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FINAL PROJECT REPORT

An Assessment of Entomofauna for Management and Conservation of Biodiversity in Gangotri Landscape

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Final Project Report

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Summary

Introduction

An inventory of biodiversity is of primary importance as part of biodiversity conservation for sustainable development, particularly in threatened and fragmented landscapes like Western Himalaya that harbours a unique assemblage of flora and fauna of considerable conservation importance. In comparison with higher plants and larger animals, the inventory of insects in Western Himalayan landscape is still fragmentary and incomplete. Butterflies (Lepidoptera: Rhopalocera) form an easily recognizable biotic component of the ecosystem, as they are visibly attractive and colorful. The ecological role of butterflies in an ecosystem is not only as herbivores, but also as important pollinators. Beside their attractiveness, butterflies are of interest because they can also be used to monitor environmental conditions. In India there are about 1,501 species of butterflies are present. Although the butterfly taxonomy and distribution is relatively well studied in Western Himalayan perspective, moth study lacks significant addition since the work of Fauna of British India series. Great ecological diversity and varied vegetative covers had contributed to a diversified beetle fauna of India, which holds about 5 percent of the world fauna comprising about 17,000 species. Keeping in view these perspectives, the project aimed at documenting insect fauna in high altitude ranges of Gangotri landscape. More specifically the project aimed to assess ecological diversity and distribution pattern of two largest insect orders, viz. Lepidoptera including butterflies and moth and Coleoptera (beetles). Besides, the project also intended to develop and suggest long-term management strategies for conservation of insect diversity in the Landscape.

Study Area

The study was conducted in Gangotri Landscape Area, *viz.* three high altitude protected areas of district Uttarkashi, Uttarakhand . Gangotri National Park and Govind National Park and Govind Wildlife Sanctuary, which represents the biogeographical zone 2B West Himalaya. The altitude varies from 1200 m to over 6500 m. A great variation in topography in the landscape results in diversity of vegetation.

Methods

Two hyper-diverse orders of class Insecta were sampled *viz.* Lepidoptera (Butterflies and Moths) and Coleoptera (Beetles). All butterflies of superfamily, Hesperioidea and Papilionoidea (Order: Lepidoptera, Suborder: Rhopalocera) were sampled. A total of five butterfly families (i.e. Hesperiidae, Papilionidae, Pieridae, Lycaenidae, and Nymphalidae) were recorded during current study. Two sampling approaches, direct search and indirect search, were used. Line transects and random forest trail/dirt tracts were walked to sample butterflies during the four seasons in April 2008 - December 2011. Vegetation data was quantified for each transect using stratified random sampling. Data on environmental parameters that represent different spatial themes *viz.* area, topography, climate, primary productivity, were compiled from satellite imageries. Two major groups of techniques have been employed for surveying moths, each with considerable individual variation. Transect count methods akin to those adopted widely for butterflies have been used for the diurnal taxa. Moth assemblages were investigated at 22 sites situated along an altitudinal gradient between 1,200 and 3,600 m above sea level in a temperate Himalayan forest in Gangotri Landscape. Moths were attracted to light, and between two and four catches were performed at each site using two light sources. Plant community of each vegetation types was sampled using a series of nested quadrats. Sampling procedure for beetles involved five methods; Pitfall trapping, Aerial and ground hand collection, Sweep netting, light trap and direct searching along transect. . This study aimed to identify species likely to be indicative of particular habitats using Indicator Species Analysis, thus allowing sites to be readily evaluated for EIA or conservation by the presence of one or more indicator species.

Faunistic Inventory and Sampling Efficiency

Lepidoptera (butterflies and moths) is a diverse order of class Insecta with about 1,80,000 described species, compared with may be 1,413,000 species of all organisms described. We recorded a total of 1639 butterfly individuals representing 34 species 29 genera and five families during the study in Gangotri NP. A total of 159 species representing 92 genera in 5 families were recorded in Govind NP, WLs and adjoining area of Tons valley in Gangotri landscape during entire sampling period from April 2008 to March 2012. Sampling was almost complete at regional level. Regional inventory completeness was around 96%, which can be suggested as exhaustive sampling. We recorded a total of 468 species of Moth from Gangotri Landscape area, covering both the protected areas representing 11 superfamilies and 20 families during entire sampling period from April 2009 to November 2012. The collected beetle specimens are identified upto 13 families and 120 species. Highest number of species has been recorded from Govind Wildlife Sanctuary followed by Govind National Park.

Lepidoptera Diversity in Gangotri Landscape

Study of distribution patterns of focal groups like Lepidoptera may be beneficial in understanding overall distribution pattern of insect diversity. A total of 1639 butterfly individuals representing 34 species 29 genera and five families were recorded during the study in Gangotri NP. Highest species richness, abundance and diversity were recorded in Himalayan temperate forest, followed by sub-alpine forest, moist alpine scrub and dry alpine scrub forest. Family Nymphalidae was the most dominant family and accounted 753 individuals representing 15 species, followed by Pieridae, Lycaenidae, Papilionidae and Hesperiidae. Species richness and abundance was reported highest for Govind WLS followed by unprotected area and Govind NP. At the habitat level, inventory completeness was highest for mixed riparian and scrub forest (91.9%) followed by pine forest (84%), broadleaf forest (70.1%) and conifer and alpine forest (44.2%). Sixteen families and 1992 specimens of moths were collected from the 20 sampling sites and were primarily sorted into 784 morphospecies. The family Geometridae was the most dominant family in all the vegetation zones sampled, followed by the families Noctuidae, Arctiidae and Pyralidae. Different diversity measures were calculated for moths in all the major vegetation zones for selecting a suitable diversity index. As all the sites were sampled with different intensity, rarefaction method was used as a suitable alternative for diversity measure. The estimated total species richness using Chao1 was 473 ± 12.32 (SD), and using Jacknife2 491±11.82 (SD) for the complete sample. The ratio of observed to estimated (Chao1) number of species was 82% suggesting that at least 18% more species are to be expected in the area than were actually collected. The present study, a systematic inventory of moths, is the first of its kind in Gangotri Landscape and is one of the few studies on moth communities in India. Overall, the moth assemblages varied among zones and revealed a pattern of assemblage response in relation to altitude and the related microclimatic regime of zones. In conclusion, it was observed that despite small differences in geographic distance the landscape was able to support a high amount of Lepidopteran diversity and the processes involved with landscape heterogeneity were strong enough to support a unique Lepidopteran assemblage between forests. The landscape along with three protected areas (Gangotri NP, Govind WLS and NP) and their adjoining habitats are important for long term conservation of entomofauna as well as biodiversity as a whole in Uttarakhand, Western Himalaya.

Patterns of Lepidoptera Distribution along Elevation Gradient

We found that the species richness of butterflies in western Himalaya demonstrated a mid-elevation peak in species richness. For butterflies, the area seems to support species richness upto 2100m after which species richness gradually decrease and area increase. This may be possible that temperature and other factors became stronger in explaining butterfly species richness at higher elevation as butterflies are ectotherms and need more energy to support themselves at these higher elevations. At local plot level, we found a more obvious association of butterfly species richness with vegetation parameters such as plant species richness, herb and shrub density and canopy cover at plot level. Herb and shrub density were major predictors of butterfly abundance. Anthropogenic factors such as logging were found to be positively associated with butterfly species richness and abundance. The major moth families like Geometridae behave almost similarly along altitudinal gradient except the fact that subfamily Larentiinae attained its highest diversity in higher elevations. The number of geometrid species and morphospecies collected in this study (1,010) is by all standards among the highest ever counted in a single study on such a small spatial scale. The diversity pattern of Larentiinae in the study area can best be described as a very broad medium to high elevation hump. The underlying mechanisms for this most exceptional distribution of Larentiinae are uncertain. Temperature, mean monthly precipitation and plant species richness all predicted the geometrid diversity pattern well. This chapter provided evidence that the Gangotri landscape area is a hotspot in Western Himalayan context with regard to one large taxon of herbivorous insects. Given the high richness and small ranges of species, the area needs to be given more protection for the conservation of Lepidoptera and other insect fauna.

Application of Lepidoptera in Insect Monitoring and Conservation

Conservation managers must be supported with quick and cost effective monitoring techniques and protocols for difficult taxon like insects. The use of indicator and surrogate taxa to monitor entire community has evolved a good option to save money, effort and time. The purpose of this chapter was to demonstrate the importance of rapid assessment studies for selecting areas important for insect conservation and to select indicator species for habitat monitoring in the Gangotri Landscape in Western Himalaya. We used an integrated approach by sampling across multiple habitats and land use types and by using multiple data collection techniques. We determined how much sampling effort was required for an adequate assessment of butterfly communities in the Western Himalayan landscape. We identified indicator species of Lepidopteran assemblage for all the major habitats in the study area and propose that these butterfly and moth assemblages can be used as indicators of vegetation zones and as surrogate species for conservation efforts. These species are habitat specialists of small size, and so they represent interesting tools at small spatial scales. It is our expectation that the results presented and discussed here will help conservation planners and managers by aiding them in the selection of biodiversity rich areas and by giving attention to remaining fragmented habitats facing human alterations, which will increase biodiversity conservation efforts in the area.

CHAPTER 1
INTRODUCTION

1.1 Insect Conservation: Challenges and Gaps

The Himalayas, are part of the world largest mountain complex and a buffer to major realms *viz.* Oriental, Palearctic and Ethiopian. Biogeographically, Himalayas are categorized into 2 zones (a) Zone 1: 1A Trans Himalaya (Ladakh Mountains) and 1B Tibetan plateau (b) Zone 2 is divided in four provinces *viz*. 2A North Western, 2B Western, 2C Central and 2D Eastern Himalaya (Rodgers et al., 2002). Rodgers & Panwar (1988) had categorized the entire Himalayan region of Uttarakhand under biogeographic province Western Himalaya (2B) (602,848 km^2). Gangotri Landscape includes three protected areas *viz.* Gangotri National Park and Govind National Park and Govind Wildlife Sanctuary, which makes this landscape important for protection and management of representative Western Himalayan biodiversity.

An inventory of biodiversity is of primary importance as part of biodiversity conservation for sustainable development, particularly in threatened and fragmented landscapes like Western Himalaya that harbours a unique assemblage of flora and fauna of considerable conservation importance. In comparison with higher plants and larger animals, the inventory of insects in Western Himalayan landscape is still fragmentary and incomplete.

In order to know how and where to protect biodiversity, it is imperative that we learn more about the diversity of terrestrial arthropods, which may comprise 80% or more of the global diversity but have been too often neglected by the resource managers and conservation planners (Wilson, 1988, 1992; Colwell & Coddington, 1994; Longino, 1994).

Invertebrates are the most diverse and abundant animals in most natural ecosystems, but their significance in sustaining these ecosystems is commonly not appreciated (New, 1995). Determining the distribution of invertebrates is an integral part of assessing their conservation status and determining their possible management needs. Invertebrates, and in particular insects, can therefore not be ignored in the assessment of biodiversity. The reluctance to use invertebrates in conservation studies, as indicated by Cardoso et al. (2011), is mainly because of the following reasons: (1) Invertebrates and their ecological services are mostly unknown to the general public. (2) Policy makers and stakeholders are mostly unaware of invertebrate conservation problems. (3) Basic scientific work on invertebrates is scarce and underfunded. (4) Most species have not been described. (5) The distribution of described species is mostly unknown. (6) The abundances of species and their changes in space and time are unknown. (7) Species' ways of life and sensitivities to habitat change are largely unknown. Furthermore, invertebrate surveys generate very large samples that demand considerable effort to process in terms of time and expertise (New 1999a). Despite the above negative aspects of working with invertebrates, they represent a group of organisms that are potentially useful when assessing the biodiversity of an area because of (1) their generality of distribution, (2) trophic versatility, (3) rapid responses to perturbations and (4) ease of sampling. There are so many taxa for which the expertise to identify to the level of species does not exist that we cannot even contemplate surveying their diversity entirely. At the current rate, it will take us several thousand years to describe all the species or have an idea about the diversity if traditional taxonomic methods are used (McNeely et al., 1995).

Estimates of the number of insect species thought to exist globally vary widely, but there are probably 4-6 million (Novotny et al., 2002). We have perhaps named only 23-35% of these (Hammond, 1992). As estimates of the number of described insects in the world vary from about 720,000 (May, 2000) 950,000 (IUCN, 2004), 1 million (Chapman, 2009) to more than 1 million. Coleoptera and Lepidoptera alone represent with approx 434,000 to 474,000 described species (Chapman, 2009) and with an estimated 1,400,000 to 1,500,000 species. Order Coleoptera and Lepidoptera alone account for approximately 45% of described species (Chapman, 2009) and thus important in understanding problems and issues with protection, conservation and management of biodiversity.

1.2 Major Insect Orders in Gangotri Landscape

Order Coleoptera (*koleos*: sheath and *pteron*: wing, thus "sheathed wing"), contains more described species than in any other order in the animal kingdom, constituting about 25% of all known life-forms. About 40% of all described insect species are beetles (about 350,000 species), and new species are frequently discovered. Some estimates put the total number of species, described and undescribed, at as high as 100 million, but 1 million is a more likely figure (Chapman, 2009).

Lepidoptera is a group of insects that include important herbivores, pollinators, and serve as food and hosts for multiple other organisms at higher trophic levels. They are the most diverse order of insects associated primarily with angiosperm plants and, with some 160,000 named species. Powell et al. (2003) estimated that the world fauna is certain to exceed 350,000 species. In common parlance, Lepidoptera comprises the butterflies (some 20,000 species in two or three superfamilies) and moths (the great majority of species, spread among some 30 superfamilies) (Kristensen & Skalski, 1999). The largest families of moth (Noctuidae: 35,000 species; Geometridae: 21,000 species) each thus include more species than the whole of the butterflies.

Butterflies (Lepidoptera: Rhopalocera) form an easily recognizable biotic component of the ecosystem, as they are visibly attractive and colorful. The ecological role of butterflies in an ecosystem is not only as herbivores, but also as important pollinators. Beside their attractiveness, butterflies are of interest because they can also be used to monitor environmental conditions. Change in butterfly abundance may indicate change in habitat conditions (Goldsmith, 1992). There are about 180,000 described species of Lepidoptera, around 10% of all described species of living organisms. In the butterflies (Papilionoidea and Hesperioidea), there are about 17,500 described species, or 1% of known organisms (Vane-Wright, 2003). In India there are about 1,501 species of butterflies are present (Kehimkar, 2008).

Although the butterfly taxonomy and distribution is relatively well studied in Western Himalayan perspective, moth study lacks significant addition since the work of Hampson (1892, 1894, 1895 & 1896) and Bell & Scott (1937) in their "*Fauna of British India*" series and Cotes & Swinhoe (1886) in "*A catalogue of moths of India*". Butterflies are also not easily trapped and are often poorly represented in forest environment. In contrast, nocturnal families of larger nLepidoptera are sufficiently speciose and diverse to offer powerful discrimination in detecting ecosystem level impact. Most families of moth are readily attracted to light traps that, used with care, can provide a standard measure of the fauna present in a particular habitat. Recent estimates reveal the report of over 127,000 species of moths from the world, of which over 12,000 species are recorded from India (Chandra, 2007).

1.3 Review of literature

1.3.1 Lepidoptera

1.3.1.1 Butterflies (Rhopalocera)

Systematic studies

We are now assured that the butterfly superfamilies Hesperioidea and Papilionoidea together form a monophyletic group. Within the Papilionoidea four families can be recognized with confidence but there is broad agreement about subfamilies within the three of them except Nymphalidae remain unconvincingly resolved. Ashizawa & Muroya (1967), Bernardi (1947), Brown (1971, 1979), Burns (1964), Bryk (1923, 1930), Clark & Dickson (1971), Common & Waterhouse (1981), Cowan (1966, 1967), Ehrlich (1958), Ehrlich & Raven (1965), Eliot (1973), Evans (1937, 1949, 1951, 1952, 1953, 1954, 1955), Field & Herrera (1977), Forbes (1939), Higgins (1975), Kudrna (1977), Lindsey et al. (1931), Munroe & Ehrlich (1960), Munroe (1961), Nabokov (1945), Sibatani & Grund (1978), Stempffer (1967) and Stichel (1928, 1930-31, 1932, 1938) work is remarkable to distinguish subfamilies under order Rhopalocera.

Faunistic Studies

The expansive nineteenth century literature, although now outdated often contains useful data. For the Palaearctic region catalogue works of Higgins

(1975) & Korshunov (1972) probably give the widest coverage. To date, Seitz (1907, 1908, 1909) remains the only comprehensive study of this region. For the Afrotropical region although Peters catalogue (1952) remains useful and updated by D'Abera's (1980) and Carcasson (1981). Otherwise only Seitz (1908-25) gives complete coverage of the entire region. In the Oriental region area is covered within Seitz (1908-28), the 'IndoAustralian' fauna and also by D'Abrera (1982) in the first part of planned series of volumes on Oriental butterflies. Pant & Chatterjee (1950), Varshney (1977) and Sevastopulo (1939), catalogued the described life histories, local lists and larval host plants of Indian fauna. In the Austro-Oriental fauna Corbet & Pendlebury (1978) for Malaysian butterflies, Roepke (1935-1942) for Java and are helpful. For the Australasian region the Moulds (1977) bibliography of Australian butterflies is the primary reference source for the area, covering the years 1773-1973. Common & Waterhouse (1981) only include species found in Australia itself. The Nearctic butterflies are covered within Seitz (1907-24) later by Tietz (1972), Ehrlich & Ehrlich (1961) and Howe (1975). For Neotropical region the major work are done by Lamas (1997), and D'Abera (1981).

Studies on Indian Butterflies

The first account of Indian butterflies was published by Horsfield & Moore (1857) in which many species from Java were included. The next work was by Moore (1865) on lepidopterous insects of Bengal. Later the butterfly fauna of Indian sub-continent have been mainly studied by Moore (1890-1907), Niceville (1886-90) three volumes contains information on Indian butterflies dealing Papilionidae, Pieridae and Hesperiidae. Colonel Bingham (1905-07) presented two volumes on butterflies in 'Fauna of British India' series containing families Nymphalidae and Riodinidae. Bell (1909-27), Antram (1924), Evans (1932), Peile (1937), Talbot (1939, 1947), Wynter Blyth (1957), Varshney (1977, 1993, 1994), Mani (1986), D'Abrera (1982, 1985, 1986, 1998), Smith (1989), Gaonkar, (1996), Ghosh (1990), Mondal (1987, 1991, 1998), Haribal (1992), Kunte (2000) and Kehimkar (2008), Singh (2011) were other main researchers studied Indian butterflies.

Many workers made the collection of butterflies from Himalayas. Besides, collections made by Mani (1986) described 377 species of butterflies except Hesperiidae from Himalayas. Collections of A.M. Lang from northwest Himalayas and A.G. Young from Kullu, were included by Major G.F.L. Marshall & de Niceville in The Butterflies of India, Burma and Ceylon (volume 1-3 : 1882-1890). Collections of J.H. Hocking from Kangra district were published by Moore (1882). Subsequently, these were included in publications by Evans (1932), and Talbot (1939, 1947).

Studies in Himalayan Region

The butterflies of the Indian region, including those from Uttarakhand in western Himalayas, were named and described by Linnaeus and Fabricius for the first time during the eighteenth century. Doherty (1886) published a list of butterflies, exclusively from Kumaon, for the first time, followed by Hannyngton (1910-11) who published an account of 373 butterflies. Mackinon & de Niceville (1899) published a list of 323 butterflies from Mussoorie and neighbouring region from the western Himalayas followed by Ollenbach (1930-31) who published a list of 143 butterflies from Mussoorie. The other important works referable to the study of Garhwal Himalayas are by Stempffer (1952); and Lesse (1952). Wynter-Blyth (1957) recorded as many as 415 species from western Himalayas out of which 323 species were listed from Uttarakhand. Subsequently Arora & Mandal (1981) recorded 45 species from Garhwal. Arora (1995) recorded 223 species from western Himalayas. Arora (1997) identified 80 species of butterflies collected from Nanda Devi Biosphere. Singh & Bhandari (2003) recorded 183 species from lower western Himalaya forests of Doon Valley and Kumar & Gupta (2004) recorded 48 species from Govind Pashu Vihar, Uttarkashi district. Singh (2009) studied butterflies of Kedarnath Musk Deer Reserve in Garhwal Himalaya. Compiled from the inventory of valid species of butterflies belonging to nine families is somewhere nearly 323 species from Uttarakhand.

Detailed assessments based on different bio-geographical regions, states, national parks and sanctuaries, forest types and landscapes were mainly undertaken by Larsen (1978), Arora & Mandal (1981), Gupta & Shukla (1987), Ghosh et al. (1990), Haribal (1992), Mathew (1993), Arora (1994, 1995), Gaonkar (1996), Rose & Sindhu (1997), Gunathilagaraj et al. (1998), Joshi et al. (1999), Rose & Sharma (1999), Singh (1999), Singh & Bhandari (2003), Singh & Pandey (2004), and Uniyal (2004). Various studies on insects and butterflies of Great Himalayan National Park in Himachal Pradesh were mainly conducted by Uniyal & Mehra (1996), Uniyal (1996, 1999), Uniyal & Kumar (1997), Uniyal & Mathur (1998). Kumar & Gupta (2004) studied the butterflies of Govind Pashu Vihar in Uttarakhand and documented 48 species. Singh published an account of 211 species from six sites in moist temprate oak forest of Garhwal region including from govind Pashu Vihar.

1.3.1.2 Moths (Heterocera)

Earliest contributions on world moths were by Boisduval (1829-1854), who described Genus *Macroglossum*, *Asterocampa* and many others of the family Saturniidae, Snellen (1877-1884) described Larch cone moth (*Retinia perangustana*) and some species of Gracillariidae. Wallengren (1856, 1860) described some moths of forests *viz.* Genus *Therisimima*. Herich-Schaffer (1854) published some records of Saturniidae from North America; Hubner (1806-1832) described different species of *Zophodia, Palpita, Trichoplusia* etc. Felder (1874) described families Castiniidae, Saturniidae from Australia.

Today the most prominent names among macrolepidopterists are: J.D. Holloway who is a specialist on Macrolepidoptera with International Institute of Entomology. He is working fulltime on 'Moths of Borneo" and recently lead a team producing "The Families of Malaysian Moths and Butterflies". Common (1990) published the first comprehensive, illustrated book covering the enormous diversity of Australian Moth with information on their distribution, larval host plant and fascinating behavior. Ian Kitchig of British Natural History Museum is an authority on biodiversity and biosystematics and phylogeny of Macrolepidoptera with special emphasis on Bombycoidea and Sphingidae. Jurie Intachat (1999) assessed the moth diversity in natural and managed forests in Peninsular Malaysia, effect of logging on Geometridae in Lowland forest of Peninsular Malaysia (1999). He did a preliminary assessment of the diversity of geometrid moths within different types of rain forest in Peninsular Malaysia (2001). C.Z. Yang of Beijing Agricultural University published two volumes of Moths of

Northern China. L.W.R. Kobes has worked on few families like Thyatiridae, Agaristidae, Noctuidae from Sumatra. E.C. Zimerman has worked on Macrolepidoptera of Hawaii Island.

Apart from taxonomic study, the most prominent works on ecology of Moth are done by: Jan Beck & Chey Khen (2007) who worked on beta diversity of Geometrid moth from northern Borneo and effect of habitat, time and space on moth assemblages, K. Summerville & T.O. Crist (2004) assessed suitability of forest moth taxa as an indicator of Lepidopteron richness and habitat disturbance, Gunnar Brehm & Konrad Fiedler (2003) who saw the pattern of body size change of some Geometrid moths along an elevational gradient in Andean rainforest, Nadine Hilt (2005) who assessed diversity and composition of Arctiidae moth ensembles along a successional gradient in Ecuadorian Andes, Ricketts et al. (2001) who studied countryside biogeography of moths in a fragmented landscape in native and agricultural habitats in Andean Montane forest.

