1	2
55	*Ypthima parasakra* Eliot 1987	Himalayan Four Ring	Ypth par	Satyridae	9	6,7,8,9,10,11
56	*Zophoessa maitrya* de Niceville 1880	Barred Woodbrown	Zop mai	Satyridae	1	7
57	*Zophoessa nicetas* Hewitson 1863	Yellow Woodbrown	Zoph nic	Satyridae	2	7,9

Appendix IV: New Additional Butterfly Species of Study Sites

SN	Scientific name	Common name	Families	Study sites (Plots no.)
1	*Acraea issoria*	Yellow Coaster	Acraeidae	1
2	*Coladenia agnioides*	Elwes Pied Flat	Hesperidae	2
3	*Dallacha hyagriva*	Brown Argus	Satyridae	11
4	*Ypthima newara*	Newari Three Ring	Satyridae	2
5	*Apatura ambica*	Indian Purple Emperror	Nymphalidae	2
6	*Oreolyce vardhana*	Dusky Hedge Blue	Lycaenidae	5
7	*Albulina galathea*	Large Green Underwing	Lycaenidae	11,12,13,14
8	*Polyommatus astrarche*	Orange-Bordered Argus	Lycaenidae	12,13,14
9	*Celastrina lavendularis*	Plain Hedge Blue	Lycaenidae	2,3,6
10	*Heliophorus tamu*	Powdery Green Sapphire	Lycaenidae	1
12	*Papilio paris*	Paris peacock	Papilionidae	1
13	*Graphium cloanthus*	Glassy blue bottle	Papilionidae	1,2,11
14	*Papilio polytes*	Common Mormon	Papilionidae	1,2
15	*Colias erate*	Pale Clouded Yellow	Pieridae	6
16	*Tirmala septentrionis*	Dark Blue Tiger	Danaidae	5,6
17	*Danaus genuita*	Common Tiger	Danaidae	1,2,3

Appendix V: Some photos of recorded butterfly species

Aglais cashmerensis

Apatura ambica

Childrena childreni

Hestina nana

Argynnis hyperbius

Vanessa indica

Colias fieldii

Gonepteryx aspasia

Gonepteryx rhamni

Pieris canidia

Terias brigitta

Crebeta lahmani

Ypthima parasakra

Ypthima newari

Raphicera moorei

Callerebia scanda

Aulocera brahminus

Danaus genuita

Tirmala septentrionis

Acraea issoria

Polyommatus stoliczkana

Heliophorus oda

Papilio paris

Papilio machaon