Moth Studies in India

The earliest faunistic records of Lepidoptera from India are by Linnaeus (1758), Cramer (1775), Fabricius (1775), Kollar (1844), Butler (1879), Donovan (1800), Swinhoe (1885). The lists and catalogue were published by Walker (1854), Kirby (1892), and Cotes & Swinhoe (1886-189). Butler (1877) and Hampson (1891-1914) published lists and catalogues along with descriptions of the Indian and exotic moths present in the collection of the British Museum (Natural History) London. Moore studied many genera and species of nocturnal Lepidoptera collected by W.S. Atkinson, W.C. Hockings, J.H. Hockings and also by himself form Kolkata and North-West Himalayas. Moore also prepared a long list of the fauna occurring in the Bengal and Andaman & Nicobar Islands. Swinhoe published the Lepidoptera of Bombay, Mhow in Madhya Pradesh. Similarly, Cotes (1889-91) contributed a series of notes on insects, pests and other important aspects of Entomological section of the Indian Museum. Snellen (1890) published on a catalogue of the Pyralidae of Sikkim collected by Henry J. Elwes and the late Otto Moller. Hampson (1891) published the information on Lepidopterous Fauna of Nilgiris. Hampson (1892, 1894, 1895, 1896) published four volumes of the "*Fauna of British India*". He (1903, 1908, 1919) further published supplementary paper and studied of new moths collected by Mons. Bell & Scott (1937) published "*Fauna of British India*" to family Sphingidae. Warren (1888, 1893, 1896, 1910, 1911, 1913, 1914) and Rothchild (1920) furnished detailed inventory of the Indian crop-pests as well as interpreted migration as a factor in pest out breaks. Notes on Heterocera of Kolkata were published by Sevastopulo (1956). The moths of south-east Asia are studied by Barlow (1982). Arora (1997, 2000) published some moth species from the Nanda Devi Biosphere Reserve and some Indian pyralid species of Economic Importance respectively. Arora & Chaudhury (1982) published on the lepidopterous fauna of Arunachal Pradesh in adjoining areas of Assam in North-East India. Arora & Gupta (1979) published monograph of family Saturniidae of India. Chandra (1993, 1996) has studied moths from Bay Islands and Great Nicobar Biosphere Reserve. Gupta et al*.* (1984) published brief reviews on family Lymantriidae of India. Moths fauna of West Bengal has been studied by Mandal & Gupta (1997), Mandal & Ghosh (1997), Mandal & Maulik (1997), Ghosh & Choudhury (1997) and Bhattacharya (1997). Mandal & Bhattacharya (1980) studied the subfamily Pyraustinae from Andaman Nicobar Island while Arora (1983) published moth fauna of Andaman & Nicobar. Bhattacharya provided historical account Indian Pyralidae. Mandal & Ghosh (1991) described some species of moths from Tripura. Moth fauna of Orissa have been studied by Mandal & Maulik (1991). "Taxonomy of Moths in India" has published by Srivastava (2002). Mehta (1933) studied comparative morphology of the male genitalia in Lepidoptera. Moth fauna of Meghalaya was studied by Mandal & Ghosh (1998). Ghosh (2003) recorded 525 Geometrid species from Sikkim. Dover, Fletcher & Bainbridge, and Smetacek (1993) have described several species of moths from India.

Moth Studies in Western Himalaya

The comprehensive work on moths of different regions of Western Himalayas within the Indian Territory was mostly carried out by Hampson (1892, 1894, 1895 & 1896) in his "Fauna of British India" series and Cotes & Swinhoe (1887) in "A catalogue of moths of India". Since then not much study has been carried out on moth fauna of Western Himalaya. Arora (1997, 2000) published some moth species from the Nanda Devi Biosphere Reserve, Garhwal Himalaya. Recently Smetacek (2008) had published an account of moth diversity from different elevations in Nainital district, Kumaon Himalaya. So far no comprehensive record of moth fauna from Gangotri landscape area, which is an important wildlife refuge in high altitudes of state Uttarakhand, is documented.

1.3.2 Coleoptera

Great ecological diversity and varied vegetative covers had contributed to a diversified beetle fauna of India, which holds about 5 percent of the world fauna comprising about 17,000 species. The Indian beetle fauna exhibits presence of various forms of neighbouring territories, in addition to its original representatives. Indian beetle fauna is represented by 169 families and 17036 species compared to 344105 species recorded from world (Pal, 2003). The first major work on Indian beetles was in Catalogue of Indian Insects published between 1924 and 1931 on various beetle families: Nitidulidae (Chatterjee, 1924), Staphylinidae (Cameron, 1925), Brenthidae (Kleine, 1926), Cicindelidae (Heyneswood & Dover, 1928), Carabidae (Andrews, 1930), Lycidae (Kleine, 1931) and Gyrinoidea (Ochs, 1931). Beeson (1941) published a book of Indian forest insects covering a number of families of the coleopteran. The most important inventory of India beetles was published in the form of Fauna of British India: Cerambycidae by C. J. Gahan (1906), Chrysomelidae by M. Jacoby (1908) and Scarabaeidae by G. J. Arrow (1910, 1917, 1931), Curculionidae by G. A. K Marshall (1916), Chrysomelidae by S. Maulik (1919, 1926, 1936), Carbidae by H. E. Andrews (1929, 1935), Staphylinidae by M. Cameron (1930, 1931, 1932, 1939). Since independence, Kapur (1951, 1963, 1966) made notable contributions to the understanding of Coccinellidae of India. Vazirani (1966, 1969, 1970, 1984) worked out extensively the aquatic beetles familles and published fauna of India volume on Haliplidae and Gyrinidae. Saha revised (1979) the family Meloidae. Supare et al. (1990) and Pajni (1990) made important contributions to the knowledge of Indian Curculionidae. Sengupta and Pal (1996) published the Fauna of India volume on Silvanidae.

1.4 Objectives of the study

The project aims at documenting insect fauna in high altitude ranges of Gangotri landscape. However, the specific objectives are as follows:

1. To assess the ecological diversity and distribution patterns of Beetles (Coleoptera) and Butterflies (Lepidoptera) in Gangotri Landscape.
2. To determine the impact of anthropogenic pressures on assemblages of butterflies and beetles.
3. To develop and suggest long-term management strategies for conservation of invertebrate diversity in the Landscape.

1.5 Key Questions

To assess the diversity and distribution pattern of target taxa following questions were drawn and answered:

1.5.1 Butterflies

Following questions were asked to study diversity and distribution pattern of butterflies in the Gangotri landscape.

1. Faunistic Inventory of butterflies in the Gangotri landscape
2. Pattern of butterfly species richness, diversity and composition in different habitats in Gangotri landscape
3. Similarity and dissimilarity of family and species composition between habitats
4. Variation of species richness along elevation
5. What factors are correlated with species richness?
6. What conclusions can be drawn for the use of moth assemblages as indicator of habitat condition or land use patterns in Gangotri Landscape?

1.5.2 Moths

1. Faunistic inventory of moths in different habitat of Gangotri Landscape
2. Variation of species richness of a major family (Geometridae) along elevation

3. Family and species composition among different habitats
4. Factors affecting the distribution pattern along elevation and vegetation gradient
5. What conclusions can be drawn for the use of moth assemblages as indicator of habitat condition or land use patterns in Gangotri Landscape?

1.5.3 Beetles

1. Faunistic Inventory of beeltes in the Gangotri landscape
2. Diversity and distribution pattern of beetles in Gangotri landscape

CHAPTER 2
STUDY AREA

2.1 Gangotri Landscape

The study was conducted in Gangotri Landscape Area, *viz.* three high altitude protected areas of district Uttarkashi, Uttarakhand (**Figure 2.1**). Gangotri National Park (NP) (Lat 30°50′-31°12′ N and Long 78°45′-79°02′ E) and Govind National Park and Govind Wildlife Sanctuary (WLS) Lat 31°02′–31°20′ N and Long 77°55′–78°40′ E), which represents the biogeographical zone 2B West Himalaya (Rodgers & Panwar, 1988). The altitude varies from 1200 m to over 6500 m. The Gangotri NP covers an area of 2390 km^2 harboring the Gaumukh Glacier, the origin of the River Ganges, and Govind National Park covers an area of 953.12 km^2 encompassing the upper catchments of the River Tons. The climate of the area is the typical Western Himalayan climate, with medium to high rainfall during July-August at lower altitudes. The average rainfall is 1500 mm s, and it is extremely cold, with three to four months of snowfall in winter, with a permanent snowline in the higher reaches.

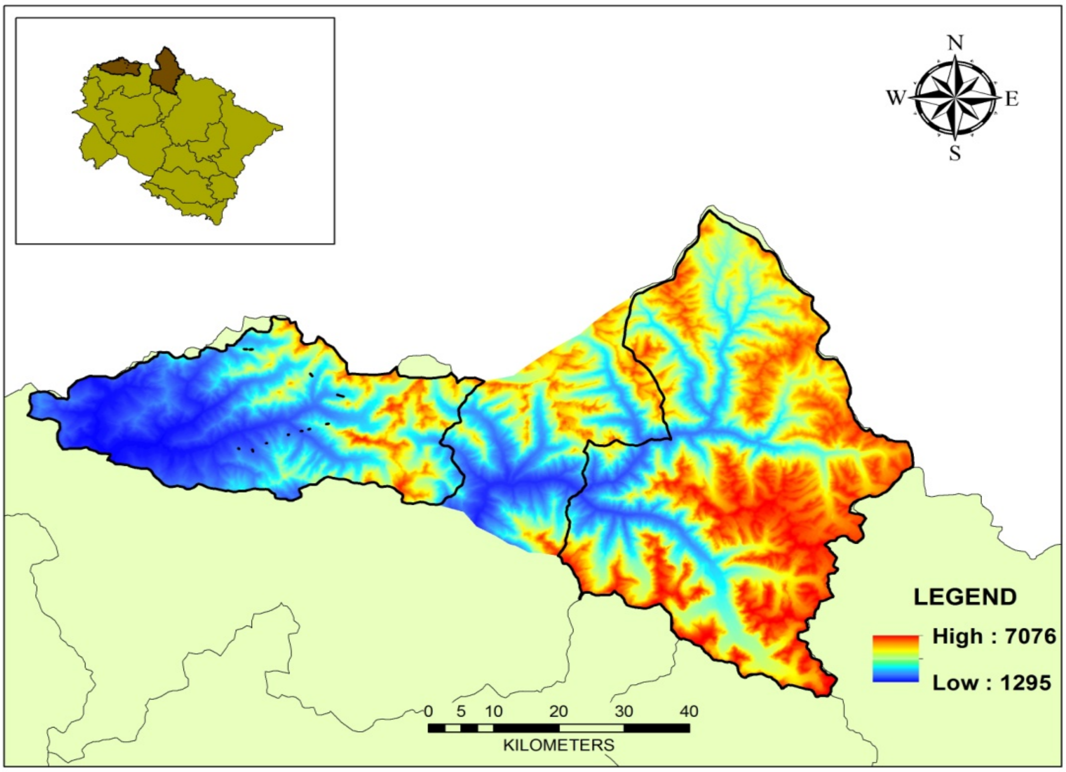


Figure 2.1: Digital Elevation Model of study area, Gangotri Landscape Area showing the boundary of Govind WLS & NP in the west and Gangotri NP in the east

2.2 Gangotri National Park

The Gangotri National Park area is located between Lat. 78°45' to 79°02' East and 30°50' to 31°12' North **(Figure 2.2)**. Administratively, Gangotri National Park area lies in the Uttarakashi district of Uttarakhand covering a total area of 2,390 sq km. The Goumukh Glacier, the origin of the River Ganges is located inside the park. Gangotri, after which the park has been named, is one of the holy shrines of Hindus. The park area forms a viable continuous corridor between Govind NP and Kedarnath WLS. The northeastern park boundary is located along the international boundary with China (Tibet). The park area is characterised by high ridges, deep gorges and precipitous cliffs, rocky craggy glaciers and narrow valleys that make the catchment of river Bhagirathi.

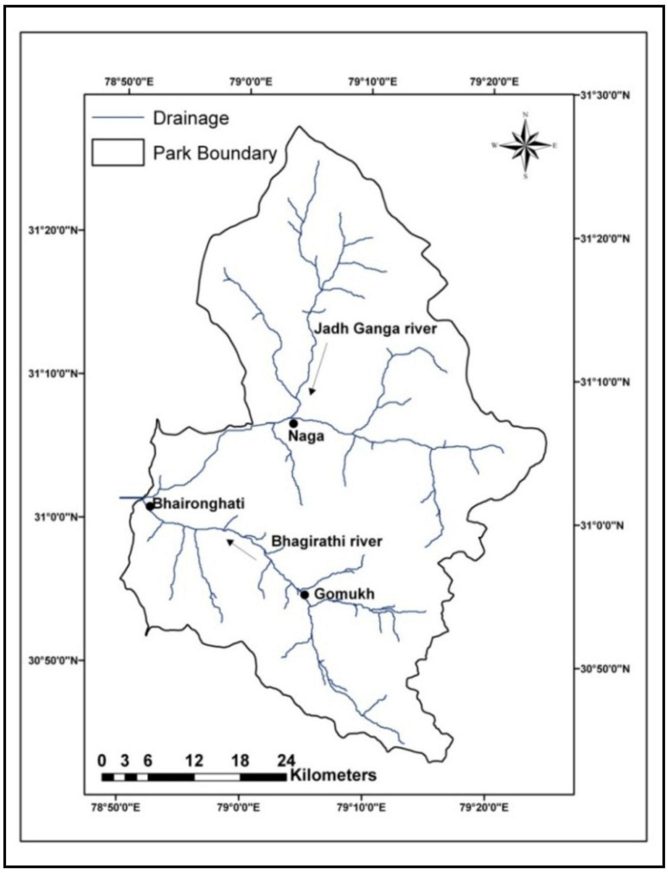


Figure 2.2: Map of Gangotri National Park

The area exhibits altitudinal variation from 1,800 to 7,083 m. Due to variation in the altitude and aspect, a high diversity of vegetation exists in the park.

The landscape immediately north of main central thrust (MCT) in the state of Uttarakhand, India represents a unique cold, arid ecosystem that has largely escaped the attention of ecologists, geographers and natural resource managers, owing to remoteness, harsh climatic conditions and inaccessibility owing to security reasons as Indian Army has occupied the area and entry of visitors, tourists etc. is prohibited in the Nilang valley. Along with part of Gangotri glacier (Greater Himalaya), the area is under protection as Gangotri NP. This area forms a narrow strip (50-80 km wide) between the crest of Greater Himalaya and water divide between Satluj and Yarlung-Tsangpo that also forms the international boundary between India and Tibet (Valdiya, 2001; Mazari, 2007; Chandola et al., 2008). This area exhibits close affinities with Tibetan plateau both in terms of topography and species composition.

So far, 15 species of mammals and 150 bird species are documented from the park. The endangered mammals and pheasant species are: Snow leopard *(Uncia uncia),* Black bear (*Selenarctos tibetanus*), Brown bear (*Ursus arctos*), musk deer (*Moschus chrygsogaster*), Bharal (*Pseudois nayaur*) Himalayan tahr (*Hemitragus jemlahicus*), Himalayan monal (*Lophophorus impejanus*), Koklass (*Pucrasia macroplopha*), and Snow cock (*Tetraogallus himalayensis*).

The forests of the park are Himalayan moist temperate type. Major vegetation consists of chir pine (*Pinus roxburghii*), deodar (*Cedrus deodara*), oak (*Quercus sp.*) and other broad-leaved species like maples (*Acer sp.*), walnut (*Juglans regia*), hazel (*Coryllus jacquemontii)* and burans (*Rhododendron arboreum*).

2.3 Govind Wildlife Sanctuary and National Park

Govind NP and Govind WLS are part of high Western Himalayan highland situated in Purola Tehsil of the Uttarkashi district in Uttarakhand state and lies between Lat - 31° 02' – 31° 20' N and Long - 77° 55' – 78° 40' E (**Figure 2.3**). Two major rivers, Rupin and Supin, flow through the Govind NP and Govind WLS and merges at Naitwar village, forming the river Tons. The altitude varies from 1,290-6,323 m. The Govind WLS covers 953.12 km^2 of which 472.08 km^2 have been demarcated as National Park encompassing the upper catchment of river Tons.

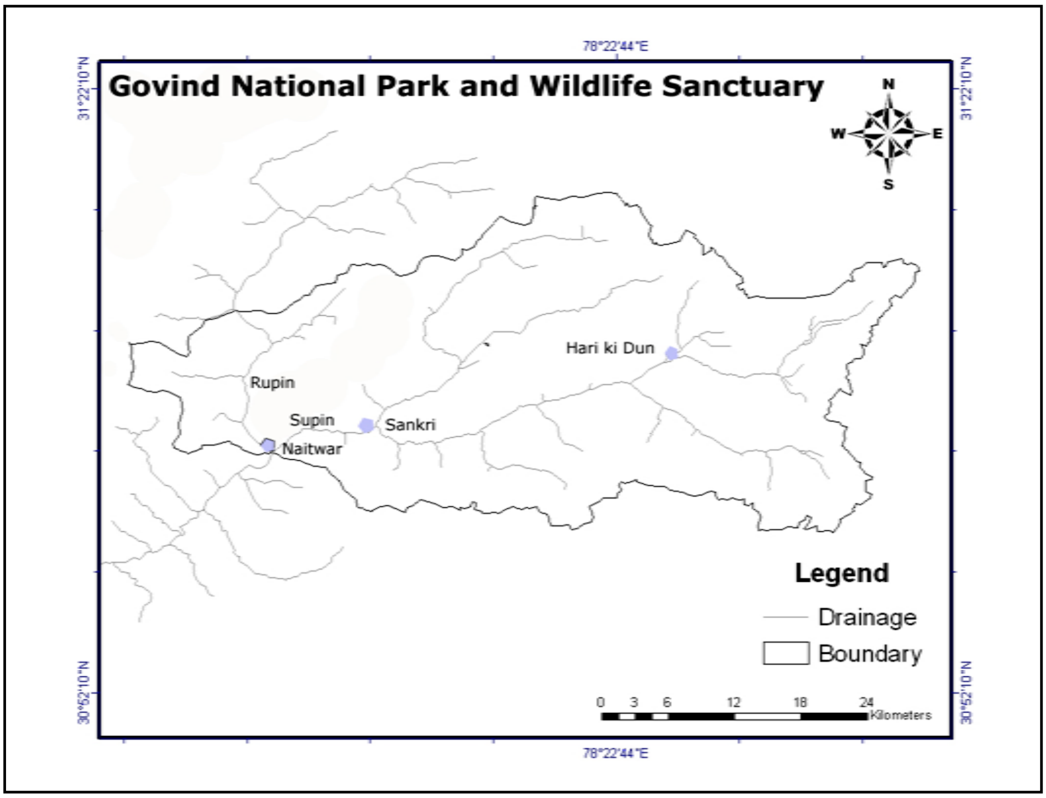


Figure 2.3: Map of Govind National Park and Wildlife Sanctuary

Tons river source lies in the 6316 m high banderpunch glacier zone. The origin of the Tons river is at the convergence of two feeder streams; the Rupin river from the northern part of the Tons catchment near the Himachal Pradesh and the Supin river rises from tributaries from glaciers at north and north-eastern part of Tons catchment. Supin joins Tons at Sankri, which is upstream of confluence of Rupin with Tons at Naitwar (1290m, asl). These two feeder streams converge near the mountain hamlet of Naitwar and the channel downstream of Naitwar is known as Tons river.

2.3.1 Geology

The area forms the knoll belt which extends from Shimla in the northwest upto the Nanital in the west. The soil is in the valley fairly deep particularly at the foothills. The soil of this tract can be differentiated into four types; red loam, brown, podsol and meadow soil.

2.3.2 Climate

The climate of the area is variable, with subtropical climate in lower part of the valley having hot and more or less humid monsoon season from July to September, pleasant autumn and spring and a cold and dry winter season bracing with clear and bright weather alternating with occasional winter rains and temperate at high elevations. The average rainfall is 1500 mm, with extreme cold and snow during the three to four month winter. Maximum rainfall is experienced during month of July and August and minimum rainfall during the months of January and October. A permanent snowline occurs at 5000 m elevation.

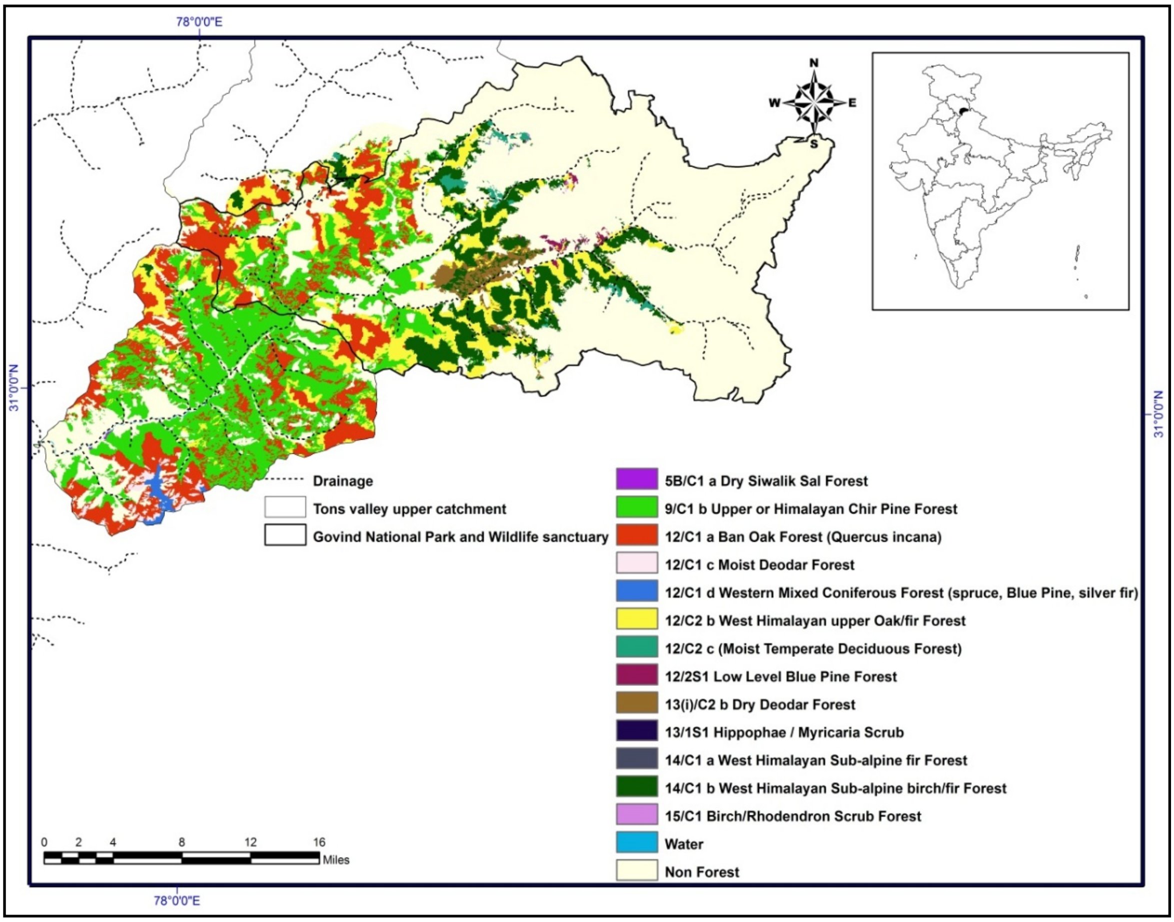


Figure 2.4: Forest types in the Govind NP and WLS and adjoining area of Tons valley, according to Champion and Seth (1968)

2.3.3 Vegetation

The forests in Tons valley are generally dense and the tree height in canopy usually varies from 15-30 m. There is an admixture of the species of tropical, temperate and sub-alpine in these forests **(Figure 2.4)**. The deciduous species generally shed their leaves from January to mid March. The forests bordering habitations suffers heavily from lopping and felling. Fortunately, considerable area and parts of the valley forest is not under serious threat and supports luxuriant growth of dense forest. Based on the vegetation composition, Rana et al. (2003) classified the forest of the area into following major types: pine forest, oak forest, deodar forest, mixed forest and scrub and thorn forest.

2.3.4 Human Habitations and Wildlife

About 47 villages are scattered throughout the Govind NP and Govind WLS (Anonymous, 1986). The people subsist mainly on livestock, cultivation, and forest products.

The fauna of the study area is poorly known other than a few scattered references on the mammals, birds, reptiles, butterflies, dragonflies and damselflies, hymenopterans and chilopods. Dang (1968) published a report on the preliminary survey of Har-ki-dun and adjacent valleys, with special reference to blue sheep and brown bear. A report from Wildlife Institute of India (Anonymous, 1986) reported 11 species of mammals from the study area. Later Sathyakumar (1994) reported about 20 species of large mammals from the Govind Pashu Vihar. Kumar et al. (2004) published a list of 257 taxa belonging to nine faunal groups (*viz.* Odonata, Lepidoptera, Hymenoptera, Chilopoda, Amphibia, Reptilia, Aves and Mammals). A total of 244 species of birds and 32 species of mammals have been recorded so far from the area. Major wildlife species are Snow leopard (*Uncia uncia*), Brown bear (*Ursus arctos*), Musk deer (*Moschus chrysogator*), Himalyan tahr (*Hemitragus jemlahicus*), Asiatic jackal (*Canis aureus*), Red fox (*Vulpes bengalensis*), Leopard cat (*Prionailurus bengalensis*), Leopard (*Panthera pardus*), , Yellow throated marten (*Marets flavigula*), Mountain weasel (*Mustela altaica*), Asiatic black bear (*Ursus thibetanus*), Sambar (*Cervus unicolor*), Barking deer (*Muntiacus muntjak*), Bharal (*Pseudois nayaur*), Royale's pika (*Ochotona roylei*), Red giant flying squirrel (*Petaurista petaurista*) and Indian crested porcupine (*Hystrix indica*). The important avifauna of the area is Himalayan bearded vulture, Western tragopan, Satyr tragopan, Himalayan monal, Koklass and Cheer pheasant which are also scheduled species in Indian Wildlife (Protection) Act, 1972 (Anonymous, 2006).

2.4 Forest Types classification of Gangotri Landscape Area

A great variation in topography in the landscape results in diversity of vegetation. According to the "Revised Survey of Forest Types" by Champion and Seth (1968) following types of forest **(Plates 1-2)** are found inside the Gangotri National Park and Govind National Park and Wildlife Sanctuary.

Group 9:	**Sub-tropical Pine Forest**
9/C1b	Sub-tropical Himalayan Chir pine forest
9/C1/DS2	Sub-tropical Euphorbia scrub
Group 12:	**Himalayan Moist Temperate Forest**
12/C1a	Ban Oak forest (*Quercus incana*)
12/C1b	Moru Oak forest (*Quercus dilatata*)
12/C1c	Moist Deodar forest
12/C1d	Western Mixed Coniferous forest
12/C1e	Moist Temperate Deciduous forest
12/C1DS2	Himalayan Temperate Secondary scrub
12/C2a	Kharsu Oak (*Quercus semicarpifolia*)
12/C2b	West Himalayan upper Oak-Fir forest
12/C2c	Upper Himalayan Moist Temperate Deciduous forest
12/DS1	Montane Bamboo brakes
12/DS2	Himalayan Temperate Park land
12/DS3	Himalayan Temperate pastures
12/E1	Cypress forest
12/IS1	Alder forest
12/IS2	Riverine Blue Pine forest
12/2S1	Low Level Blue Pine forest
Group 13:	**Himalayan Dry-Temperate Forest**
13C2b	Dry Temperate (Deodar forest)

13/IS1	Hippophae scrub
Group 14:	**Sub-Alpine Forest**
14/C1a	West Himalayan Sub-alpine High Level Fir forest
14/C1b	West Himalayan Birch-Fir forest
14/IS1	Hippophae scrub
14/2S1	Sub-alpine Blue Pine forest
14/DS1	Sub-alpine pastures
Group 15:	**Moist Alpine Scrub**
15/C1	Birch-Rhododendron Scrub forest
15/C2	Deciduous Alpine scrub
15/C3	Alpine Pasture land
15/E1	Dwarf Rhododendron scrub
15/E2	Dwarf Juniperus scrub
Group 16:	**Dry Alpine Scrub**
16/C1	Dry alpine scrub

Habitats Sampled in the Study Area

Pine Forest

Mixed Riverine Forest

Subtropical Mix Forest

Agriculture Scrub

Subalpine Mix Forest

Oak Broadleaf Forest

Plate- 1

Habitats Sampled in the Study Area

Conifer Mixed Forest

Alpine Grassland

Alpine Scrub

Dwarf Rhododendron Scrub

Sub Alpine Mix Forest

High Altitude Grassland

Plate-2

CHAPTER 3
METHODS

3.1 Study organism

Two hyper-diverse orders of class Insecta were sampled *viz.* Lepidoptera (Butterflies and Moths) and Coleoptera (Beetles).

3.2 Sampling of Butterflies, Moths and Beetles and Habitat Characteristics

3.2.1 Butterflies (Rhopalocera)

All butterflies of superfamily, Hesperioidea and Papilionoidea (Order: Lepidoptera, Suborder: Rhopalocera) were sampled. A total of five butterfly families (i.e. Hesperiidae, Papilionidae, Pieridae, Lycaenidae, and Nymphalidae) were recorded during current study.

Two sampling approaches, direct search and indirect search, were used. Line transects and random forest trail/dirt tracts were walked to sample butterflies during the four seasons in April 2008 - December 2011. Opportunistic sampling was also conducted in rare habitats to increase species inventory of the area. Butterflies were sampled in areas between the elevations of 900 m - 3500 m in both PAs. All transect lengths were 300 m - 500 m (depending on different objectives) and transects were traversed on foot by single observer. Abundance data were collected when cloud cover was less than 70% and between 0900 - 1700 hrs, the most favorable conditions for butterfly flight. All butterflies seen during the transect walk in an imaginary 5×5×5 (m) box around the observer were recorded. Baited traps with a mixture of rotten bananas and beer fermented for 5 days were also employed to capture and record fruit-feeding butterflies. Baited traps were alternately placed 5 m to the left and right of transect at every 100 m. Thus, there were 3 baited traps on each of the 300 m transect.

In addition to sweep nets (**Plate 3**) and traps opportunistic sightings at mud puddles, nectar sources, and other resource rich sites was also used. Butterflies that were too fast or too distant to reliably identify during flight were not counted. Butterflies that could not be readily identified visually were either photographed or captured using a hand held sweep net and were released after identification. The few voucher specimens that we collected were deposited at the insect repository of the Wildlife Institute of India in Dehradun.

3.2.1.1Sampling Vegetation, Disturbance and Microclimate variables at Plot level for Butterflies

Vegetation data was quantified for each transect using stratified random sampling. Circular plots (10 m radius) were established at the centre of each transect at 100 m intervals to quantify trees. Circular plots (5 m radius) were established on either side (5m from center) of each transect at 100 m intervals to quantify shrubs. In each of these plots, two plots (1 m diameter) were established within the 5 m shrub plot to estimate herb abundance and grass cover. Within each vegetation plot, flowering plant species richness, average density of trees, shrubs, and herbs, grass cover and canopy cover (using canopy densitometer) were measured. Disturbance parameters, including logging, fire signs, and livestock abundance was also quantified. Fire signs (number of signs of past fire inside the plot) and logging (number of logged trees) were recorded in a 10 m radius plot at 100 m intervals at the centre of each transect. Here, livestock abundance refers to number of livestock observed on transects during sampling. Microclimatic variables, such as temperature, relative humidity (RH), and wind speed, were recorded using a digital thermometer, digital hygrometer, and digital anemometer (Forestry suppliers, USA), respectively. Topographic information, such as altitude, aspect, and slope, were also recorded on transects using an altimeter, compass, and clinometer (Forestry suppliers, USA), respectively.

3.2.2.2 Data Source for GIS Variables

Data on environmental parameters that represent different spatial themes *viz.* area, topography, climate, primary productivity, were compiled from satellite imageries. The area at 100 m interval within the study region was calculated based on global digital elevation model (DEM, GTOPO30) from the United States Geological survey's Hydro 1k dataset (http://edcdaac.usgs.gov/gtopo30/hydro), with the resolution of a grid cell of 30 x 30 m. The area is a product of grid number by grid area. Climatic variables (temperature and precipitation) used in the analysis were downloaded from worldclim online archive (http://www.worldclim.org). These data are available at 1 km resolution and in the form of monthly averaged value of last 50 years (1950 - 2000).

NDVI was used as a surrogate for primary productivity and the values were extracted from MODIS terra satellite product, available free from USGS website (http://mrtweb.cr.usgs.gov). MODIS terra satellite products are available at high temporal resolution (one day). The data used here has 1000 m resolution and are averaged for one month (period of maximum vegetation growth).

3.2.2 Moths

Two major groups of techniques have been employed in surveying moths, each with considerable individual variation. Transect count methods akin to those adopted widely for butterflies (Pollard & Yates, 1993) have been used for the diurnal taxa. More rarely and depending on biological knowledge, transect methods have been used for nocturnal moths. Spadling (1997) monitored the abundance and in conjunction with mark-release-recapture studies estimated the total population size of Noctuid moth by searching 10 m wide nocturnal transect. He emphasized that such single species surveys necessitate basic understanding of the target's biology, and identification can then become straightforward even in the dark because behavioural and other characteristic features are clear. Birkinshaw and Thomas (1999) modified this approach further, using torch-light transect surveys which was apparently effective in recording moth population data and in appraising specific habitat components along transects.

By far the most widely used method for detecting, enumerating and surveying moths have been use of light traps, in various forms and drawing on a predominant tool used by hobbyist and professionals alike. Although numerous patterns of light trap have been devised, three main patterns- with some variations encompass a high proportion of surveys: The Robinson trap, The Rothamsted trap and the Heath trap. A frequently cited advantage of light traps for nocturnal lepidoptera is that they consistently capture large numbers of individuals and a great array of species. The aims of light trap surveys for moths can differ substantially. They include targeted surveys for notable species of individual conservation interest, mapping distribution or abundance of species; estimates of local diversity; clarification of phenology, through determining flight periods etc. In short, the ecological and conservation monitoring contexts involving moths from light trap samples are both numerous and varied. The results are not always easy to interpret, because of numerous variables alluded to above and which influence the moth flight activity in many and subtle ways.

Many species of moths can easily be attracted to artificial light sources (Canaday, 1987; Muirhead-Thomson, 1991). This renders moths a very attractive group to study, particularly if large data sets are required for statistical analyses. Although the underlying physiological and behavioural mechanisms of the attraction to light are still not fully understood (e.g. Bowden, 1982), light-traps have become an important tool for taking an inventory of insects in a wide range of studies. No other trapping method has proved so consistently successful in capturing large numbers or such a great variety of species (Muirhead-Thomson, 1991). Moreover, light traps have been used for monitoring for more than 50 years (Leinonen et al. 1998). There is extensive literature detailing advantages and disadvantages of light-trapping and factors that might influence the results of this technique (Holloway et al., 2001). Three specific criticisms on the method were formulated by Schulze & Fiedler (2002): (1) Light traps sample selectively rather than randomly, (2) moths are attracted from a distance, i.e. from other habitats than those targeted, and (3) the effective attraction radius may depend on the visibility of the trap and hence be influenced by vegetation structure. Besides these issues, there are problems regarding the trap type, the site, and the influence of weather and the moon on the catches.

Moth assemblages were investigated at 22 sites situated along an altitudinal gradient between 1,200 and 3,600 m above sea level in a temperate Himalayan forest in Gangotri Landscape. Moths were attracted to light, and between two and four catches were performed at each site using two light sources: 15 W white tubes run by solar-powered batteries and 60 W Sodium vapour light run by gas petromax (**Plate 3**). The light sources were placed in front of a vertically hung white sheet so that moths arriving at the light traps can rest on the sheet. Sites with very dense vegetation were avoided. The traps were operated between 8.30 p.m. and 2.30 a.m. local time, and the catches were separated into six intervals of 30 minutes duration. Catches were restricted to periods from three days after full moon until five days before full moon. Specimens were collected manually using killing jar filled with Benzene vapour. After killing they were spread in standard manner and labelled. Specimens were sorted to morphospecies level and were identified as far as possible in the Zoological Survey of India, Kolkata and Jabalpur. Each specimen was labeled with information on locality, GPS-derived geographical coordinate and altitude data (Garmin GPS III), date and time of catch, and collector. This data, taxonomical information and sex of the specimen were entered into the database Microsoft Excel 2007.

Relative abundances of species in trap collections do not necessarily reflect relative abundances of species in a particular habitat but rather their activities (Wolda, 1992; Simon & Linsenmair, 2001). Furthermore, not all insect groups and species are attracted to light traps to the same extent (Bowden, 1982; Butler et al., 1999). Therefore, samples cannot perfectly represent all flying insects in a habitat. Even if they would, flying specimens do not inevitably represent the actual populations (Schowalter, 1995; but see Lepš et al., 1998). This problem is illustrated by the proportion of females that were collected by sampling. Only 18.7% of all analysed specimens are females. The higher proportion of males in trap catches probably reflects their higher activity when they are searching for mates. Sex biases are common in Lepidoptera samples (Pollard & Yates, 1993; Fischer & Fiedler, 2000; Holloway et al., 2001) and their interpretation does not present any difficulties. Generally, light trap samples represent a certain unknown “distortion” of the real situation. Some species might actually be more abundant than the light trap samples suggest. On the contrary, species that were found to be very abundant in samples must also be abundant in a habitat. Statistical analyses have to consider these methodological constraints.

The density of the vegetation around a light trap might be assumed to have an impact on the number of individuals and species caught. Although this assumption is plausible to a certain extent, evidence for such an impact is lacking and needs to be tested explicitly. As experienced, the effective radius of a light trap is rather small. Hence, differences in the attraction of insects can only be expected if the vegetation differs between sites within a narrow radius around the trap. In any case, dense stands of vegetation should be avoided.

3.2.2.1 Effect of Weather and Lunar Phase

There is extensive literature concerning the influence of weather factors and the phase of the moon on light-trap catches (e.g. Muirhead-Thompson, 1991; Yela & Holyoak, 1997; Holloway et al., 2001; Intachat et al., 2001). Sample size is generally known to be influenced by weather conditions such as temperature, wind and humidity (Holloway et al., 2001). For example, Persson (1976) and Yela & Holyoak (1997) found that light-trap catches decreased with mean wind speed. An increased mean temperature can be associated with an increased catch in some Lepidoptera groups (McGeachie, 1989).

To observe whether the moon phase has any significant effect on catch success, an experimental light trap set up was run on daily basis for one month period in the month of April, 2011 at an altitude of 1440 m from 20:00–24:00 hr. The result of the observed species catch and individual catch per day in a complete lunar cycle is shown in **Figure 3.1**. Most species as well as individuals were attracted in and around no moon nights and declined as the ambient moon light started to increase and came to a minimum around full moon nights when the ambient moon light was at its best.

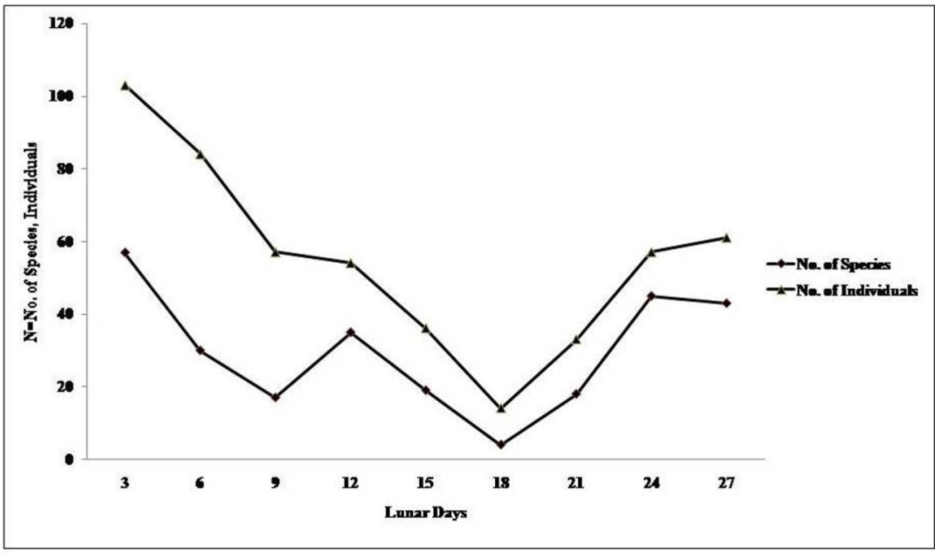


Figure 3.1: Effect of lunar phase on catch success in light trapping for moth

Yela & Holyoak (1997) from their study recommended to restrict the light trapping to periods without strong moonlight because moths are not attracted to artificial light in the presence of high ambient moonlight, though their activity remains at its peak. Our study documented the same phenomenon where maximum numbers of species as well as individuals were attracted to light traps in the beginning and end of lunar cycle, i.e. from 3rd to 6th day and 24th to 28th day when there was apparently no ambient moon light. Catch success eventually dropped as the ambient moon light started to increase and became almost zero in the full moon period from 14th to 18th day. One factor that masked this general pattern was the presence of cloud cover evident from the slightly increased catch success in 12th day when there was strong moon light but its effect was nullified by the clouds.

3.2.2.2 Vegetation and Disturbance Parameters Sampling for Moth Assemblage

Sites situated between 500m – 4000m was considered and these was split up to into three attitudinal levels ('low': 500 -1600 m; 'medium': 1700 – 2800m; 'high': 2900- 4000m). Furthermore sites were also classified based on 4 vegetation types. Out of these 12 factorial categories (altitude level x vegetation types) 4 sites per category were selected at random. To minimize the effect of observation period on the results, during the five seasons *viz.* Spring: March to April, Summer: May to June, Monsoon: July-August, Post Monsoon: September-October and Winter: November to December, one site per treatment combination (altitude x vegetation type) was visited at least once. Additionally following variables were considered as sites covariates: **Habitat Variables**: Canopy Cover, Tree Density, Shrub Density, Litter cover at Ground, Bare Soil at Ground, Grass cover at Ground, Foliage Height Diversity, Dominant Flowering Plants (Herbs, Shrubs and Grass). **Microclimatic Variables**: Ambient Temperature, Relative Humidity, Monthly Mean Precipitation, Wind Speed, Atmospheric Pressure, Cloud Cover. **Disturbance Variables**: Logging & Lopping Signs Present, Presence of Felled Trees, Presence of Grazing & Livestock, Presence of Fire Sign

Plant community of each vegetation types was sampled using a series of nested quadrats. Initially, each series was designed such that, within a vegetation type, one set of quadrates was centred on the position of the light trapping station and the remaining two was randomly located 50 m from the centre. 20x20 m quadrat was used to quantify species richness, abundance, and the diameter at breast height of all trees greater than 10 cm dbh. Canopy cover was measured using a densitometer at 8 points spaced at 10m intervals along the perimeter of each 20x20 m quadrat. Within 20x20 m quadrats two 5x5m quadrats were used to quantify species richness and abundance of shrubs and saplings. Two 1 sqm quadrats nested within each shrub plot was taken account to measure species richness, abundance, and percent cover of herbaceous layer. Plant data collected from nested quadrat sampling was used to calculate a number of variables to describe the structure and composition of each vegetation types. Diameter-at-breast-height values for the trees were used to calculate stand basal area (in units of square meter per hectare). Mean canopy cover for each stand was calculated as the average of cover estimates from each large quadrat in the series. Stand density was determined as the number of stems per hectare. To account for potential variation in species dominance among stands, the relative abundances of each plant species was used to calculate Simpson's Index of species diversity for each structural layer of the forest (e.g., tree, herb, and shrub). In addition, Importance Percentages for each tree species sampled was calculated within the vegetation community. An importance percentage is simply the mean of three relative values determined for each tree species: basal area, abundance and frequency (Greig-Smith, 1983; Bonham, 1989). The relative frequency of a given species is the number of 20x20 m quadrats within a vegetation type in which the species was sampled (n/3), providing an estimate for spatial distribution of each tree species. Importance percentages for shrub and herbaceous species were calculated as for tree species, except without basal area.

3.2.3 Coleoptera (Beetles)

Sampling procedure involved five methods; Pitfall trapping, Aerial and ground hand collection, Sweep netting, light trap and direct searching along transect. Direct searching involves looking up and down while moving along transect (50 m) and listing possible beetle species encountered. Aerial sampling involves searching leaves, branches, and tree trunks. Ground collection involves searching on hands and knees, exploring the leaf litter logs, rocks, and plants that are between low knee level. Pitfall trapping (**Plate3**) was carried out by placing a container dug into the soil in such a manner that the mouth of the container stays at the level of surface. The container was filled with 70% alcohol for preserving specimens whereas detergent was added to reduce the surface tension. Sweep netting was carried out in order to access the foliage dwelling insects. Nocturnal beetles were sampled using light traps.

3.3 Collection, Preservation and Identification of Specimens

(i) Collection Bottle

Collection bottles (**Plate 3**) were used to collect insect specimens. Usually, used jam and pickle bottles were used. Glass jar with a layer of Benzene was used. The liquid benzene was poured over a layer of cotton and filter papers or blotting papers were used to soak cotton and also to prevent the specimen from coming in direct contact with cotton. Specimens were handled carefully after catch inside killing bottle to prevent any morphological damage. Different species were allowed for different period inside bottle as keeping specimens for longer durations inside the bottle get them decolorized and stiff.

(ii) Pinning

Unidentified specimens were pinned directly by piercing pin through the body and care to choose the correct size and number of specific entomological pins (each insect pin has a specific number) to avoid damage to the internal part. Insect pins vary in diameter and length and are numbered 0, 1, 2, 3, 5, etc. the first being very slender and last most stout. Most often 0-3 size pins were used, although longer pins of 37-39 mm in length for large bodied specimens.

(iii) Spreading

It is a process to arrange the wings or elytra for taxonomic study, with the help of spreading board **(Plate 3)** which consists of two flat parallel pieces of soft wood with an inner groove lined by cork. A properly relaxed specimen with a pin thrust vertically is inserted inside the groove so that the elytra remain at level with the edge of top part.

(iv) Mounting

All collected specimens were pinned with a minute, fine pin on a piece of pith, through other end of which a longer pin is inserted. Collectors name, place and date of collection, habitat from which the specimen was collected and other necessary details on a paper label were mentioned and pinned below specimen.

(v) Preservation

Insects once collected and preserved in such a manner allow examination of the specimens even after a long lapse of time (**Plate 3**). These specimens completed *viz*. mounting, pinning and labelling with complete information of collection *viz*. date, time, location, altitude, and host plant. Specimens once mounted or pinned were arranged in drawers of insect storage cabinets and boxes which act as permanent storing place. Naphthalene balls, benzene and

Para-di-chloro benzene etc. are used for safe preservation against any pest or fungal attack in cabinets.

(vi) Identification

Butterflies

The preserved butterfly specimens were identified to 5 butterfly families (i.e. Hesperiidae, Papilionidae, Pieridae, Lycaenidae, and Nymphalidae) during current study using Wynter-Blyth (1957) and Evans (1932). In current study the recent nomenclature from Kehimkar (2008) is used be identified using relevant literature and insect repositories.

Moths

The specimens were first sorted into morphospecies and later identified with the help of the available literature and by comparison with the reference collections available at the Zoological Survey of India, Jabalpur and Kolkata. The classification used mainly follows Hampson (1892, 1894, 1895 and 1896) and subsequent changes in the families based on Kerstensen (1999). The voucher specimens were submitted to the national repository at the Zoological Survey of India. The collected moth specimens were identified to 11 Superfamiliies, 20 Families and 468 species.

3.4 Data analysis

3.4.1 Butterflies

3.4.1.1 Diversity and Inventory Completeness

Species richness estimates (non-parametric) were calculated based on individual-based species accumulation curves (Gotelli and Colwell, 2001) for assessing sampling effort and efficiency using program EstimateS (Colwell, 2009). Program EcoSim (Gotelli and Entsminger, 2004) was used to generate rarefaction curves for comparing species richness estimates between sites.

Many indices have been developed to measure and compare diversity (Magurran, 1988). Fisher's alpha of the log series was calculated as measure of total diversity using EstimateS 8.0 (Colwell, 2009). Log series-type distributions commonly occur in nature and measures such as Fisher's alpha are suitable to characterize such datasets. Fisher's alpha has also been extensively used in many other arthropod studies, thus facilitating comparisons between studies (Shochat et. al., 2004).

3.4.1.2 Community Composition and Site Similarity Analysis

Analyses for community composition were done with non-parametric tests. The ANOSIM test, (Analysis of similarities - Clarke, 1993) an analogue to the ANOVA, was employed to test for significance in the butterfly species and family composition among sampling sites using PRIMER software (Clarke and Gorley 2006). The ANOSIM results in dissimilarity values in community composition of compared groups. Importantly, the dissimilarity is calculated using the overlap of species lists and the species abundances, which makes this test appropriate for comparative community composition assessments. Before ANOSIM was executed, transformations were applied to the abundance data in order to limit the effect of zeros and the contrast of extreme high and low abundance values. Where ANOSIM revealed significant differences between groups, SIMPER analyses (PRIMER) were used to identify those species that contributed most to the observed assemblage differences (Clarke and Gorley, 2006). Similarity percentages (SIMPER) allowed identification of species and guild important in discriminating between groups that differed significantly from each other. Cumulative contributions were cut arbitrarily at 50%. The species with the highest dissimilarity to standard deviation ratios were identified as good discriminators for each comparison (Clarke, 1993).

Community-level analysis was performed using MDS (multidimensional scaling) analysis in program Primer (Clarke and Gorley, 2006) to look at the grouping between sites in ordinate space. The ordination was based on Bray–Curtis dissimilarity matrix (single link) (Bray and Curtis, 1957; Krebs, 1989) of ecological distance using both species and guild composition. Bray-Curtis resemblance matrices for butterflies were generated (Bray and Curtis 1957) and used for differences in sampling plots. The Bray-Curtis resemblance values show plot to plot combinations, and create, e.g., a 96 by 96 matrix (of which half contains values). Furthermore, the Bray-Curtis matrix expresses resemblance values varying between 0 and 1, where 0 is no resemblance and 1 means complete resemblance. Every value reflects the resemblance of one plot with another considering the species list and their abundances.

3.4.1.3 Effect of Microclimatic, Habitat and Disturbance Characteristics

Pearson correlation coefficients (r) were calculated using program SPSS (SPSS 16.0, 2007) to examine the relationship between butterfly species richness, abundance, and plot (transect) level microclimatic, habitat, and disturbance characteristics. All variables were tested for normality. Strongly skewed variables were transformed prior to analyses (i.e. butterfly, moth, and beetles species richness, abundance, and plant species richness data were square root trannsformed) to examine associations of butterfly species richness and abundance with microclimatic, habitat, and disturbance variables.

3.4.2 Moth

3.4.2.1 Diversity and Inventory Completeness

Moths captured by light trapping at a single site for 2-3 nights were pooled for quantitative analysis. For structural composition within the family Geometridae, proportion of subfamilies was calculated from species number as well as from specimen number. The species richness of moths of each vegetation zone, as well as of the regional data set, was measured according to the following four methods (i) Species number: The absolute species number can never be the measure of diversity, particularly for such hyperdiverse taxa such as moths as it never incorporates different sampling sizes or efforts (Colwell & Coddington 1994) (ii) To avoid sample size dependence, using an extrapolation method, non-parametric estimators such as Chao 1 and Jackknife were estimated. Chao1 gives an estimate of the absolute number of species in an assemblage based on the number of rare species (singletons and doubletons) in a sample. Chao1 estimation of species richness is recommended for inventory completeness values, completeness being the ratio between the observed and estimated richness (Sørensen et al., 2002; Scharff et al., 2003). Jackknife estimators in general, and Jackknife2 in particular, have been found to perform quite well in extrapolation of species richness, with greater precision, less bias and less dependence on sample size than other estimators (Palmer, 1990, 1991; Baltanás, 1992; Brose et al., 2003, Petersen et al., 2003; Chiarucci et al., 2003). (iii) An individual based rarefaction curve was used to obtain an idea about the species richness and sampling success across different habitat categories. This method is particularly useful if assemblages are sampled with a different intensity or success. These curves standardize different data sets on the basis of the number of individuals and not on the number of samples. The curves were rarefied to the lowest number of individuals recorded in a vegetation type (198) to ensure valid comparisons of species richness between different sites (Gotelli & Colwell, 2001). Rarefaction was used as a diversity index because it considers the number of individuals collected and species richness (Magurran, 2004), allows comparison of diversity between sites with a similar sample size, and, by showing the rate of new species accumulation, allows verification that enough samples were collected to make proper comparisons of diversity (Gotelli & Colwell, 2001; Magurran, 2004; Buddle et al., 2005). (iv) The most reliable method for calculating the alpha diversity when it is impossible to obtain a complete inventory due to the presence of maximum singletons and doubletons is the use of Fisher's alpha of the log series distribution (Fisher et al., 1943). It has been widely used in tropical arthropod diversity studies. It is efficient in discriminating between habitats and is mainly influenced by the frequencies of species of medium abundance (Kempton & Taylor, 1974).

All measures of alpha diversity were tested for their sample-size independence. All the analyses were performed separately for all the moths sampled, for Geometridae family level and at the level of two largest subfamilies Ennominae and Larentiinae. Spearman rank correlation coefficient was used and multiple tests of significance were Bonferroni corrected.

Recent approaches to community analysis have utilized ordination techniques that identify ecological or environmental gradients that can be further investigated to understand the main factors affecting community composition (ter Braak, 1995). In other words, ordination methods are used for pattern description rather than hypothesis testing (following James & McCulloch, 1990). The evaluation of a site for conservation or environmental impact assessment usually involves an estimate of species richness and diversity. There is a long history of measurements of species richness and diversity, reviewed by Magurran (1988), used specifically for moths by Waring, and most recently reviewed and updated by Gray (2000). Gray (2000) recommended three indices for characterizing the species diversity of a community; total species richness, the reciprocal of Simpson's index - primarily a measure of dominance according to Whittaker (1972) and less sensitive to rare species (Magurran, 1988) - and *exp*(H'), where H' is the Shannon-Wiener index, which is more strongly influenced by species from the centre of a ranked sequence of species in a sample (Gray, 2000). For moths, Fisher's diversity index (α), has been used to estimates diversity using species abundance in a log-series (Kempton & Taylor, 1974, Magurran, 1988; Waring, 1990). Pielou's evenness measure (*J*') indicates the degree of evenness of individuals' abundance amongst species from a sample (Magurran, 1988), although Gray (2000) noted that the Berger-Parker index is now being used as well.

3.4.2.2 Indicator Species Analysis

Indicator species are of use for environmental assessment and conservation monitoring, as analysis is based upon correspondence analysis (CA) (Minchin, 1987) and detrended correspondence analysis (DCA) (Hill & Gauch, 1980), methods already shown to be inappropriate for the data used in this study. A newer approach, Indicator Species Analysis (ISA) (Dufrene & Legrande, 1997) is based upon intra-specific comparisons amongst sites and takes no account of how other species might affect that species. This study aims to identify species likely to be indicative of particular habitats using ISA, thus allowing sites to be readily evaluated for EIA or conservation by the presence of one or more indicator species.

Insect Sampling Methodology and Collection, Preservation

Swipe Netting

Light Trapping

Swipe Net & Collection Bottle

Pitfall Trapping

Pinning and Spreading

Long term preservation

Plate-3

CHAPTER 4

FAUNISTIC INVENTORY AND SAMPLING EFFICIENCY

4.1 Introduction

Lepidoptera (butterflies and moths) is a diverse order of class Insecta with about 1,80,000 described species, compared with may be 1,413,000 species of all organisms described (Wilson 1992), around 10% of all described species of living organisms (Kristensen, 1999) in the world. Whereas, a total of 17,500 species of butterflies have so far been reported from the world (Ackery et al., 1999) and rest of them are moths. Butterflies represent around 1% of all species known. Nearly half of all butterflies (about 7500 species) are estimated to be in the new world tropics (Heppner, 1991; Lamas 1997; Robbins and Opler, 1997). A total of 1200-1300 species are found in Oriental region. World moths are distributed among 30 superfamilies, 117 families and nearly 1,27,000 species have been described so far (Alfred et. al., 1998). 18 superfamilies had been described from India so far with 7,014 species representing 84 families. Largest families of moth such as Noctuidae (35,000 species) and Geometridae (21,000 species) thus include more species than whole of butterflies. Coleoptera is the largest order of class insecta and more than one out of every four named species is a beetle and out of about 8,00,000 described species of insects, coleopteran share about 3,45,000 species. The beetles are found in abundance in tropical and subtropical parts of the world, which receive good precipitation and have substantial vegetation cover. Great ecological diversity and varied vegetative covers have contributed to diversified beetle fauna of India, which holds about 5% of the world fauna comprising about 17,000 species (Pal, 2003).

4.2 Butterflies

4.2.1 Inventory of Butterflies and Inventory Completeness in Gangotri landscape

We recorded a total of 1639 butterfly individuals representing 34 species 29 genera and five families during the study in Gangotri NP (**Appendix 4.1**). A total of 159 species representing 92 genera in 5 families were recorded in Govind NP, WLs and adjoining area of Tons valley in Gangotri landscape (**Appendix 4.2**), (**Plates 4-14**) during entire sampling period from April 2008 to March 2012. Of all the species, 44.7% were Nymphalidae followed by Lycaenidae (24%). For family Hesperiidae very low species richness was observed (14 species and 6.7% of total butterfly species richness).

We calculated six estimators of species richness. Estiamtes of species richness of ACE and Chao1 were the largest estimates of species richness at Gangotri landscape. These estimators are generally agreed to be used for inventory completeness values, giving the ratio between observed and estimated richness (Sorenson et al., 2002; Scharff et al., 2003). Estimates of species richness produced by Chao1 are a function of singletons and doubletons and will exceed observed species richness by greater margins as the relative frequency of singletons and doubletons increases. Chao1 measures are especially sensitive to patchiness, and were effective in cases where species were randomly distributed (Magurran, 2004). Using ACE and Chao1 estimate (largest estimates) for inventory completeness we detected 77-80% of the estimated species richness in Gangotri NP and 96% in Govind NP, WLS and some part of the Tons valley. The pooled accumulation curve reached an asymptote for all the estimators (**Figure 5.2**), indicating that sampling was almost complete at regional level. Regional inventory completeness was around 96% (**Table 5.1**), which can be suggested as exhaustive sampling.

4.2.2 Description of Butterfly families

General appearance, natural history, biology and host plants of families and subfamilies of butterfly sampled in Tons valley are described below is adapted from Evans (1937, 1949, 1951, 1952, 1953, 1955), Talbot (1939, 1947), Ehrlich, (1958), Munroe (1961), Emsley (1963), Miller (1968), Eliot (1969, 1973, 1986), Kristensen (1976) and Common and Waterhouse (1981).

Superfamily Papilionoidea

The true butterflies are composed of five families - Papilionidae, Pieridae, Nymphalidae, Riodinidae and Lycaenidae. There are estimated to be some

13,700 species in the world (Robbins, 1982), distributed on every continent except Antarctica, and most remote oceanic islands as well. The greatest diversity occurs in tropical regions, particularly the Neotropics. Kristensen (1976) suggests two characters for the Papilionoidaea; wing coupling amplexiform in both sexes and antennae with apical clubs. There are four families included as Papilionidae, Pieridae, Lycaenidae and Nymphalidae. The "true" butterflies are composed of five families - Papilionidae, Pieridae, Nymphalidae, Riodinidae and Lycaenidae. There are estimated to be some 13,700 species extant in the world (Robbins, 1982), distributed on every continent except Antarctica, and most remote oceanic islands as well. The greatest diversity occurs in tropical regions, particularly the neotropics. A total of 150 species belonging to 4 families were recorded from the Gangotri landscape (including Gangotri NP, Govind NP and WLS and part of Tons valley) (**Appendix 4.1 and 4.2**).

I. Family Papilionidae (Swallowtails and Apollos)

The Papilionidae belong to the Superfamily Papilionoidea, the true butterflies. Swallowtails are worldwide in distribution and comprise approximately 625 species (Ackery et al., 1999). About 84 species are reported from Indian region. The family includes the largest butterflies in India (Golden Birdwing – *Troides aecus*).

The Swallowtails are large, bright butterflies; many are black and yellow bearing one or two long tail-like extensions off the rear of the hind wing. They are often black and yellow in colour. Members of this family are generally characterized by: a unique pattern of wing venation on the fore and hind wing; pretarsal arolium and pulvilli reduced; third anal vein of forewing free to the margin and uppermost bundle of thick metathoracic inner dorsal longitudinal muscle almost vertical. Eggs of both Swallowtails and Parnassians are generally round, green, dome-shaped, smooth or obscurely facetted, not as high as wide, somewhat leathery and opaque. The young caterpillars of Swallowtails often look like a bird dropping while older caterpillars are often greenish and marked with large eyespots. They are equipped with an osmeterium, a Y-shaped gland located behind the head which can be pushed out to emit a chemical disagreeable to potential predators. The Parnassian caterpillars vary in appearance but are often black, and they may be equipped with an osmeterium. Swallowtail pupae form no cocoon, often have both a cremaster and a silk girdle, and typically are the overwintering stage. Parnassian pupae generally are in a loose cocoon located on the ground in leaf litter; the egg and the caterpillar are the usual overwintering stages. Other traits of swallowtails include a behaviour called hill topping, in which males and females congregate at the tops of slopes, trees or ridges in their effort to locate a mate.

II. Family Pieridae (Whites and Yellows)

Family Pieridae contains about 1050 species in 74 genera (Ackery et al., 1999) throughout world. The family is characterized by distinctly bifid pre-tarsal claws. Pronotum with medio-posterior membranous cleft. Lateral ‘pre-spiracular bar’ absent in the abdominal base. Wing scales containing pterine-type pigments. Most pierid butterflies are white, yellow or orange in coloration, often with black spots. The Pieridae have the radial vein on the forewing with 3 or 4 branches and rarely with 5 branches. The fore legs are well developed in both sexes, unlike in the Nymphalidae, and the tarsal claws are bifid unlike in the Papilionidae. The pigments that give the distinct colouring to these butterflies are derived from waste products in the body and are a characteristic of this family. The sexes usually differ, often in the pattern or number of the black markings. Superficially the larvae of the Pieridae look remarkably uniform. A single general description probably suffices - larva cylindrical, slightly tapering posteriorly and also laterally in later instars; shortly setose or pubescent, usually cryptic. Four subfamilies are identified globally (Ehrlich, 1958)

Like the Papilionidae, Pieridae also have their pupae held at an angle by a silk girdle, but running at the first abdominal segment unlike the thoracic girdle seen in the Papilionidae. Males of many species exhibit gregarious mud-puddling behaviour, when they may imbibe salts from moist soils.

III. Family Lycaenidae (Blues, Coppers and Hairstreaks)

More than 5650 species in about 705 genera (Ackery et al., 1999) are found with cosmopolitan distribution although greatest diversity is found in the tropics. There are five main subfamilies represented in India: Polyommatinae, Lycaeninae, Curetinae, Portiinae and Theclinae. A few authorities still include the family Riodinidae within the Lycaenidae. Antennal bases adjacent to the margin of the eye. Frontoclypeus usually less arched than in other butterflies. Patagia entirely membranous and adult individuals often have hairy antenna-like tails complete with black and white annulated appearance. Many species also have a spot at the base of the tail and some turn around upon landing to confuse potential predators from recognizing the true head orientation (false head hypothesis). This causes predators to approach from the true head end resulting in early visual detection. Adults are small, less than 5 cm usually, and brightly coloured, sometimes with a metallic gloss. The male's forelegs are reduced in size and lack claws but full-sized forelegs in females. Most of the Hairstreaks have a thin tail extending from the rear of the hindwing.

Eggs generally appear round and flattened. Caterpillars generally are small, shaped like slugs, and hairy. Larvae are often flattened rather than cylindrical, with glands that may produce secretions that attract and subdue ants. Their cuticles tend to be thickened. Some caterpillars are capable of producing vibrations and low sounds that are transmitted through the substrates they inhabit. They use these sounds to communicate with ants. The caterpillars of many of the species of blues and hairstreaks have a dorsal nectary organ which produces a sugary solution agreeable to ants. The ants feed on the solution and in turn protect the caterpillar from predators (a tending behaviour). Pupae are generally small and round, may have a silk girdle, and are located near or on the ground. Generally no cocoon is formed. The pupa may have a nectary organ as well, allowing it to be tended by ants. Overwintering occurs as the egg, caterpillar, or pupa.

IV. Family Nymphalidae (Brush-footed Butterflies)

About 5600 species in 650 genera (Ackery et al., 1999) are distributed worldwide, approximately 30% of all butterflies and only competed by Family Lycaenidae in species numbers. Male forelegs always atrophied and clawless. Most antennal segments with two ventral grooves and very distinct separation of upper laterocervico-tentotrial muscles into bundles.

Many species are brightly coloured and include popular species such as the emperor, admirals, tortoiseshells and fritillaries. However, the underwings are in contrast often dull and in some species look remarkably like dead leaves, or are much lighter; producing a cryptic effect that helps the butterfly disappears into its surroundings. The forewing has the submedial vein (vein 1) unbranched and in one subfamily forked near base; medial vein with three branches, veins 2, 3 and 4; veins 5 and 6 arising from the points of junction of the discocellulars; subcostal vein and its continuation beyond apex of cell; vein 7, with never more than four branches, veins 8–11; 8 and 9 always arising from vein 7, 10 and also 11 sometimes from vein 7 but more often free, i.e. given off by the subcostal vein before apex of cell. The hindwing has internal (1a) and periosteal veins. The cell in both wings closed or open often closed in the fore, open in the hindwing. Dorsal margin of hind wing channeled to receive the abdomen in many of the forms. Antennae always with two grooves on the underside; club variable in shape. Throughout the family the front pair of legs in the male and with three exceptions (Genus: Libythea, Pseudergolis and Calinaga) and in the female also, is reduced in size and functionally impotent. In some the sub-families atrophy of the forelegs is considerable, e.g. Danainae and Satyrinae. In many of the forms of these subfamilies the fore legs are kept pressed against the underside of the thorax, and are in the male often very inconspicuous. Pupae usually suspended from cremaster at the abdominal tip.

Superfamily Hesperioidea

Neither the Papilionoidea nor the Hesperioidea has a convincing array of autapomorphies. Kristensen (1976) provide the following character for the

Hesperioidea – forewing with no stalked peripheral veins; forewing with cubito-parietal absent; antennae with subapical thickenings. There is only one included family – Hesperiidae.

V. Family Hesperiidae (Skippers)

At global scale, Hesperiidae is represented by about 3435 species into 545 genera (Ackery et al., 1999) into to six subfamilies, of which 130 are found in oriental region. A total of 14 species are found in study area. Butterflies belonging to this family are known as skippers because these butterflies exhibit a rapid, erratic, skipping flight pattern. Skippers have the antennae clubs hooked backward like a crochet hook, while the typical butterflies have club-like tips to their antennae, and moth-butterflies have feathered or pectinate (comb-shaped) antennae similar to moths. They also have generally stockier bodies and larger compound eyes than the other two groups, with stronger wing muscles in the plump thorax, in this resembling many moth species.

Some have larger wings, but only rarely as large in proportion to the body as in other butterflies. When at rest, skippers keep their wings usually angled upwards or spread out, and only rarely fold them up completely. There are some with prominent hind wing tails, and others have more angled wings; the Skippers basic wing shape varies not much by comparison to Papilionoidea. However most have a fairly drab coloration of browns and greys; some are more boldly black-and-white. Generally, they lay dome shaped eggs, red or white. Eggs are laid generally singly on the underside of leaves or large grass blades and usually towards tip. Caterpillars in this family are usually with smooth body skin, more or less cylindrical shaped. Their head is large with constricted head and usually live and feed in concealed environment. They live and pupate in shelter build using silk to draw together the leaves of host plant.

A total of 9 species belonging to 8 genera and 4 families were recorded from the Gangotri landscape (including Gangotri NP, Govind NP and WLS and part of Tons valley) (**Appendix 4.1 and 4.2**).

4.3 Moths

Description of Moth families

We recorded a total of 468 species of Moth from Gangotri Landscape area, covering both the protected areas representing 11 superfamilies and 20 families (**Plate 15 - 51**) during entire sampling period from April 2009 to November 2012.

Superfamily Pyraloidea

The Pyraloidea (pyraloid moths) are a superfamily containing about 16,000 described species worldwide (Munroe & Solis, 1998), and probably at least as many more remain to be described. They are generally fairly small moths. This superfamily used to contain the Hyblaeidae, Thyrididae, Alucitidae (plus Tineodidae), Pterophoridae, and Pyralidae. Currently, the Crambidae are usually separated from the Pyralidae, but the first four families are now each split off as a distinct superfamily. Some genera (e.g. Hydriris, Micronix and Tanaobela) still defy easy classification and have been variously assigned to the Crambidae or the Pyralidae. Among all Lepidoptera, pyraloids show the most diverse life history adaptations and as a result are an ideal group for biodiversity studies (Schulze & Fiedler, 2002).

We encountered two families under this superfamily in Gangotri Landscape, Pyralidae and Crambidae.

Family Pyralidae

- Head usually smooth, sometimes rough-scaled
- Wings held in many different poses, sometimes out at right angles to the body and horizontally, sometimes steep roof-wise, sometimes flattened roof-wise, sometimes rolled about body
- Antennae usually simple but sometimes pectinate, usually about half length of wing, but sometimes very short or long
- Antennae often held back over wings or body and together but sometimes along leading edge of forewing

- If wings held back at rest then hindwing often without intricate pattern and broader than forewing but if wings held out then the hindwing may be patterned and no broader than the forewing.

This is one of the mega-diverse families of moths and the adults adopt many postures, behaviours and biologies. They are technically easily distinguishable from other moths by usually having a scaled base to the proboscis (found otherwise in the gelechioid families), abdominal hearing organs, and often visible maxillary palpi in addition to the prominent labial palpi that usually protrude forward directly in front of the head, although they are sometimes large and ascending. The legs may be long and fragile, or short. The pupal shell is extruded from the cocoon on emergence of the adult.

The family is globally represented by 5 subfamilies, *viz.* Chrysauginae, Epipaschiinae, Galleriinae, Phycitinae and Pyralinae. From Gangotri Landscape we recorded species only from subfamily Phycitinae which stands out even by standards of their family with over 600 genera considered valid and more than 4000 species described. They unite up more than three-quarters of living snout moth diversity. Together with the closely related Epipaschiinae, they are apparently the most advanced lineage of snout moths. In general, Phycitinae are smallish and slender-bodied moths, resembling fungus moths (family Tineidae) in appearance, though they have the well-developed proboscis typical of snout moths and in many cases also the tell-tale "snout" consisting of elongated and straight labial palps.

We were able to record 7 genera and 8 species under this subfamily from Gangotri Landscape Area.

Family Crambidae

- Wingspan usually 10-35 mm
- Proboscis with scales at base
- Tympanal organs (ears) at base of abdomen ventrally and 'opened' anteriomedially
- Larvae are stem borers, root feeders, leaf tiers, and leaf miners

They are quite variable in appearance, the nominal subfamily Crambinae (grass moths) taking up closely folded postures on grass stems where they are inconspicuous, while other subfamilies include brightly coloured and patterned insects which rest in wing-spread attitudes. In many classifications, the Crambidae have been treated as a subfamily of the Pyralidae or snout-moths. The principal difference is a structure in the ears called the praecinctorium, which joins two tympanic membranes in the Crambidae, and is absent from the Pyralidae. The latest review by Munroe and Solis, in Kristensen (1999) retains the Crambidae as a full family.

There are about 11,630 described species in 15 subfamilies in the world. From GLA, we recorded 5 subfamilies, 18 genera and 21 species.

The Scopariinae is a small subfamily with 3 genera described from India. They are characterized by well developed and dialated maxillary palpi with scales at extremity. The larvae are recorded to feed primarily upon grass, mosses and lichens. We recorded single species from GLA.

The subfamily Crambinae currently includes over 1,800 species worldwide. The larvae are root feeders or stem borers, mostly on grasses. A few species are pests of grasses, maize, sugar cane, rice, and other Poaceae. The monophyly of this group is supported by the structure of the tympanal organs and the phallus attached medially to the juxta. We recorded 2 genera of Crambinae from GLA.

The members of the subfamily Spilomelinae were formerly included in the Pyraustinae as tribe Spilomelini; furthermore taxonomists' opinions differ as to the correct placement of the Crambidae, some authorities treating them as a subfamily (Crambinae) of the family Pyralidae. If that is done, Spilomelinae is usually treated as a separate subfamily within Pyralidae. The Spilomelinae are believed to be polyphyletic; many genera are only tentatively placed here even at this point. With nearly 3,800 described species worldwide, this is the most speciose group among pyraloids. We recorded 10 genera and 13 species from GLA.

The subfamily Pyraustinae is a large subfamily with over 1400 species described, majority of them tropical. Many species have larvae that bore into stems and fruit of plants, and several are serious agricultural pests. We recorded 4 species from GLA.

The subfamily subfamily Nymphulinae has aquatic larvae with tracheal gills for living in still or running fresh water. This small and rare subfamily is represented by 1 genus and 1 species from GLA.

Superfamily Pterophoroidea and Family Pterophoridae

The superfamily Pterophoroidea is a unique group of slenderly built moths with long legs and narrow and fissured/clefted wings. The forewing may have one, sometimes two and rarely three clefts, whereas the hindwing is always clefted twice. The moths referred to this superfamily are commonly called the Plume-moths. Except from Meyrick and Fletcher in early parts of twentieth century, no concrete attempt has been made to collect and study these moths from India. The fact remains that due to their being smaller in size and difficult to handle taxonomically, this group of moth poses serious problems in collection and identification.

- Smooth head
- Wings held out at right angles to body at rest and horizontally high up off the substrate
- Antennae simple, fairly short and held out in front of head, horizontally and at a 90-degree angle to each other
- Long, thin body with very long and fragile legs
- Wings narrow, forewings deeply cleft once, hindwings deeply cleft two or three times

These are extremely fragile moths sometimes active in the day or at early dusk but some also come to light at night. The larvae feed on flowers or occasionally on leaves openly during the day and have numerous small hairs on them. We recorded three species from GLA, all of them by light trapping.

Superfamily Zyganoidea and Family Zyganidae

Zygaenoidea is the superfamily of moths that includes burnet moths, forester moths, and relatives. This superfamily in many respects appears to straddle the gap between butterflies and moths - they are brightly coloured, fly in sunshine, and have clubbed antennae; but they rest with the wings folded down, and they pupate in silk cocoons. The superfamily is divided into 13 families. Some of these, e.g. Dalceridae, Limacodidae & Megalopygidae, are comprised of mostly nocturnal species - these are usually drab in colour, and have feathered antennae. Others including Zygaenidae are day-flying, brightly coloured, with unfeathered antennae that are swollen at the tips like those of butterflies.

The Zygaenidae comprises of about 1,000 species, found mainly in the tropics. The moths generally have a metallic blue or green sheen, and many of the species have prominent red spots on the forewings, and red hindwings. These bright colours are a warning to predators that they are poisonous - their bodies contain levels of hydrogen cyanide that are lethal to small birds.

We recorded 6 species from GLA.

Superfamily Cossoidea

Cossoidea is the superfamily of moths that includes carpenter moths (Family Cossidae), Dudgeoneidae – dudgeon moths and relatives. Like their likely sister group Sesioidea they are internal feeders and have spiny pupae with moveable segments to allow them to extrude out of their exit holes in stems and trunks during emergence of the adult. The Limacodidae are sometimes included here as a third family.

Family Cossidae

- Rough-scaled head; small compared to body.

- Male antennae very short, pectinate, pectinations rapidly shortening halfway along, rarely long all the way to tip.
- Antennae held back under forewings at rest
- Tibiae with spurs absent or minute.
- Wings held roof-wise. Wings narrow for the size of the moth
- Palpi very small
- Proboscis absent or greatly reduced

Most cossids are brown, grey or white, often finely speckled with a net-like pattern and with a characteristic black and iridescent blue inverted ‘V’ on the thorax. The eggs may be large and placed in small batches, or small and deposited in large numbers in crevices in trees and covered with a glutinous secretion that later hardens.The young larvae, on hatching, often disperse on strands of silk carried by the wind. The larvae are borers in stems, branches, trunks, butts or roots of trees or shrubs. They usually bore singly but a few are communal. In most cases, they bore into the centre of the trunk to provide a shelter, and the larva feeds in an entrance vestibule intersecting the bark and sapwood. As the plant tries to repair the tissue the larva continues to graze, remaining inside the tree with only a small hole to the outside to expel droppings.

Larvae normally bore upwards and pupate in the tunnel after scoring the bark at the entrance to aid the escape of the moth. Even for the giant species, larval life is rarely more than two or three years. The pupal shell protrudes from the trunk after the emergence of the moth.

There are about 670 species worldwide. We recorded 3 genera and 4 species from GLA and all four species are universally distributed.

Family Limacodidae

- Head rough-scaled, often small compared to body
- Wings held steeply roof-wise over body
- Antennae in male short, pectinate, with pectinations shortening rapidly towards tip

- Antennae held back along leading edge of wing at rest
- Wings short and very broad and covered in slightly ‘fluffy’ scales
- Body short and stout and covered in long hair scales and wings

These moths usually have no proboscis; their labial palpi are small and directed forwards. The larvae are well known for their bright colours, flattened slug-like shape and the ability of some to sting if handled. They feed openly on the leaves of a wide range of foodplants. They pupate in impressively neat cocoons, almost spherical in shape, and spun on twigs. Some pupate in the litter, also in almost spherical cocoons. To emerge, the pupa pushes up a cap prepared by the larva, and the pupal shell is protruded on emergence. The unique cup shape of the cocoon minus cap gave rise to the common name “Cup Moths”. There are over 100 species recorded worldwide so far. We recorded 8 species from GLA.

Superfamily Totricoidea and Family Totricidae

Tortricoidea is the superfamily of leaf roller moths.

- Head usually smooth-scaled
- Wings held flat roof-wise or rolled about body
- Antennae simple, held back along leading edge of the wing
- Forewing near base often strongly curved
- Palpi projected forward directly in front of head
- Both wings broad with short scale fringes
- Hindwing often slightly pointed near front edge

The family Tortricidae contains the codling moth and oriental fruit moth both serious pests, particularly of fruit. Most adult tortricids come readily to light but there are a small number of diurnal species. The larvae are typically ‘leaf-tiers’: they silk leaves together and live and feed in the shelter so formed. Some are borers in stems, cones, under bark, in seeds, and many are borers in fruit. One group feeds on dead leaves on the forest floor. Most live solitarily, a few live in large communal webs. They pupate in the larval shelters from which the pupal shell protrudes when the moth emerges. The family is found worldwide with more than 5000 species.

The Tortricids include many economically important pests, including codling moth which is considered to be the single most important group of insects that feed on apple, both economically and in diversity of feeding niches found on fruit, buds, leaves and shoots. We recorded 4 species from GLA.

Superfamily Uranioidea and Family Uraniidae

This superfamily contains one family, Uraniidae, with three subfamilies, Uraniinae, Micrniinae and Epipleminae. The Epipleminae have been treated by most authors as a separate family and with Uraniidae, were referred either to the Geometroidea or to the Uranioidea. However Minet (1983) distinguished the Uraniodea from Geometroidea and assigned the Uraniinae, Microniinae and Epiplemiinae to one family, the Uraniidae, basing his conclusions on the structural features of the tympanal organ of the adults.

The Uraniidae are distinguished from other families with abdominal tympanal organs and by the sexual dimorphism of these organs; they are present at the base of the abdomen in the female and at the junction of the second and third abdominal segments in the male.

- Small to very large moths with broad wings
- The head is small and smooth-scaled, without ocelli
- Head is with a pair of large chaetosemata
- The antennae are filiform in females, but thickened, dentate and pectinate in males
- Proboscis is present and unscaled
- The forewing is broad and triangular, without a basal area of wing-locking microtrichia
- The hind wing is often as broad as the forewing, but is sometimes narrower

- The margin of the hind wing is dentate and produced into one or two tails in Uraniinae

  The family is widely distributed on a world basis, but is mainly tropical and subtropical. The family includes more than 650 species in some 40 genera. We recorded two subfamilies, Microniinae and Epiplemiinae from GLA.

  The subfamily Microniinae consists of species with white, creamy white or greyish white wings, the hindwing usually tailed or angled at M3, often with black spots associated. The flight of the adults is laboured, conspicuous, normally crepuscular or nocturnal. When disturbed by day, they flutter slowly for awhile before alighting on or underneath a leaf. We recorded two species from GLA.

  The Epiplemiines are very much smaller than most members of the other subfamilies. The subfamily is pantropical, extending only weakly into temperate zones. However, it has a much greater representation in montane zones than do the other subfamilies. We recorded 7 species from GLA.

Superfamily Geometroidea and Family Geometridae

Only one family, Geometridae, is referred to the superfamily Geometroidea following Minet (1983), who based his decision on the structure of tympanal organ. Many authors have included several other families, such as the Drepanidae and Uraniidae, which have tympanal organs at the base of the abdomen.

Geometridae is one of the largest families of Lepidoptera and are distributed throughout the world. Munroe (1982) estimated that some 20,000 species, referred to at least 1,500 genera, belong to this family.

- Smooth or rough-scaled head

- Wings usually outstretched from body pressed flat against the substrate, but sometimes back along body roof-wise or rolled about body, and a few with wings held upright together like butterflies
- Antennae in male usually pectinate, sometimes pectinate in female but usually simple, antennae held back under forewing when at rest
- Wings very broad and only rarely with forewings narrower than hindwings
- Usually with intricate patterns on both fore and hindwing, rarely without pattern on hindwing and then hindwings covered at rest
- Wing pattern usually consists of a large number of wavy more or less parallel lines crossing the wing and without prominent circles.

The geometridae are a varied group, but most have broad, rather triangular forewings and rather light, slender bodies, enabling low-energy flight rather than power and speed. Many species fly at dusk, before light traps are fully affective, and are best searched for with a net, or by trapping vegetation to disturb them by day. Many come readily to light, but sometimes only late at night, and some have dawn or daytime flight. Many Geometrids have functional tounges and can drink moisture, but relatively few can be found reliably by searching flowers or by trying to attract them to sugary baits, probably because low energy flighty requires less frequent refuelling. Another distinguishing feature of the family is that the caterpillars have only two pairs of hind legs, or prolegs, situated at the rear end. The central region of the body has no legs and is looped up when the caterpillar moves, drawing the hind end up to the three pairs of legs at the head end.

There are five main subfamilies: Ennominae, Geometrinae, Larentiinae, Sterrhinae and Oenochrominae.

The subfamily Ennominae is the largest subfamily with some 9,700 described species in 1,100 genera. They are usually fairly small moth species, though some (such as the Peppered Moth) grow considerably larger. The group has a wide ecological range, occurring in diversity at all except very high latitudes and, in the tropics, altitudes. The subfamily also includes several species that appear to fly predominantly in the forest understorey. Ennominae are therefore highly suitable as an environmental indicator group except for poor representation in open habitats. This subfamily has a global distribution. It includes some species that are notorious defoliating pests. This subfamily was represented by 71 species from GLA and hence the largest subfamily representation for all the taxa sampled.

The nominate subfamily Geometrinae is strongly split, containing a considerable number of tribes of which most are presently very small or monotypic however. These small moths are often a light bluish green, leading to the common name of emerald moths, though a few species called thus are also found in the tribe Campaeini of the Ennominae. There are about 2,300 described species, mostly from the tropics. We recorded 26 species from GLA.

Larentiinae moths contain roughly 5,800 species and occur mostly in the temperate regions of the world. They are generally divided into a few large or good-sized tribes, and numerous very small or even monotypic ones which might not always be valid. Well-known members are the "pug moths" of the Eupitheciini and the "carpets", mainly of the Cidariini and Xanthorhoini. This subfamily tends to predominate over other groups of geometridae with increasing latitude. In the tropical region this same trend is observed with increasing altitude. We recorded 22 species from GLA.

The subfamily Sterrhinae characterized by only adult feature that appears to be general to almost all tribes is a hindwing discal spot with pale markings in a darker surround, the pale colour distinct from that of the general ground colour. Covell (1987) mentioned the presence of black discal spots on both wings, and indeed they are of more general occurrence than in other subfamilies, but pale centering is unusual. We recorded 9 species from GLA.

The subfamily Oenochrominae is poorly represented in GLA with single species recorded. Some consider it as most primitive subfamily of geometridae from the point of wing venation.

Superfamily Drepanoidea and family Drepanidae

Hooktip moths of family Drepanidae comprises 812 species worldwide, but they are predominately Oriental (647 sp.); none are known for the Neotropics and only a few are in the Nearctic; the actual fauna probably exceeds 950 species. Three subfamilies are known: Drepaninae, Oretinae, and Nidarinae (the latter only from Madagascar). The family is in the superfamily Drepanoidea.

- Adults small to medium size (18-66 mm wingspan)
- head scaling normal
- haustellum small or absent in some species;
- maxillary palpi vestigial;
- antennae bipectinate to filiform; body sometimes somewhat robust.
- Wings broadly triangular, usually with the forewings falcate; hindwings mostly rounded
- Maculation mostly shades of brown to yellow with various markings, sometimes more colorful, or hyaline to white with tan bands.
- Adults nocturnal. Larvae are leaf feeders

Few species rest with their wings in a rather tent like position, others hold them flat to the surface. Some fly by day or are sometimes disturbed from among the foliage of the larval foodplants, or netted on the wing at dusk. However, they are most frequently encountered in light trap. Some adults are able to feed, with a rather short tongue and do not visit flowers. The larvae of many species are very distinctive, tapering to a point at the tail and usually resting with both head and tail raised. They usually feed on the leaves of trees and shrubs, pupating between leaves spun together with silk. We recorded 9 genera and 11 species from GLA.

Superfamily Bombycoidea

This superfamily, as currently recognized, groups together many families of large moths associated primarily because of various specialized trends in each family which unfortunately are neither found universally in the group, nor restricted to it. These include the reduction or loss of many structures which are present in other superfamilies. This has usually been associated with the development of very broad wings, in which the anal field of the hind wing is not folded when the insect is at rest, large bipectinate antennae, especially in males and the ability of the larva to spin elaborate cocoon. They have specialized in sedentary behaviour, are mostly unable to feed or drink, and are short-lived. They lay large eggs almost anywhere and all have broadly pectinate antennae in the male with the pectinations usually long until the tip of the antenna. The females emerge from the cocoon with almost all their eggs ready to lay and are often much larger than the males. The males can detect the scent of the female with great efficiency—females may call males from up to a kilometer away. They have also specialized in strong extensive cocoons of silk; almost all the moths whose silk is used by humans come from this group.

On these characters alone, therefore, there is no indication that the superfamily is monophyletic, a natural grouping.

The families of Bombycoidea in South-East Asia are the Bombycidae, Eupterotidae, Lasiocampidae, Brahmeidae and Saturniidae.

Family Bombycidae

- “Furry’ or ‘woolly’ moths with head and body well covered in long hair-like scales
- Wings held partly out but flattened at rest
- Antennae in male very short, broadly pectinate to the tip, never bent
- Antennal pectinations ‘droop’downwards
- Antennae held back under wings at rest
- Wings broad

- Hindwings not nearly as large as forewings and usually with little pattern of colours
- The folded part of the hindwing next to the body has an enhanced colour pattern
- Females usually with very large bodies in which almost all eggs are ready to lay when the moth emerges from the cocoon

The family is most diverse in the oriental region, but is recorded from all old world zoogeographic regions. We recorded 4 genera and 4 species from GLA.

Family Eupterotidae

- ‘Furry’ or ‘woolly’ moths with head and body well covered in long hair-like scales
- Wings held partly out but low roof-wise or flattened over body at rest
- Antennae in male broadly pectinate to the tip, never bent
- Antennal pectinations ‘droop’downwards
- Antennae held back under wings at rest
- Wings broad
- Hindwings usually nearly as large as forewings and usually with a pattern of colours
- The tip of the forewing is extended. The folded part of the hindwing, next to the body, has an enhanced colour pattern
- Females usually with very large bodies in which almost all eggs are ready to lay when the moth emerges from the cocoon

  This family has its greatest development in the Ethiopian and oriental regions, with only a couple of Neotropical genera and a few in the Australian region. Worldwide some 400 described species in about 50 genera are known. We recorded 2 genera and 2 species from GLA.

Family Lasiocampidae

- Very large (upto 150 mm)

- "Furry'or 'woolly' moths with head and body well covered in long hair-like scales
- Wings held roof-wise back over body when at rest
- Antennae in male broadly pectinate, often gradually bent in the middle
- Pectinations 'droop'downwards
- Antennae held back under wings at rest
- Wings broad
- The hindwings are usually much smaller than the forewings and usually without so much colour pattern
- Females usually with very large bodies in which almost all eggs are ready to lay when the moth emerges from the cocoon

The moths in this family have no hearing organs, and the proboscis is reduced or absent. Lasiocampids may be recognized by the presence of a pincushion-like organ on the underside of the palpi (when viewed with a strong lens), which is found in no other family. They also lack the hook-and-bristle mechanism between forewings and hindwings. Lasiocampids are mostly night-flying, but a few species have day-active males and night-active females. The larvae are very hairy, often flattened, and often with spreading hairs on the sides of the larvae extending down to touch the branch they rest on, which helps to blur the outline of the larva. Some rest during the day on twigs and branches while others hide beneath bark and come out to feed at night.

The Lasiocampidae are reasonably diverse in the old world tropics, less so in New. They have moderate representation in the Holarctic and Australia. It includes about 1,500 species referred to about 150 genera. We recorded 8 genera and 9 species from GLA.

Family Brahmaeidae

The Brahmaeidae are a small but spectacular family found in the African and Oriental tropics, and extending north into the warmer Palaearctic.

- Proboscis present,

- Palpi large rounded and upturned.
- Antennae Bipectinated in both sexes.
- Mid tibia with a single pair of of spurs., hind tibia with two pairs.
- Frenulum absent.

We recorded a single species *Brahmidia hearseyi* from GLA.

Family Saturniidae

- Very large (upto 250 mm)
- ‘Furry’ or ‘woolly’ moths with head and body well covered in long hair-like scales
- Wings held partly out but flattened at rest
- Antennae in male very short, broadly pectinate to the tip, never bent
- Antennal pectinations stiffly projecting from each side of the antenna in one plane
- Antennae held partly up and out and back parallel to the front of the forewing
- Both wings have either a triangular window or an eye-spot in the middle but in some the hindwing may just have a dot
- Tip of forewing often broadly extended
- Hindwings smaller than forewings but well patterned
- The body is very small for the size of the moth

The Saturniidae are found worldwide. They have their greatest diversity in the tropics, particularly the Neotropics. Most of the species are highly decorative and are thus prized by collectors. The larvae are often highly polyphagous and easy to rear in captivity. We got 4 genus and 6 species from GLA.

Superfamily Sphingoidea and Family Sphingidae

Only one family, Sphingidae, is included in the superfamily Sphingoidea, but the family has sometimes been included in the superfamily Bombycoidea. Hawk moths are very well known and popular group for collectors as well arguers for insect conservation. Although they were previously placesd under bombycoids, they have evolved in a very different direction to the other bombycoid families. They have become superb fliers and voracious feeders at nectar, hovering before a flower to feed rather than alighting. They are important pollinators, often one of the few moths that can reach the nectaries of long tubular flowers. Most hawk moths fly at night but many fly at dusk when they can often be glimpsed speeding away against the sky. A few species in the genus *Cephonodes*, with clear wings, fly during the day.

- Smooth-scaled head and body
- Wings held back near body but extended outwards and flat
- Antennae simple, fairly short, often very gradually thickening until near tip
- Antennae held flat, outwards from head at rest
- Wings relatively narrow, hindwing much shorter than forewing
- Highly streamlined moths; very agile fliers and hoverers
- Very long prominent proboscis

Some of the species have a wide world distribution, but the family reaches its greatest development in wet tropical areas. The world fauna includes about 850 species referred to about 190 genera. Today the Sphingidae are usually divided into two subfamilies, Macroglossinae and Sphinginae. Distinctions of the two subfamilieas are based on characters of both adults and larva.

The Macroglossinae subfamily is represented by 4 genera and 5 species where the subfamily Sphiginae was represented by 17 genera and 21 species from GLA.

Superfamily Noctuoidea

Noctuoidea is the superfamily of noctuid (Latin "night owl") or "owlet" moths, and has more than 70000 described species, the largest number of for any Lepidopteran superfamily. Its classification has not yet reached a satisfactory or stable state. Since the end of the 20th century, increasing availability of molecular phylogenetic data for this hugely successful radiation has led to several competing proposals for a taxonomic arrangement that correctly represents the relationships between the major lineages.

Briefly, the disputes center on the fact that in old treatments (which were just as unable to reach a general consensus) the distinctness of some groups, such as the Arctiidae or Lymantriidae, was overrated due to their characteristic appearance, while some less-studied lineages conventionally held to be Noctuidae are in fact quite distinct. This requires a rearrangement at least of the latter family (by simply including anything disputed within it). This is quite unwieldy, and various more refined treatments have been proposed in response to it.

The presence of metathoracic tympanal organs is the chief apomorphic character that unites the families of Noctuoidea, although these organs are reduced or vestigial in some Doptidae and Ctenuchinae. There is usually a large counter-tympanal cavity at the base of the abdomen, with a projecting hood. The position of the hood in relation to the first abdominal spiracle is of special significance; it is prespiracular in Lymantriidae, Arctiidae but postspiracular in the Notodontidae and Noctuidae. Ocelli may be present or absent, but chaetostomata are never present.

We recorded 4 families under this superfamily from GLA, Arctiidae, Lymantriidae, Noctuidae and Notodontidae.

Family Arctiidae

This is the second largest family of the Noctuoidea, with a world fauna of some 11,000 species referred to about 900 genera. It is represented in all regions, but is most numerous in the tropics. The Arctiidae are defined principally by the presence of a tymbal organ on the metepisternum and aprespiracular counter-tympanal hood. Another potential Arctiid apomorphy is the presence of a pair of glands, possibly pheromonal, dorsally and anteriorly between the ovipositor lobes. These are frequently branched, usually in a regular dichotomous manner. They have not been noted in Lymantriidae, Noctuidae or Notodontidae.

- Smooth-scaled head and body
- Antennae held out from head
- Antennae simple or pectinate
- Wings held back steeply roof-wise over body, flattened, or rolled about the body; the ctenuchines have their wings held out away from the body and held flat
- Moths are often yellow, red, white and black

Members of this family are frequently brightly coloured and many are presumed to be poisonous or distasteful to predators. Arctiids also have hearing organs on the thorax and sound-producing organs on the sides of the thorax. They produce sounds beyond human hearing but which may warn bats of their unpalatability or jam the bats' sonar. Arctiid larvae are very hairy with heads that are without a colour pattern and the hairs, though usually long, are sparser than in lymantriids. They feed openly on a wide range of plants and many in the subfamily Lithosiinae (called 'footmen') feed on lichens growing on tree trunks. Arctiids pupate among leaves, under bark or in litter or the soil; those pupating exposed often have a flimsy cocoon, easily seen through, and a few have a neat open cocoon reminiscent of several noughts-and-crosses grids joined up.

There are about 6000 species recorded worldwide and from India, 90 genera and 510 species of are recorded so far. From Gangotri Landscape Area (GLA), we have identified 54 species of Arctiidae so far representing 3 subfamilies, *viz.* Syntomidae, Arctiinae and Lithosiinae.

The subfamily Syntominae is characterized by taxa with elongate forewings, reduced hindwings, and often banded abdomens, probably mimicking day-flying Hymenoptera. We recorded 2 genera, *Syntomoides* and *Amata* and 3 species from GLA.

The subfamily Arctiinae is characterized by adults in white or orange, with red or black markings. Most species have proboscis greatly reduced or vestigial and are incapable of feeding, except *Nyctemera.* The larvae usually feed on low-growing herbaceous plants, and many are polyphagous. The larva is always densely hairy, popularly known as wooly bears. This subfamily is represented by 17 genera and 30 species from GLA.

The subfamily Lithosiinae is characterized by species with aposematic coloration with orange, red and black predominating. However, in few species the the forewings are cryptically patterned and conceal the brightly colored hindwing while the insects are at rest. Most of the species have slender bodies and broadly rounded hind wings. The females of some species are brachypterous or apterous. The proboscis is usually present and is often well developed. The larvae usually feed on lichens, but occasionally on mosses or algae. We recorded 13 genera and 21 species from GLA.

Family Lymantriidae

This family of about 2,700 species is distributed throughout the world, but reaches its greatest development in the old world tropics. These are furry, medium-sized or fairly large-bodied moths. They are collectively called tussoks on account of the characteristic tufts of hairs on the back of the larvae, which are incorporated into their silken cocoon, formed above ground. In the adults, the proboscis is usually absent, the thorax and abdomen are clothed in long piliform scales, and the females have dense bunch of specialized scales used to cover the egg masses.

- ‘Furry’ or ‘woolly’ moths with head and body well covered in long hair-like scales
- Wings held back steep, or flat, roof-wise and slightly extended
- Antennae broadly pectinate in the male with the pectinations extending to the tip of the antennae, which are gradually curved along their length
- Antennae held back along or under the forewings
- Hindwings smaller than forewings and with less colour pattern
- When they emerge from the pupa, females have a very large abdomen full of eggs ready to lay

The adults are usually nocturnal and come readily to light, but some species are strictly diurnal. They rest with their forewings covering the hindwings and folded either steeply roofwise over the body or flat with the legs displayed.

From India 175 species has been recorded so far. From GLA we recorded 10 genera and 21 species. Two major genera are *Euproctis* with 8 species and *Lymantria* with 5 species.

Family Noctuidae

Containing over 25,000 species referred to more than 4000 genera, the Noctuidae is the largest family of moths. They occur in all the regions, but both the genera and species are more abundant in the tropical areas of the world. Most noctuids are specialized for powerful, maneuverable flight and fly mainly at night. The majority of the long-distance migrant moths are noctuids. They require regular refueling for flight and feed at flowers, oozing tree-sap, aphid honeydew or sugary baits. Most of the species rest with the trailing edges of the forewings brought together or slightly overlapping, over the folded hindwings, and hold their wings tent like over the body. There is usually a conspicuous kidney-shaped marking and an adjacent oval and other marks in the central area of forewing, the size, colour and configuration of which provide useful recognition features. This pattern of markings rarely occurs in other families. Many species are quite distinctive, but others are similar to one another, and variable, and are easily misidentified. The majority of noctuid moths have bald larvae. The full complement of five pairs of claspers or prologs is present. Most noctuid larvae feed on the leaves, stems or roots of grasses or broadleaved herbaceous plants, but some feed on the foliage of trees and shrubs.

- Smooth to rough-scaled head and body
- Wings may be held back over body steep roof-wise, low roof-wise or flat or with wings extended and flat against the substrate; a few adopt odd poses and one group rests with wings up like butterflies
- Antennae usually simple; very rarely pectinate in male
- Antennae at rest held back under wings
- Wings broad, in some groups hindwing broader than forewing. If resting with wings extended then significant colour pattern on hindwing that is not

broader than forewing, if resting with wings closed then hindwing usually broader than forewing and with little colour pattern

- Forewing pattern usually incorporates in some way a kidney-shaped spot about two thirds of the way along the wing in the middle and a smaller round spot at about one third of the way along the wing

Subfamilies of Noctuidae can be grouped into two: the Trifinae and the Quadrifinae. The Trifinae is characterized by: loss of vein M2 such that the posterior angle of the cell has only three veins arising from it, M3, CuA1 and CuA2. The trifines are of great interest as they have been highly successful at moving into, and diversifying within, open habitats, feeding on herbaceous plants. Many are highly dispersive, sometimes migratory, being quick to colonise ephemeral, weedy habitats, the early stages in vegetational succession. This versatility has brought them into conflict with man. Some of the most devastating pests in tropical agriculture are trifine noctuids. Their predominance at high latitudes is reflected in the tropics at high altitudes.

The Trifine subfamilies recorded from GLA are: Noctuinae, Heliothinae, Hadeninae, Acronictinae, Amphipyrinae, Agaristinae.

Subfamily Noctuinae

They are commonly known as Darts and Clays. This group has traditionally been recognized by possession of spined hind tibiae. Another feature with any potential for defining the group is its resting posture: the wings of each side are held in the same plane rather than at angle to each other forming a roof. We recorded 6 genera and 10 species from GLA.

Subfamily Heliothinae

The Heliothinae are a relatively small subfamily found predominantly in semiarid subtropical habitats. They decrease in diversity in the humid tropics and into temperate latitudes. The group includes a number of serious crop pests and thus has been studied exclusively. The most defining character of the subfamily is its larvae with spiny skin and a peculiar arrangement of setae on the prothorax. We recorded 2 species from GLA.

Subfamily Hadeninae

The hadeninae can be best defined as trifines with hairy eyes. Thay have stocky thorax with broad, usually well-patterned forewings held in shallow tent like fashion, with ends forming a V-shape. We recorded 7 genera and 19 species from GLA, among which the genus *Mythimna* was most abundant with 9 species recorded.

Subfamily Acronictinae

This subfamily is characterized by possession of secondary setae on the larval trunk. They are commonly known as Daggers with dagger like markings on grey foerewing in many species. The larvae are also elaborately marked. We recorded 5 genera and 7 species from GLA.

Subfamily Amphipyrinae

Commonly known as arches, brindles, minors, rustics or ears, this subfamily is large and diverse group originally grouped together on shared pattern of wing venation, lack of eye-lashes and lack of spines on legs. They have spiny, stem-borer larvae. We recorded 5 genera and 6 species from GLA.

Subfamily Agaristinae

The Agaristinae have often been treated as a full family, though with relationships to the Noctuidae. The group is defined by the presence of a more or less well developed paired vesicle at the base of the abdomen associated with counter-tympanal organ. Adults are generally active by day and brightly coloured. We recorded 3 genera and 4 species from GLA.

The other set of subfamilies under family Noctuidae are grouped together as Quadrifinae with vein M2 of the hindwing strong, as distinct from weak or lost as in Trifinae. The subfamilies recorded are:

Subfamily Calpinae

It is closely related to the Catocalinae; both subfamilies contain large species with wingspans larger than 5 centimetres. The status of this subfamily is somewhat disputed; it is sometimes merged into the Catocalinae. Most of the calpine genera are not further classified; the phylogenetic structure of this group is essentially unresolved, and, in many cases it is even doubtful whether the genera are indeed correctly placed in this subfamily. We recorded 5 genera and 7 species from GLA.

Subfamily Plusiinae

This is easily recognized subfamily containing species with adults having fairly stout body, long, dense scales on the body and dorsal thoracic crests and dorsal tufts on the abdomen. The labial palpi are well developed, with the apical segment long, and the eyes have lashes. The forewing is smooth-scaled and always has an areole. We recorded 5 genera and 5 species from GLA.

Subfamily Cuculliinae

This small subfamily, which is best developed in the northern temperate regions of the world, may not be homogenous. The adults are very similar to Amphipyrinae and Acronictiinae, but the eyes have lashes in the front. The tibiae are rarely spined and the larvae are without secondary setae. We recorded 6 genera and 7 species from GLA.

Subfamily Euteliinae

The species are generally more brightly coloured than most Noctuidae. The forewings are either elongate or squarish. The hindwing has a subtornal marking, often incorporated in a broad, dark border to pale ground colour. At rest, the adults adopt a very characteristic posture, with the abdomen curled up between the wings, which are partly rolled and spread. We recorded 5 genera and 7 species from GLA.

Subfamily Herminiinae

Commonly known as Litter moths, Herminiinae is one of the smaller subfamilies of the moth family Noctuidae. They are sometimes treated as a separate family, Herminiidae. We recorded 3 species from GLA.

Subfamily Pantheinae

This subfamily is hard to define satisfactorily and may prove to contain a paraphyletic assemblage of genera. The main characteristics used to recognize the subfamily are hairs in the eyes, hairs usually being long and conscpicuous. The antennae in male are usually pectinate. The tympanic membrane is fairly small, but well exposed. We recorded single species from GLA.

Subfamily Chloephorinae

This subfamily is best developed in the old world tropics and its position within Noctuidae has still to be determined. In the adult, the labial palpi are fairly long and upturned, with the apical segment slender. The forewing is smooth-scaled and an areole is sometimes present. We recorded 8 genera and 11 species from GLA.

Subfamily Hypeninae

Commonly known as snout moths, the adults of this subfamily are small to medium sized, usually dull-colored moths, of slender build, with very large labial palpi, which are either upcurved over the head like a snout. The eyes have marginal lashes and ocelli are present. The legs are long, slender and smooth-scaled. We recorded 4 genera, prominent among them is *Hypena* and 8 species from GLA.

Subfamily Catocalinae

This large group, commonly known as underwings, is especially well developed in tropical and subtropical areas. However the subfamily is not well understood on a world basis and when critically studied, may well be subdivided. It includes most of the largest species of Noctuidae as well as some very small species. Some have brightly coloured and banded hindwing, forewings somber and brightly in colour. They are often with prominently spined legs and semi-looper larvae with some reduction in prolegs. The larvae feed on the foliage of shrubs, trees and vines, and pupate in rather scant like cocoon. This is the largest subfamily of Noctuidae recorded from GLA with 31 genera and 39 species.

Family Notodontidae

The Notodontidae are a family that has proved very popular with amateur entomologists over the past two centuries. The species are mostly moderate to large in size with biologically cryptic but aesthetically cryptic wing patterns. The wing scaling is often coarse and the patterns never very crisply defined; the body and legs are usually clothed densely with longer scales giving the whole insect a rather shaggy appearance. In collection, the specimens are prone to become greasy, suggesting a high fat content in the adult moth. The larvae are often highly modified into bizarre shapes, again primarily cryptic, but often with additional aggressive defenses such as protrusible lashes on modified anal claspe.

- Medium-sized to large (30-120 mm)
- Those in the subfamily Thaumetopoeinae have a ‘furry’or ‘woolly’ appearance; the remainder have rough scales or are smooth on head and body
- Wings held back roof-wise over body
- Antennae usually pectinate but sometimes simple and held back under forewings at rest
- Hindwing shorter than forewing,with less colour pattern

- Thaumetopoeinae males have a tuft of long scales at the end of the body; females have a very large tuft of deciduous scales used to cover the eggs

The adults are often with rather long, tapering forewings, which aere normally held quite close to the body when at rest. The trailing edge of forewings of some species have prominent projections which are raised over the back when the moth is resting with its wings closed, hence the common name for the group is Prominent or Kitten moth. The adults are unable to feed and are seldom seen by day, but the especially comes to light at night. The wing markings are subtle and cryptic, with a preponderance of brown, grey and white, often in beautifully textured patterns, which help them blend with bark and dead leaves.

This family contains about 2000 species referred to about 650 genera and has a wide distribution in all regions of the world. From GLA, we recorded 8 genera and 10 species.

4.4 Coleoptera (Beetles)

The order Coleoptera can be divided into 2 major sub-order Adephaga and Polyphaga, which comprise most number of species and are generally found. These 2 major sub-orders are based on the positions of the hind coxal cavities in relation to the 1st visible sternite. If the hind coxae divide the 1st visible abdominal sternite, the specimen belongs in Adephaga. If hind coxae do not completely divide the 1st visible sternite (**Figure 4.1**), the specimen belongs to Polyphaga.

Identification: Beetle identification requires study of antennal shapes, tarsi (formulas, shapes of segments) mouthparts (labial and maxillary palpi), ventral characters (sterna, pleura, coxae), and other morphological characters

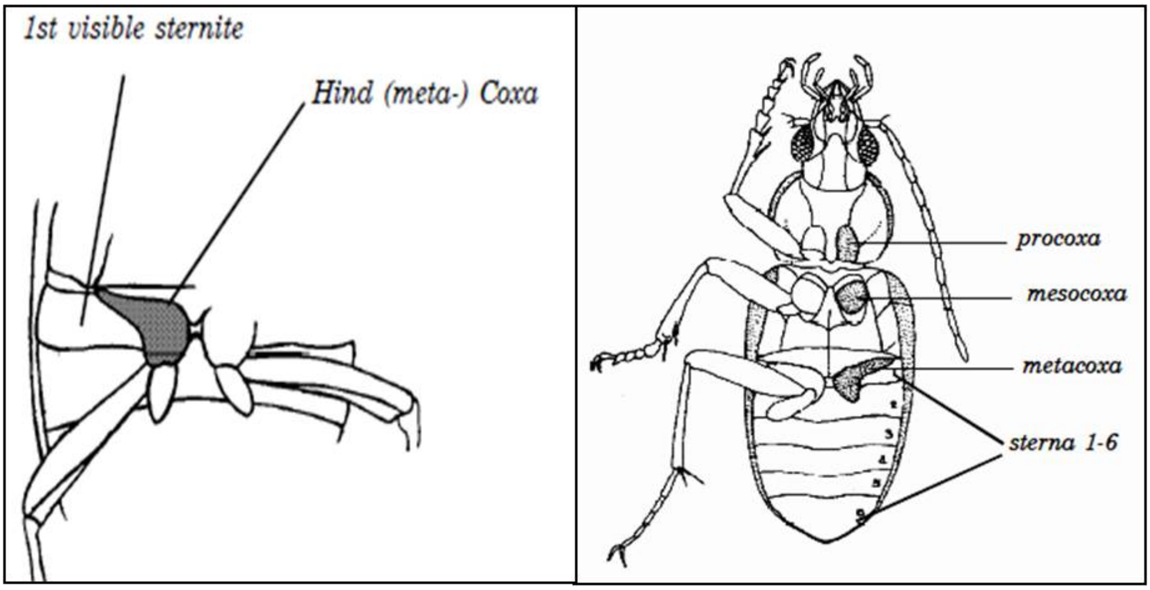


Figure 4.1: (a) Adephaga: Coxae divide first sternite; (b) Ventral view of Adephaga beetle (After Choate, 1999)

The collected specimens are identified upto 13 families and 120 species. Highest number of species has been recorded from Govind Wildlife Sanctuary followed by Govind National Park (**Table 4.1**) (**Appendix 4.4**). We recorded least number of species form Gangotri National Park. The details of key characters of families and the species recorded under them are as follows:

Table 4.1: Beetles recorded in three protected areas of Gangotri Landscape.

Protected Areas	**Beetles**		
	Family	**Genera**	**Species**
Gangotri National Park	5	21	35
Govind Nationl Park	9	27	47
Govind Wildlife Sanctuary	13	67	93
Total	**13**	**76**	**120**

Family composition: Highest numbers of beetles were recorded in family Scarabaeidae followed by Curculionidae, Carabidae and Elateridae (**Figure 4.2**). While only one and two specimens were identified respectively in family Dyticidae and Lucanidae.

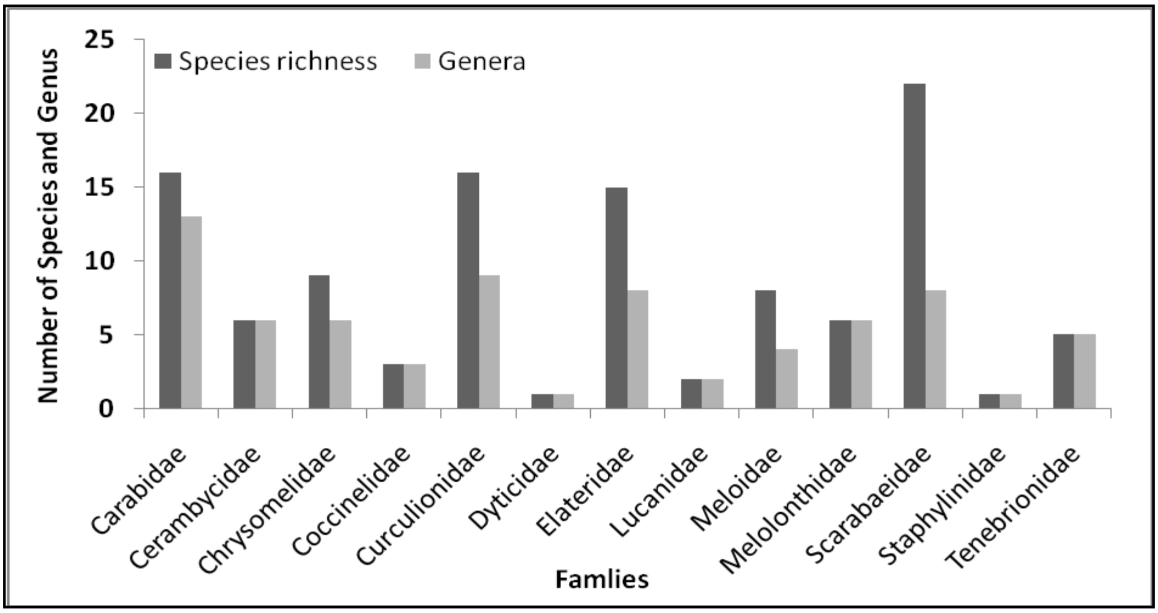


Figure 4.2: Family composition showing number of families and genus identified per family of beetles from the study area.

Families with key characters for species identification: (**Plates 52-59**)

(i) Carabidae (Ground Beetles)

We have identified 16 species from 13 genera from the study area so far. Number of genera, which is recorded 13 in this family also found to be highest generic diversity in a family comparing to other families recorded.

Key characters:

- First abdominal sternite divided by hind coxae (suborder Adephaga)
- Head at eyes nearly always narrower than pronotum (cf; Cicindelidae).
- Antennae threadlike, inserted between mandibles and eyes (cf; Cicindelidae).
- Generally black and shiny with striate elytra, but sometimes metallic or colorful.

(ii) Cerambycidae (Longhorned Beetles)

Members of this family are peculiarly characterized by very long antenna, sometimes longer even than the body length. Grubs of these species are important forest pests. We have recorded 13 species; while only 6 species have been from 6 genera in this family have been identified so far.

Key characters:

- Long filiform antennae, ranging from one-half to over two times the length of the body.
- Body usually elongate and cylindrical; 2 to 60 mm in length.
- Eyes generally notched with antenna arising within the notch.
- Tarsi apparently 4-4-4, really 5-5-5 with the 4th segment small and inconspicuous.

(iii) Chrysomelidae (Leaf, Flea Beetles)

A number of nine species from six genera have been identified so far. Leaf beetles are important pests on various agricultural and forest plants. Sometimes the infestation is so heavy, that soft parts of whole plants are eaten up, which leads in death of young plant.

Key characters:

- Elongate subcylindrical to oval shaped beetles, 1 to 16 mm in length.
- Antennae generally less than 1/2 the length of the body.
- Eyes generally not notched.
- Tarsi generally appear 4-4-4, actually 5-5-5.

(iv) Coccinellidae (Ladybird Beetles)

This family being predator on aphids and other insects are recorded from low altitude to high altitude nearby flower patches feeding on insects. A total of 3 species from 3 genera have been identified so far from the study area.

Key characters:

- First abdominal sternite entire, not divided by hind coxae (suborder Polyphaga).

- Most species with distinctive shape, strongly convex dorsally and flat ventrally.
- Tarsi appearing 3-3-3, but actually 4-4-4.
- Head often concealed by pronotum.
- Antennae short with a 3 to 6 segmented club.

(v) Curculionidae (Weevils and snout beetles)

The family is observed to be an important pest of forest trees in the study area. Members were quite abundant in subtropical and tropical zones, while very few species were recorded in temperate zones. A total of 16 species from nine genera have been identified so far. Most abundant Coleopteran family recorded from the study area.

Key characters:

- Head usually with snout ranging from broad and flat in a few species to elongate and narrow in most species.
- Antennae usually elbowed and with 3-segmented club.
- Length from 0.6 to 35 mm, mostly less than 10 mm; body often covered with scales.
- Tarsi apparently 4-4-4, actually 5-5-5.

(vi) Dytiscidae (Diving Beetles)

Only one species have been identified so far recorded from Mix riverine forest patch during Monsoon season.

Key characters:

- First abdominal sternite divided by hind coxae (suborder Adephaga).
- Distinctive shape, elongate-oval; range from 1.2 to 40 mm in length.
- Hind legs flattened and fringed for swimming.
- Antennae threadlike, longer than maxillary palpi (cf. Hydrophilidae).
- Tarsi mostly 5-5-5.

(vii) Elateridae (Click Beetles)

A total of 15 species from eight genera have been identified so far. Individuals comes at light traps in large abundance (5-10 per species), just on the night of rain. The family have been reported to found even at temperate zone in the study area e.g. *Melanotus hirticornis*.

Key characters:

- First abdominal sternite entire, not divided by hind coxae (suborder Polyphaga).
- Elongate, parallel sided beetles, generally rounded at each end.
- Pronotum pointed on the posterior corners.
- Prosternum with a spine like process that fits into a grove in the mesosternum.
- Prothorax and mesothorax loosely joined, enabling adults to arch, "click," and flip over when they are upside down.
- Antennae generally serrate, sometimes filiform or pectinate.
- Tarsi 5-5-5.
- Many buprestid species look like elaterids, but have the pro and mesothorax tightly fused rather than separated and flexible.

(viii) Lucanidae (Stag Beetles)

Stag beetles are characterized by very long, strong mandibles. Only two species have been identified so far from the study area.

Key characters:

- Shape usually weakly convex, subdepressed, or cylindrical, elongate.
- Black to reddish brown, sometimes testaceous or metallic.
- Head prognathus, not deflexed. Antennae geniculate or straight, 10-segmented, with 3-7 segmented club; first segment elongate and often subequal to remaining segments.
- Eyes with eucone or acone ommatidia; eye canthus present or absent.

- Clypeus and labrum fused to frons. Mandibles produced beyond apex of labrum, prominent (males often with large, curved, elongate mandibles). Maxillae with 4-segmented palpi; labium with 3-segmented palpi.
- Elytra weakly convex, with or without impressed striae. Scutellum exposed, triangular or parabolic. Pygidium concealed by elytra or only weakly exposed.

(ix) Meloidae (Blister Beetles)

A total of eight species from six genera have been identified and were found to be abundant family in floral patches.

Key characters:

- First abdominal sternite entire, not divided by hind coxae (suborder Polyphaga).
- Head broad, generally rectangular when viewed from above.
- Pronotum cylindrical and narrower than both the head and base of elytra.
- Body elongate, soft and somewhat leathery.
- Antennae filiform or moniliform.
- Tarsi 5-5-4; claw either toothed or lobed.

(x) Melolonthidae (May, June Beetles and Chafers)

A total of six species from six genera have been identified so far. Family was found to be abundant in broadleaf forest and scrub land with high abundance during summer season.

Key characters:

- Head unarmed with mandibles, well developed, sclerotized, completely concealed from above usually.
- Antennal 7 to 10-segmented, antennal lamellae 3 to 7-segmented club, oval to elongate, glabrous or with only a few setae.
- Labrum located below clypeus or on apical clypeal margin, transverse, narrowed, or conical.

(xi) Scarabaeidae (Dung Beetles)

A total of 22 species belonging to relatively low generic diversity (8) have identified so far. This is most species rich family from the study area, abundant from subtropical to temperate zones. Family diversity was highest in Post Monsoon Season.

Key characters:

- Robust beetles varying greatly in shape; size ranging from 2 to 62 mm.
- Distinctive lamellate antennae; club generally 3 to 4 segments (max. 7) and capable of being closed tightly.
- Tarsi 5-5-5.

(xii) Staphylinidae (Rove Beetles)

Key characters:

- First abdominal sternite entire, not divided by hind coxae (suborder Polyphaga).
- Adults elongate-slender, 0.7-25 mm.
- Elytra short, leaving 3 to 6 abdominal segments exposed.
- Tarsi usually 5-5-5, but 4-5-5, 5-4-4.

(xiii) Tenebrionidae (Darkling Beetles)

Only 5 species belonging to five genera have been identified so far from the study area.

Key characters:

- First abdominal sternite entire, not divided by hind coxae (suborder Polyphaga).
- Eyes notched by a frontal ridge.
- Antennae usually 11 segmented and filiform, moniliform, or weakly clubbed.
- Tarsi 5-5-4; claws simple.

- Body form variable, ranging from elongate to oval and smooth to very rough.

Butterflies sampled in the study area

(Family: Papilionidae)

Paranassius epaphus

Paranassius hardwickii

Papilio machaon

Papilio paris

Papilio protenor

Plate 4

Butterflies sampled in the study area

(Family: Pieridae)

Eurema blanda

Dellias belladonna

Gonepteryx rhamni

Pieris canidia

Pareronia valeria

Leptosia nina

Plate 5

Butterflies sampled in the study area

(Family: Lycaenidae)

Heliophorus tamu

Tarucus nara

Loxura atymnus

Aricia astrarche

Spindasis lohita

Plate 6

Butterflies sampled in the study area

(Family: Lycaenidae)

Lampides boeticus

Everes argiades

Heliophorus sena

Lycaena phlaeas

Lycaena pavana

Pseudozizeeria maha

Plate 7

Butterflies sampled in the study area

(Family: Nymphalidae)


Libythea lepita


Tirumala limniace


Danaus genutia


Parantica sita


Euploea core


Melanitis leda

Plate 8

Butterflies sampled in the study area

(Family: Nymphalidae)

Lethe rohria

Lethe confusa

Lethe verma

Aulocera swaha

Pseudergolis wedah

Plate 9

Butterflies sampled in the study area

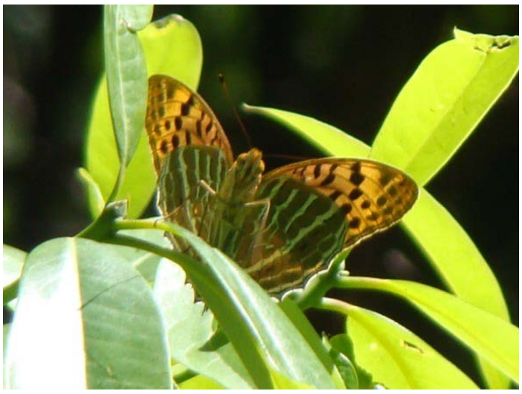
(Family: Nymphalidae)

Ypthima nareda

Ypthima sakra

Ypthima baldus

Acraea violae



Childrena childreni

Plate 10

Butterflies sampled in the study area

(Family: Nymphalidae)


Speyeria aglaja


Fabriciana adippe


Phalanta phalantha


Cyrestis thyodamas

Plate 11

Butterflies sampled in the study area

(Family: Nymphalidae)

Dilipa morgiana

Vanessa cardui

Vanessa indica

Aglais cashmiriensis

Kaniska canace

Plate 12

Butterflies sampled in the study area

(Family: Nymphalidae)

Junonia hierta

Junonia atlites

Junonia orithya

Junonia lemonias

Junonia almana

Junonia iphita

Plate 13

Butterflies sampled in the study area

(Family: Hesperiidae)

Spialia galba

Sarangesa purendra

Pelopidas mathias

Tagiades litigiosa

Choaspes benjaminii

Plate 14

Moths sampled in the study area

(Family: Pyralidae)

Endotricha olivacealis

Diloxia fimbriata

Epicrocis hilarella

Orybina flaviplaga

Plate-15

Moths sampled in the study area

(Family: Crambidae)

Glyphodes sp

Glyphodes crithealis

Pygospila tyres

Goniorhynchus signatalis

Botyodes asialis

Diaphania_indica

Plate-16

Moths sampled in the study area

(Family: Crambidae)

Eoophyla peribocalis

Eromene ocellea

Chilasa clytia

Lamprocema commixta

Herculia ignifiualis

Nomophila noctuella

Plate-17

Moths sampled in the study area

(Family: Crambidae)

Pachynoa sabelialis

Pleuroptia sp

Pleuroptia ruralis

Sameodes cancellali

Epicrocis hilarella

Plate-18

Moths sampled in the study area

(Pterophoridae)

Buckleria paludum

Deuterocopus socotranus

Diacrotricha fasciola

Plate-19

Moths sampled in the study area

(Cossidae)

Xyleutes strix

Zeuzera coffeae

Zeuzera multistrigata

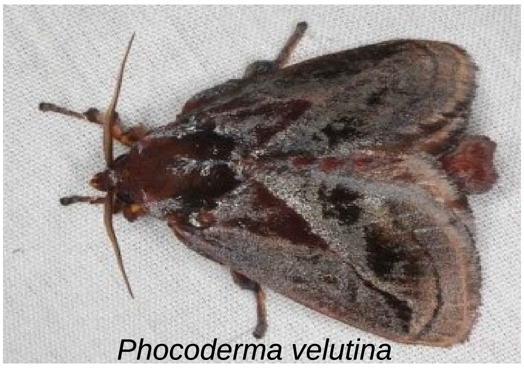
Plate-20

Moths sampled in the study area

(Family: Limacodidae)


Altha subnotata


Chalcoscelides castaneipars


Phocoderma velutina


Scopelodes unicolor

Plate-21

Moths sampled in the study area

(Family: Geometridae Subfmily: Ennominae)

Abraxas peregrina

Alcis semiclarata

Anonychia violacea

Biston recursaria

Biston suppressaria

Boarmia subplagiata

Plate-22

Moths sampled in the study area

(Family: Geometridae, Subfmily: Ennominae)

Ectropis bhumitra

Elphos pardicelata

Fascellina plagiata

Godonela avitusaria

Heterolocha phaenicotaeniata

Hypochrosis hyadaria

Plate-23

Moths sampled in the study area

(Family: Geometridae, Subfmily: Ennominae)

Lassaba acribomena

Luxiaria sp

Corymica arnearia

Mimomiza cruentaria

Opisthograptis moelleri

Troides aeacus

Plate-24

Moths sampled in the study area

(Family: Geometridae, Subfmily: Ennominae)

Opthalmitis herbidaria

Oxymacaria temeraria

Phthonandria artilineata

Psyra angulifera

Psyra indica

Urapteryx sciticaudaria

Plate-25

Moths sampled in the study area

(Family: Geometridae Subfmily: Geometrinae)

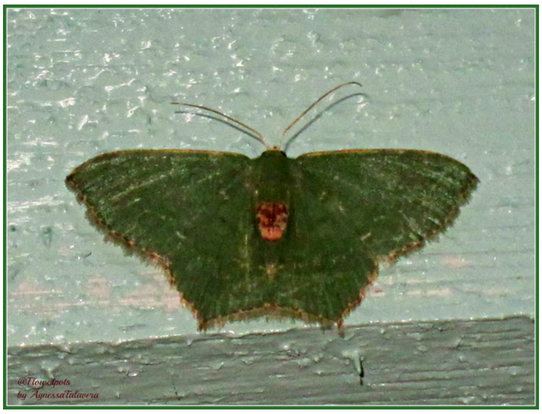
Agathia hemithearia

Chlorissa gelida

Comibaena fuscidorsata

Comibaena inductaria

Comostola subtiliaria



Hemithea tritonaria

Plate-26

Moths sampled in the study area

(Family: Geometridae Subfmily: Geometrinae & Larentiinae)

Herochroma cristata

Pingas rubicaunda

Pingasa alba

Aporandria specularia

Ecliptopera relata

Eupithecia rajata

Plate-27

Moths sampled in the study area

(Family: Geometridae Subfmily: Lentiinae, Sterrhinae & Oenochrominae)

Perizoma seriata

Xanthorhoe aurata

Problepsis vulgaris

Scopula pulchellata

Timandra Ruptilinea

Eumelea rosalia

Plate-28

Moths sampled in the study area

(Family: Drepanidae)

Auzata superba

Callidrepana argenteola

Euchera substigmaria

Nordostromia duplicata

Oreta extensa

Tridrepana flava

Plate-29

Moths sampled in the study area

(Superfamily: Bombycoidea)

Bombyx huttoni (Bombycidae)

Ocinara albicollis (Bombycidae)

Apona cashmirensis (Eupterotidae)

Estigena pardalis (Lasiocampidae)

Euthrix laeta (Lasiocampidae)

Lebeda sp. (Lasiocampidae)

Plate-30

Moths sampled in the study area

(Superfamily: Bombycoidea)

Paralebeda plagifera (Lasiocampidae)

Trabala irrorata (Lasiocampidae)

Trabala vishnou (Lasiocampidae)

Brahmidia hearseyi (Brahmaeidae)

Antheraea paphia (Saturniidae)

Samia Cynthia (Saturniidae)

Plate-31

Moths sampled in the study area

(Family: Sphingidae)

Hippotion boerhaviae

Hippotion celerio

Macroglossa walkeri

Rophalopsyche nycteris

Leucophlebia lineata

Agrius convolvuli

Plate-32

Moths sampled in the study area

(Family: Sphingidae)

Ambulyx liturata

Clanis titan

Marumba dyras

Marumba spectabilis

Psilogramma menephron

Theretra clotho

Plate-33

Moths sampled in the study area

(Family: Arctiidae)

Syntomoides imaon

Amata bicincta

Spilarctia obliqua

Spilarctia sagittifera

Spilosoma erythrozona

Spilosoma multiguttatum

Plate-34

Moths sampled in the study area

(Family: Arctiidae)

Spilosoma sangaicum

Spilosoma unifascia

Thyrgorina unifascia

Utetheisa lotrix

Nyctemera adversata

Nyctemera cenis

Plate-35

Moths sampled in the study area

(Family: Arctiidae)

Areas galactina

Argina astrea

Creatonotus transiens

Creatonotos gangis

Olepa ricini

Asura calamaria

Plate-36

Moths sampled in the study area

(Family: Arctiidae)

Chrysorabdia bivittata

Macrobrochis pallens

Macrobrochis prasena

Sidyma albifinis

Cyana puella

Cyana bianca

Plate-37

Moths sampled in the study area

(Family: Lymantriidae)

Euproctis varia

Euproctis vitellina

Euproctis scintillans

Lymantria concolor

Lymantria mathura

Himala argentea

Calliteara sp

Gazalina apsara

Plate-38

Moths sampled in the study area

(Family: Noctuidae)

Maliattha signifera (Acronictinae)

Nacna sp. (Acronictinae)

Maliattha vialis (Acronictinae)

Oruza divisa (Acronictinae)

Calesia haemorrhoa (Calpiinae)

Ericeia inangulata (Calpiinae)

Plate-39

Moths sampled in the study arean

(Family: Noctuidae)

Ericeia pertendens (Calpiinae)

Lacera nyarlathotepi (Calpiinae)

Oraesia emerginata (Calpiinae)

Oresia indecisa (Calpiinae)

Agrotis biconica (Noctuinae)

Agrotis sp (Noctuinae)

Plate-40

Moths sampled in the study area

(Family: Noctuidae)

Diarsia erubescens (Noctuinae)

Diarsia nigrosigna (Noctuinae)

Euxoa sp. (Noctuinae)

Xestia renalis (Noctuinae)

Aletia medialis (Hadeninae)

Callopistnria placodoides (Hadeninae)

Plate-41

Moths sampled in the study area

(Family: Noctuidae)

Callopistria replete (Hadeninae)

Callopistria rivularis (Hadeninae)

Leucania compta (Hadeninae)

Mythimna fragilis (Hadeninae)

Mythimna loreyi (Hadeninae)

Mythimna separata (Hadeninae)

Plate-42

Moths sampled in the study area

(Family: Noctuidae)

Mythimna sp. (Hadeninae)

Spodoptera litura (Hadeninae)

Tiracola plagiata (Hadeninae)

Atrophaneura aristolochiae (Plusiinae)

Axylia renalis (Plusiinae)

Thysanoplusia orichalcea (Plusiinae)

Plate-43

Moths sampled in the study area

(Family: Noctuidae)

Erythroplusia pyropia (Plusiinae)

Acronicta pruinosa (Cuculliinae)

Eutelia adultraricoides (Euteliinae)

Chlumetria transversa (Euteliinae)

Targalla delatrix (Euteliinae)

Paectes subapicalis (Euteliinae)

Plate-44

Moths sampled in the study area

(Family: Noctuidae)

Penicillaria maculata (Euteliinae)

Polypogon vermiculata(Herminiinae)

Progonia kurosawai (Herminiinae)

Simplicia robustalis (Herminiinae)

Gabala argentata (*Chloephorinae*)

Risoba prominens (*Chloephorinae*)

Plate-45

Moths sampled in the studny area

(Family: Noctuidae)

Earias biplaga (Chloephorinae)

Negeta sp. (Chloephorinae)

Tyana chloroleuca (Chloephorinae)

Xanthodes albago (Chloephorinae)

Xanthodes transversa (Chloephorinae)

Hypena melanica (*Hypeninae*)

Plate-46

Moths sampled in the study area

(Family: Noctuidae)

Hypena indicatalis (Hypeninae)

Callyna jugaria (Amphipyrinae)

Conservula indica (Amphipyrinae)

Anomis mesogona (Catocalinae)

Anomis figlina (Catocalinae)

Arcte coerula (Catocalinae)

Plate-47

Moths sampled in the study area

(Family: Noctuidae)

Catocala inconstans (Catocalinae)

Catocnala macula (Catocalinae)

Dysgonia latifascia (Catocalinae)

Mocis discios (Catocalinae)

Ophiusa tirrhaka (Catocalinae)

Spirama retorta (Catocalinae)

Plate-48

Moths sampled in the study area

(Family: Noctuidae)


Thyas juno (Catocalinae)


Thyas coronate (Catocalinae)


Bastilla crameri (Catocalinae)


Bastilla arcuata (Catocalinae)


Erebus albicinctus (Catocalinae)


Erebus macrops (Catocalinae)

Plate-49

Moths sampled in the study area

(Family: Noctuidae)

Hypopyra vespertilio (Catocalinae)

Serrodes campana (Catocalinae)

Grammodes geometrica (Catocalinae)

Trigonodes hyppasia (Catocalinae)

Fodina stola (Catocalinae)

Calesia dasypterus (Catocalinae)

Plate-50

Moths sampled in the study area

(Family: Notodontidae)

Phalera parivala

Phalera raya

Zaranga pannosa

Neopheosia fasciata

Netria viridescens

Ginshachia gemmifera

Plate-51

Beetles sampled in the study area

 *Agrypnus tuberosus*	 *Anomala sp*
 *Brahmina crinicollis*	 *Campsosternus splindidus*
 *Cartasecpus whithithi*	 *Catharcius sagas*

Plate-52

Beetles sampled in the study area

Catharsius capucinus

Chlaenius hamifer

Catharsius molossus

Catharsius sagax

Chlaenius vivibus

Epicanta manyerheimni

Plate-53

Beetles sampled in the study area

Copris repertus Walker

Gymnopleurus cyaneus

Glena sp

Gymnopleurus anamensis

Gymnopleurus dejeani

Gymnopleurus opacus

Plate-54

Beetles sampled in the study area

 *Gymnopleurus sinuatus*	 *Heliocopris bucephalus Fabricius*
 *Heterobines teris*	 *Janymecus circumbatus*
 *Hilyotrogus holosericeus*	 *Holotrichia longipennis*

Plate-55

Beetles sampled in the study area

Lepidiota albistigma

Melolontha cuprescens

Lepropus indicus

Lophosterus hugeli

Macrochilus tnmaculatus

Mecirtocenus fossatifrons

Plate-56

Beetles sampled in the study area

 *Melolantha furcicauda*	 *Mylabris pustulatus*
 *Omphara duplicatus*	 *Pectocera cantorii*
 *Onitis philemon*	 *Onthophagus griseosetosus*

Plate-57

Beetles sampled in the study area

Onthophagus bonasus

Onthophagus dama

Onthophagus pactolus

Onthophagus ramosellus

Pharopsopus cateirei

Poppittia impressipyga

Plate-58

Beetles sampled in the study area

Pycnudactylus hypocritus

Rhytidodera boweinia

Scarties indicus

Serrognathus titanus

Trigenotoma indica

Xylotrechus smei

Plate-59

CHAPTER 5

LEPIDOPTERA DIVERSITY IN GANGOTRI LANDSCAPE

5.1 Introuduction

Lepidoptera is a highly diverse order of class Insecta, accounting for more than 180,000 species. It is becoming more widely recognized that conservation biologists should include insect diversity as a data source for planning conservation in tropical forests (Kremen et al., 1993; Meyers et al., 2000; Clark and May, 2002; Leather et al., 2008). Lepidoptera have been proposed as surrogate species by several authors (Kremen, 1992; Beccaloni & Gaston, 1995; Fleishman et al., 2000). Several features of the group make them good candidates for indicator, umbrella and/or flagship species (New, 1997; Fleishman et al., 2000; Maes & Van Dyck, 2001). They are exntremely sensitive to changes in vegetation composition and structure, and different types of vegetation show different lepidopteran species composition. So, the lepidopteran assemblages may be used to characterize different habitats (Erhardt, 1985). Plants are the essential source of nourishment of lepidoptera; some specific plant species provide the trophic resources for caterpillars, while others provide nectar for adults. The vegetation can also play an important role for their survival offering particular structural elements for sun-basking (butterflies), day time hiding (moths) or mating and determining certain suitable microclimates (Dover et al., 1997). Therefore, it would be expected that lepidoptera respond more strongly to vegetation gradients than to edaphic gradients (Sawchik et al., 2003). Human disturbance in Himalayan ecosystem has accelerated during last few centuries, resulting in a very high pressure on these ecosystems. An important factor for these changes is drastic changes in landuse. Many of the natural vegetations are being invaded by invasive species, while others suffer fragmentation, deforestation etc. Moreover, these modifications lead to an increasing isolation of the remaining fragments. Hence, study of distribution patterns of these focal groups like Lepidoptera may be beneficial in understanding overall distribution pattern of insect diversity.

5.2 Butterflies

5.2.1 Gangotri NP

5.2.1.1 Butterfly Diversity and Community Composition

A total of 1639 butterfly individuals representing 34 species 29 genera and five families were recorded during the study in Gangotri NP (**Appendix 4.1**). Highest species richness, abundance and diversity were recorded in Himalayan temperate forest, followed by sub-alpine forest, moist alpine scrub and dry alpine scrub forest. Interestingly there were 16 species, which were restricted only to single vegetation zone. This accounts for 47% of the total butterfly species richness recorded in the Gangotri NP.

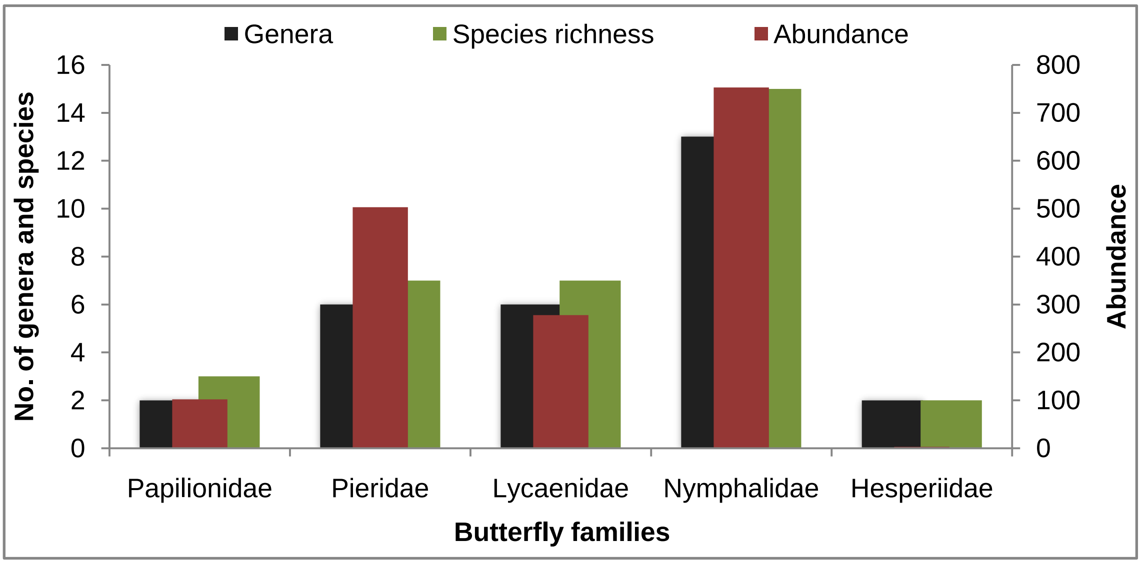


Figure 5.1: Genera, species richness and abundance represented for five butterfly families in Gangotri NP.n

5.2.1.2 Family Composition

We recorded five butterfly families namely, Hesperiidae, Papilionidae, Pieridae, Lycaenidae and Nymphalidae. Family Nymphalidae was the most dominant family and accounted 753 individuals representing 15 species, followed by Pieridae, Lycaenidae, Papilionidae and Hesperiidae (**Figure 5.1**). We recorded high genera richness *viz*. 34 species belonging to 29 genera. Family

Nymphalidae represented through 15 genus was highest followed by Pieridae and Lycaenidae (both 6) and Papilionidae and Hesperiidae (both represented by 2 genus) (**Figure 5.1**).

5.2.1.3 Habitat Similarity

Dendrogram obtained from cluster analysis of 29 transects in different elevation zones showed butterfly composition grouped into three major clusters (Figure 5.2), (i) 2800 - 3200 m (ii) 3300-3900 m and (iii) 4200 - 5200 m. Cluster analysis revealed that butterfly assemblages grouped into 3 major and four sub clusters, consistent with elevation and vegetation zones. High altitude butterfly assemblage was represented between 4200 - 5200 m, which was found in dry/moist alpine scrub habitat. The Himalayan moist temperate forest support unique butterfly assemblage was found between 2800 - 3200 m.

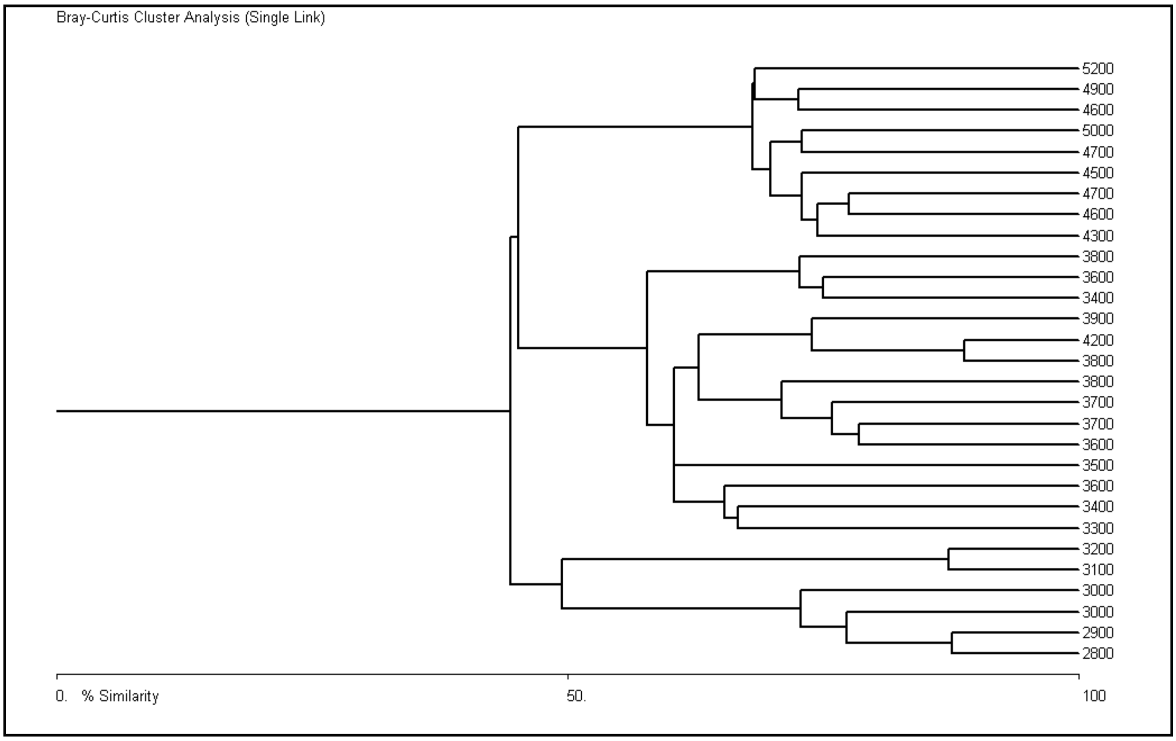


Figure 5.2: Dendrogram showing similarities between 29 elevational transects in Gangotri National Park (Based on Bray-Curtis dissimilarity matrix-single link)

5.2.2 Govind NP and WLS

5.2.2.1 Butterfly Diversity and Community Composition

A total of 8432 individuals of butterflies were recorded representing 5 families, 92 genera and 159 species during sampling on 96 transects in four habitats, which account for 38% of butterfly species recorded in western Himalayan region and about 13% of species in Indian mainland (**Appendix 4.2**). Species richness and abundance was also reported highest for Govind WLS followed by unprotected area and Govind NP (**Figure 5.3**).

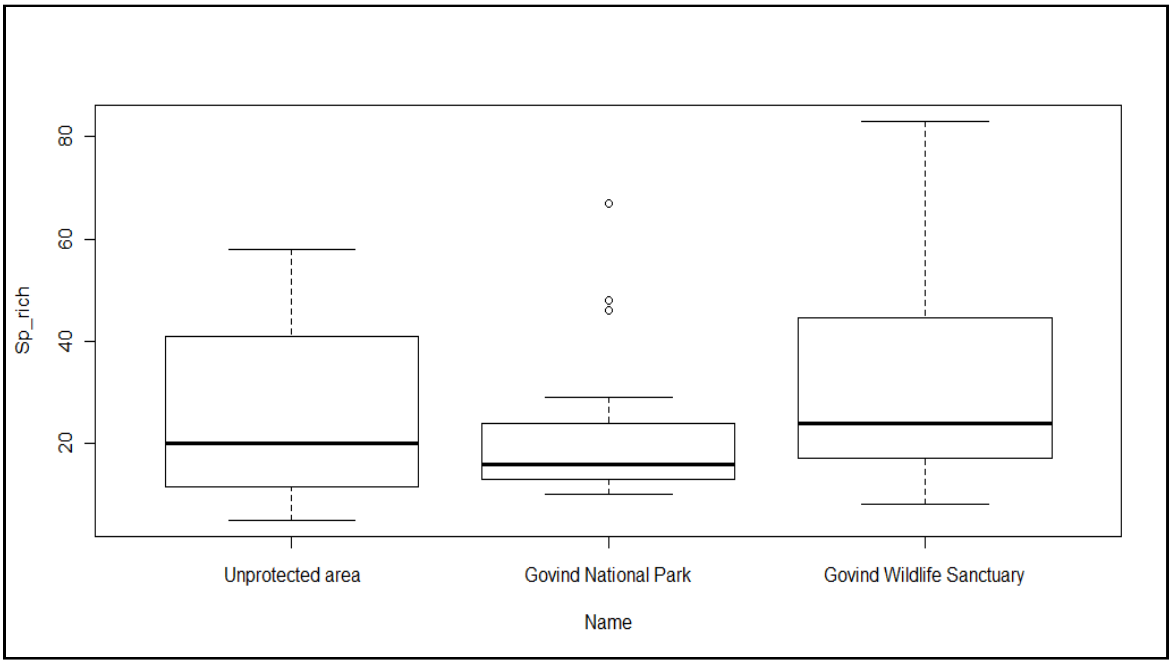


Figure 5.3. Box plots showing differences in species richness of butterflies across three protection categories in Govin NP and WLS and adjoining areas.

The pooled accumulation curve reached an asymptote for all the estimators (**Figure 5.4**), indicating that sampling was almost complete at regional level. Regional inventory completeness was around 96% (**Table 5.1**), which can be suggested as exhaustive sampling. The ratio of observed to estimated (Chao1 and Jacknife2) suggested that invenntory was almost complete at regional level while 3-5% more species are to be expected in the area than what were actually recorded.

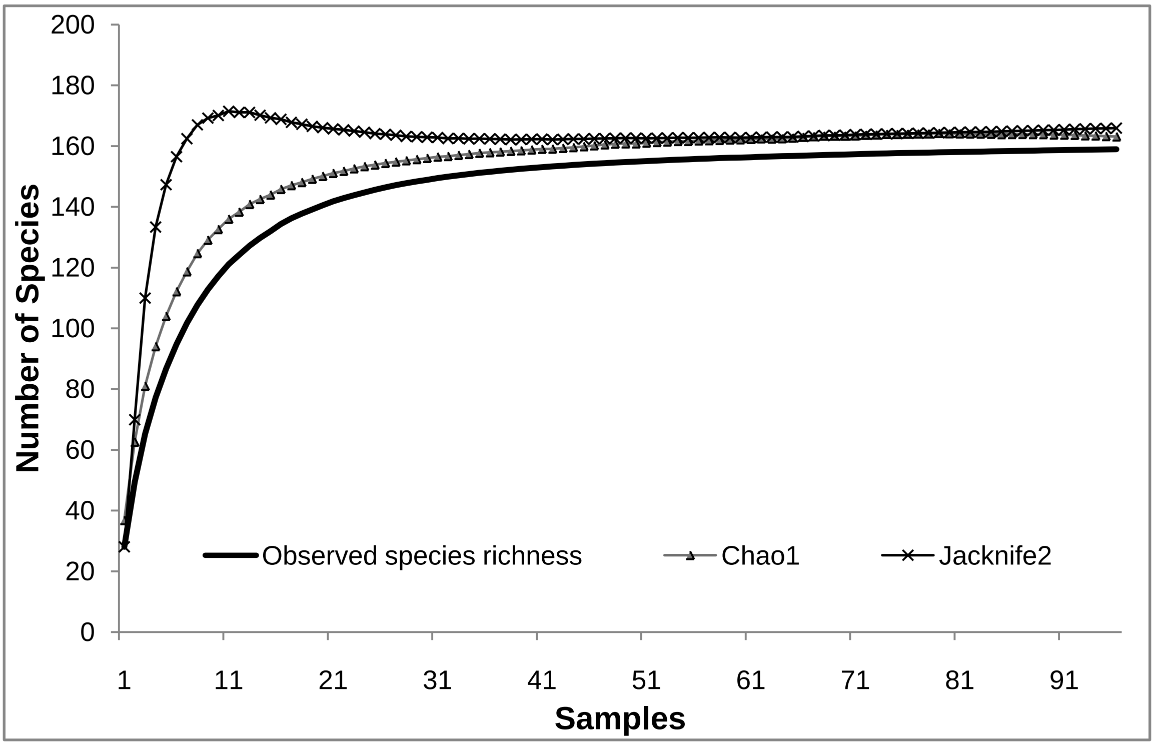


Figure 5.4: Species accumulation curves and non-parametric estimators for the regional (all samples pooled) inventory. Curves are generated from 100 randomizations.

Table 5.1: Species richness, abundance, fisher's alpha, estimates of species richness and inventory completeness for each habitat type and for the regional dataset.

Habitats	Mixed riparian and scrub forest	Pine forest	Broad leaf forest	Conifer and alpine forest	Regional
No. of Specimens	3885	564	2298	1342	8432
Species richness	149	58	120	50	159
Fisher's α	28.96	9.99	2.9	8.56	15.59
Chao1	156.7 (±5.8)	65.1 (±5.9)	152.45 (±9.1)	102.08 (±16.0)	163
Jacknife2	161.8	69.1	171.8	113.4	166
% Completeness	91.9	84.0	70.1	44.2	95.7

Average number of species recorded at each site (N = 96) was 28.28 (SE ± 2.09) with a minimum of 5 and a maximum of 83 species. Mean number of butterfly individuals at each site varied from a minimum of 7 to 343 individuals. The most abundant species was *Pieris canidia* (503 individuals) and most individuals were recorded in mixed riparian and scrub forest (201). Highest number of species (149) and individuals (3885) were recorded from mixed riparian and scrub forest and lowest in pine forest (564 individuals representing 58 species).

From all the species recorded, 28 were singletons (17% of all species) and 15 (9.4% of all species) were doubletonns. The highest numbers of singletons were found in conifer and alpine forest. However, there were not many differences in singletons between sites of mixed riparian forest and broadleaf forest. Mean butterfly diversity at each site was 15.59 (Fisher's alpha) and varied from a minimum of 2.9 at pine forest site to 28.9 at mixed riparian and scrub forest (**Table 5.1**). Diversity was significantly lower in other three butterfly habitats.

At the habitat level, inventory completeness was highest for mixed riparian and scrub forest (91.9%) followed by pine forest (84%), broadleaf forest (70.1%) and conifer and alpine forest (44.2%).

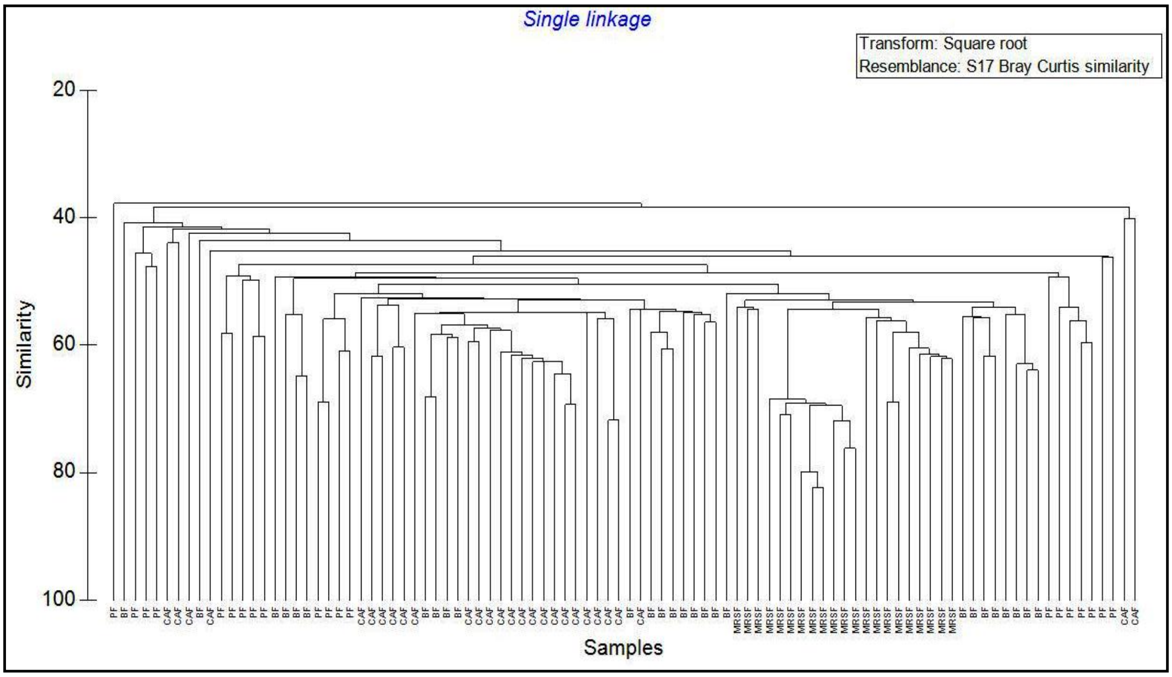


Figure 5.5: Dendrogram showing the classification of sampling plots (N = 96) into four distinct habitat types with respect to butterflies in Govind NP and WLS and adjoining area of Tons valley.

5.2.2.2 Habitat Similarity and Occupancy

The hierarchical cluster analysis classified all of the 96 sampling sites into four distinct groups with respect to butterfly compositions (Figure 5.5). Among these habitats mixed riparian and scrub forests clustered separately and showed similarity in butterfly composition with nbroadleaf forest.

Of all the 159 butterfly species recorded, 117 species occupied 1 **-** 20 sites in the Tons valley and 36 species occupied sites between 21 - 50 sites (Figure. 5.5), there were only three species that occupied highest number of sites, 61-80. There were 13 generalist species that occupied number of sites from 39 – 72: Large Cabbage White, Common Brimstone, Indian Cabbage White, Indian Tortoiseshell, Pioneer, Spotless Grass Yellow, Pale Grass Blue, Common Emigrant, Common Copper, Indian Red Admiral, Plain Tiger and Painted Lady (**Table 5.2**). Most of the habitat specialist species belong to the families Nymphalidae and Lycaenidae. Species like Golden Emperor, Great Windmill, Chapman's Cupid and Eastern Blue Sapphire were highly habitat specialist species and were recorded only at one site. While Large Golden Fork, Broadstick Sailer, Dark Green Fritillary and Indian Purple Emperor were species that occupied 2 - 3 sites (**Table 5.2**).

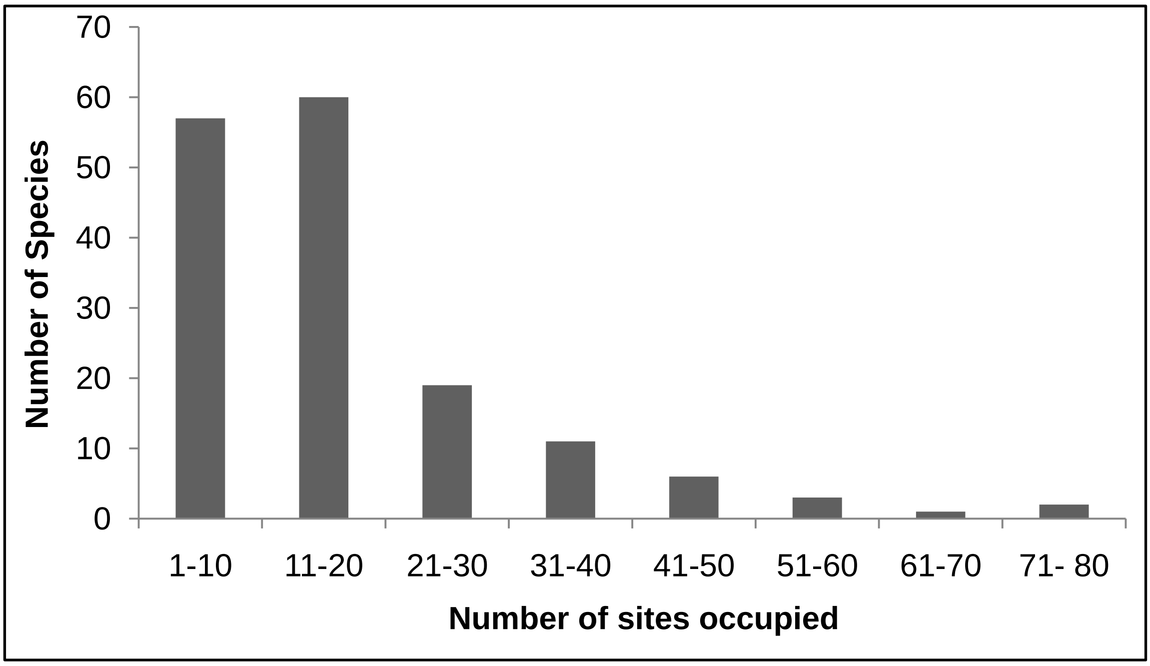


Figure 5.6: Site occupancy rates of butterflies in Tons valley, shown as the number of butterfly species in each class interval of number of sites occupied.

Table 5.2: A list of major butterfly species recorded on both extremes of the habitat-specialization gradient in Tons valley. A total of 96 sites in 4 major habitat types were sampled.

Habitat category	Butterfly species	No. of sites occupied
Habitat Generalists	Large Cabbage White	72
	Common Brimstone	71
	Indian Cabbage White	68
	Indian Tortoiseshelln	53
	Pioneer	52
	Spotless Grass Yellow	51
	Pale Grass Blue	48
	Common Emigrant	47
	Common Copper	46
	Indian Red Admiral	44
	Plain Tiger	41
	Painted Lady	39
Habitat Specialists	Common Baron	4
	High Brown Silverspot	4
	Himalayan Jester	4
	Indigo Flash	4
	Yellow Sailor	3
	Dark Green Fritillary	3
	Indian Purple Emperor	3
	Large Goldenfork	3
	Broadstick Sailor	2
	Fulvous Pied Flat	2
	Chapman's Cupid	1
	Dusky Yellow-Breasted Flat	1
	Golden Emperor	1
	Great Windmill	1
	Eastern Blue Sapphire	1

5.2.3 Discussion

The present study provides a systematic inventory of butterflies, in Gangotri landscape in western Himalayan region. There are approximately 417 species of butterflies in the western Himalayas (Wynter-Blyth, 1957). However 50% of the species that may be found in the western Himalayan region were recorded during present study. It is difficult to precisely know the exact number of regional species. However, based on estimated species richness, the inventory was almost complete at the regional scale (96%) and the study can be described as exhaustive. While undoubtedly species were missed at local scale, since the current study was focus to sample the understory layer. Thus, the species that predominantly occur in the canopy were under sampled. Furthermore, sampling efficiency was decreased in dense forests. Therefore, capturing cryptic species (Subfamily: Satyrinae) in dense vegetation habitat is probably less complete than open habitats. Using a sample size independent diversity measures (Fisher's alpha), minimizes distortions of between habitat comparisons (Hayek and Buzas, 1997).

The sampling protocol used here provides a comprehensive sampling of local and regional butterfly diversity. Highest species richness was encountered in mixed riparian and scrub forest and broadleaf forest and inventory completeness was also over 90%, for both of the habitats. These two forest communities support very heterogeneous vegetation assemblages. A relatively low diversity of butterfly in conifer and alpine forests can be attributed to the differences in temperature, rainfall and historical factors. It was observed that butterfly diversity showed a decreasing pattern from mixed riparian and scrub, broadleaf, pine, to conifer and alpine forest. Conifern and alpine forests are distributed at higher elevations and as butterflies are ectotherms, thus a low diversity was found at higher elevation forests. The high butterfly diversity in broadleaf forest may be due to the fact that broadleaf forests are found in mid-elevation zones and may work as a buffer or ecotone habitat between low and high elevation butterfly assemblages, as climatic and resource conditions are in contrast at both ends. High elevation butterfly communities may come down to lower elevations during a large decrease in temperature at higher elevations. Low elevation communities may move up to mid elevations as temperature become very high during dry season. The intermediate disturbance hypothesis (Connell, 1978) might provide an additional explanatory support for the high diversity in mixed riparian and scrub forests and broadleaf forests. According to this hypothesis species diversity is greatest in communities experiencing intermediate levels of disturbance. Disturbance creates novel opportunities for species not found in undisturbed forest, and the habitat mosaic resulting from regeneration after patchy disturbance further increases the number of niches available. As local communities are dependent on these forests for fodder and fuel wood. This may lead to creation of open patches which butterfly uses for basking and thermoregulation. Logging creates open patches and these patches also maintains relatively high temperature, which may be important for thermoregulation requirements. Similar results were found by Devi and Davidar (2001), Ghazoul (2002), Cleary (2004) and Akite (2008) studying effects of logging on butterfly diversity.

5.3 Moths

5.3.1 Govind NP and WLS

5.3.1.1 Habitat Similarity

Sixteen families and 1992 specimens of moths were collected from the 20 sampling sites and were primarily sorted into 784 morphospecies, among which 1480 individuals could be assigned to the family level and 234 were identified up to the species level. The 20 sampling points (details of these are given in **Table 5.3**) were broadly grouped into six nmajor vegetation zones, from lower to higher elevation zones: Chir Pine Forest, Agricultural Mixed Land, Mixed Riverine Forest, Broadleaved Mixed Forest, Conifer Forest and Alpine Scrubland.

The number of moth species and the number of individuals trapped varied considerably between the vegetation zones, ranging from 118 to 261 species and 198 to 561 individuals. The family Geometridae was the most dominant family in all the vegetation zones sampled, with 522 individuals and 186 species, followed by the families Noctuidae (252 individuals and 74 species), Arctiidae (190 individuals and 60 species), Pyralidae (159 individuals and 62 species), Crambidae (126 individuals and 37 species), Lymantridae (69 individuals and 29 species) and Lasiocampidae (49 individuals and 21 species) (**Figure 5.7**). The other nine families, *viz.* Eupterotidae, Drepanidae, Sphingidae, Nolidae, Notodontidae, Pterophoridae, Saturniidae, Heliodinidae and Totricidae, had minor representations in terms of species richness as well as individuals.

Table 5.3: Location, GPS co-ordinates, altitude (m), protected area and major vegetation zones of 20 sampling sites for recording moths

Sampling Site	Location	Protectd Area	Altitude (m)	GPS Co-ordinates	Major Vegetation Zones
Chir Pine Forest	Naitwar	GWS	1450	31°04′07.5″ N 78°06′21.4″ E	Chir Pine
Riverine Mix Forest 1	Bhatwari	GNP	1530	31°04′07.5″ N 78°06′21.6″ E	Mixed Riverine
Riverine Mix Forest 2	Dhaula	GWS	1580	31°07′40.7″ N 78°02′41.0″ E	Mixed Riverine
Riverine-Broadleaf Mix	Jakhol	GWS	2100	31°06′7.7″ N 78°13′39.1″ E	Mixed Riverine
Low Agriculture Scrub	Naitwar	GWS	1450	31°04′07.3″ N 78°06′21.1″ E	Agriculture Mix
High Agriculture Scrub	Osla	GVNP	2600	31°07′09.8″ N 78°20′35.1″ E	Agriculture Mix
Broadleaf Mixed Forest 1	Harsil	GNP	2100	31°02′32.7″ N 78°44′51.7″ E	Broadleaf
Broadleaf Mixed Forest 2	Istragad	GWS	2100	31°07′40.7″ N 78°02′41.0″ E	Broadleaf
Broadleaf Forest 1	Haltadi	OP	2200	31°03′39.5″ N 78°07′38.0″ E	Broadleaf
Broadleaf Forest 2	Taluka	GWS	2200	31°04′03.0″ N 78°13′13.7″ E	Broadleaf
Disturbed Grassland	Chirwasa	GNP	3200	30°58′52.5″ N 79°01′17.0″ E	Agriculture Mix
Conifer Forest 1	Bhaironghati	GNP	2400	31°01′36.2″ N 78°52′04.7″ E	Conifer
Conifer Forest 2	Istragad T23	GWS	2450	31°07′24.0″ N 77°59′10.4″ E	Conifer
Conifer Mixed Forest 1	Istragad T25	GWS	2500	31°07′35.3″ N 78°01′31.7″ E	Conifer
Conifer Mixed Forest 2	Pustara	GWS	2600	31°04′03.6″ N 78°15′06.8″ E	Conifer
Rhododendron campanulatum P 1	Changsil	GWnS	2300	31°07′24.0″ N 77°59′10.4″ E	Broadleaf
Rhododendron campanulatum P 2	Devgad	GNP	2300	30°59′44.4″ N 78°58′57.8″ E	Broadleaf
Juniper Scrub	Bhojwasa	GNP	3350	30°57′09.0″ N 79°03′01.7″ E	Alpine Scrub
Alpine Grassland 1	Har-ki-Dun	DVNP	3350	31°09′01.89″N 8°25′ 44.74″ E	Alpine Scrub
Alpine Grassland 2	Gomukh	GNP	3850	30°55′33.0″ N 79°04′44.0″ E	Alpine Scrub

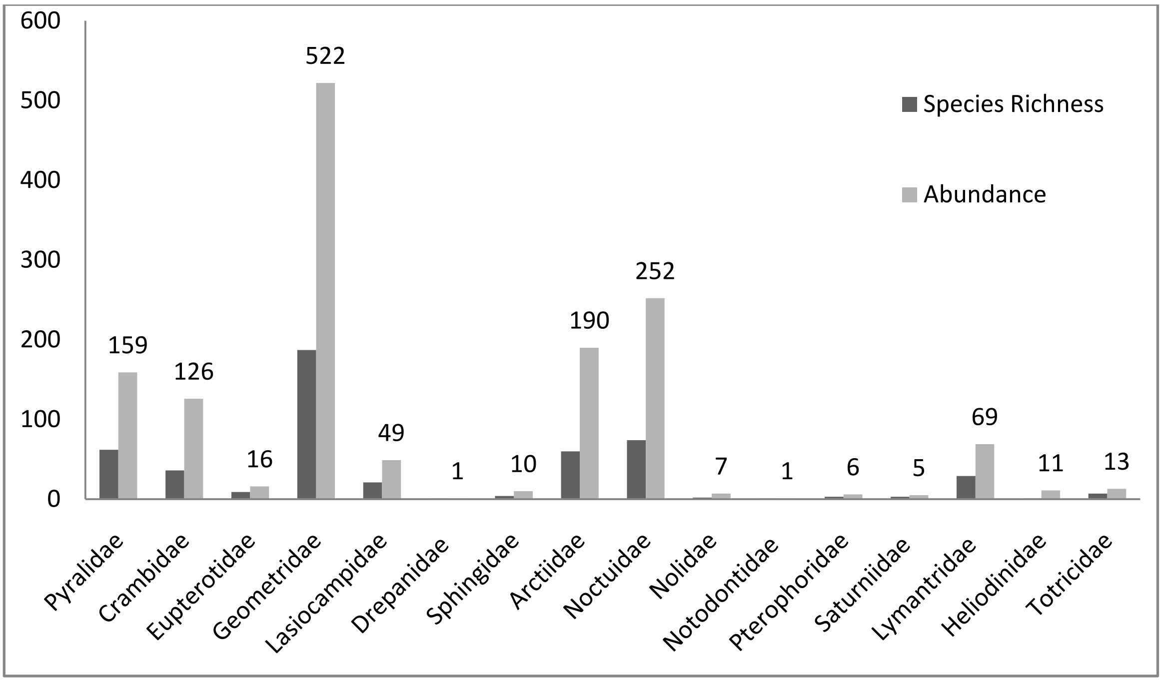


Figure 5.7: Species richness and abundance of 16 families of moth recorded in the study area. The family Geometridae was the most dominant family, followed by the families Noctuidae, Arctiidae and Pyralidae

5.3.1.2 Alpha Diversity Measures and Habitat Comparison

Different diversity measures were calculated for moths in all the major vegetation zones for selecting a suitable diversity index. Among all the indices, Fisher's alpha performed most efficiently to discriminate between all the zones. Pine Forest (158.7) had the highest diversity, followed by Mixed Riverine Forest (97.86) and Conifer Forest (70.75). Diversity was low in rather homogenous habitats such as Alpine Scrubland (42.72), Agricultural Scrub (49.94) and Broadleaf Forest (39.07) **(Figure 5.8)**.

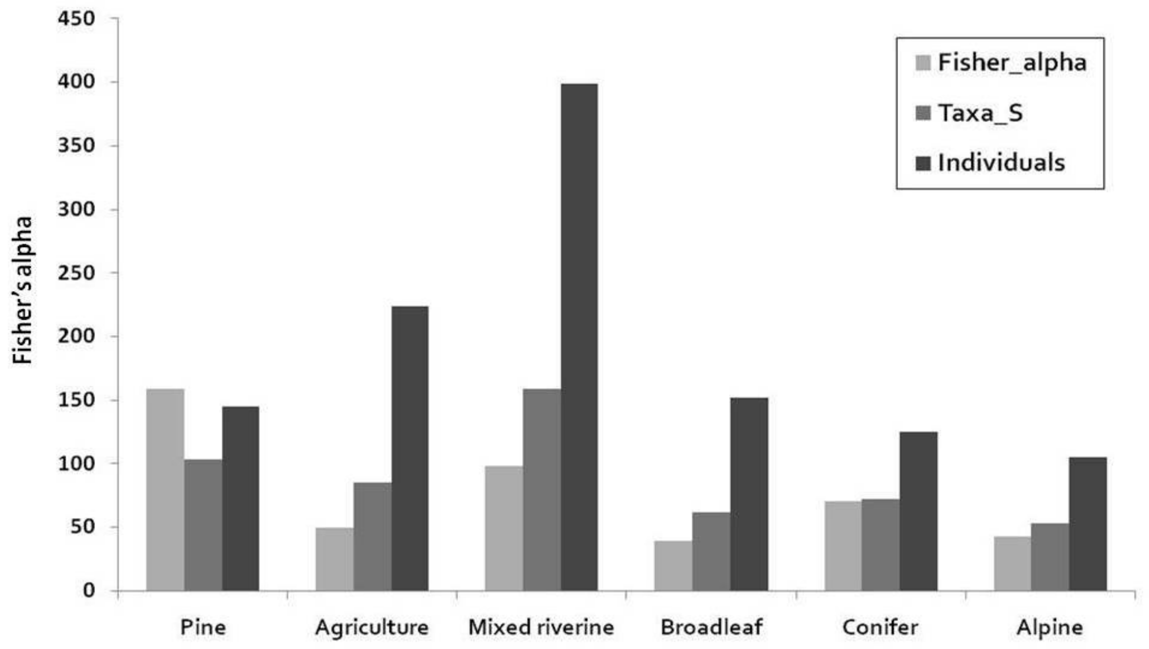


Figure 5.8: Species richness, abundance and Fisher's alpha value of moth assemblage at different Vegetation zones. The alpha value was highest in Chir Pine Forest and lowest in Broadleaved and Alpine Scrubland. Species richness and individuals recorded were highest in Riverine Forest

5.3.1.3 Species-Accumulation Curve

As all the sites were sampled with different intensity, rarefaction method was used as a suitable alternative for diversity measure. Asymptotes were not reached in the species accumulation curves (**Fig 5.9**) for any of the five habitats except agriculture scrub showing that a complete inventory had not been achieved. All the curves lay within a relatively narrow band and no clear pattern is visible. Sampling inadequacy was evident in all the habitats. Rarefaction curves showed Chir Pine Forest and Mix Riverine forests to have higher species richness than any other habitat types, with Mix Riverine emerging as a diversity hotspot. Diversity was lowest in alpine scrubland and broadleaf mix forest.

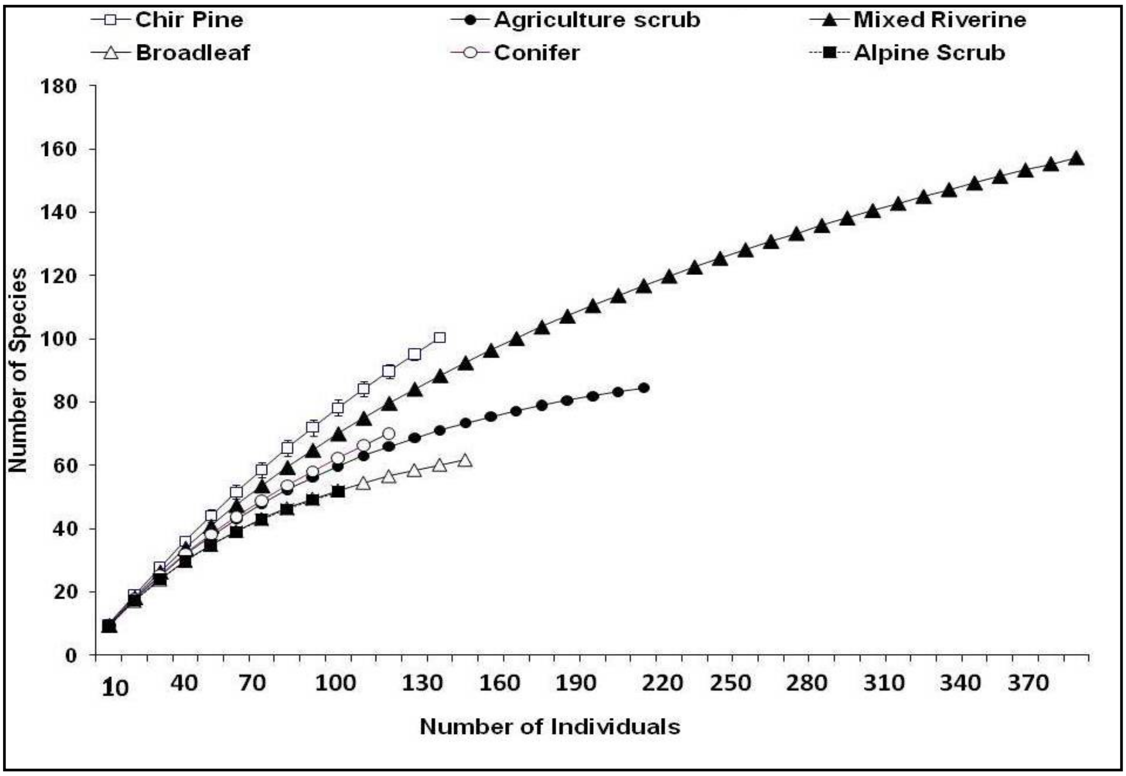


Figure 5.9: Individual based rarefaction curves to see the species richness and sampling success across different vegetation zones. Curves were rarefied to the lowest number of individuals recorded in a vegetation type (198) to ensure valid comparisons.

5.3.1.4 Species-Richness Estimators

The estimated total species richness using Chao1 was 473 ± 12.32 (SD), and using Jacknife2 491±11.82 (SD) for the complete sample. The ratio of observed to estimated (Chao1) number of species was 82% suggesting that at least 18% more species are to be expected in the area than were actually collected. However, at local level, in Chir Pine, Broadleaf and Conifer forest, we failed to collect such a high percentage of species (44% missing) compared with other habitat types (**Table 5.4**). From all species recorded, 153 were singletons (34% of all species) and 83 were doubletons (18% of all species). The highest species richness was found in the Mixed Riverine Forest (261 species), while lowest species richness was in the Alpine Scrubland (118 species). The remaining four habitat types did not differed statistically in richness considering the overlap of confidence intervals of richness value. The fraction of local singletons relative to species numbers recorded per site varied between 26% and 77%. The highest contribution of singletons was found in Chir Pine forest and this is the least successfully sampled habitat (58% completeness). Conifer and Alpine scrub habitat had lower proportion of singletons; these were lowest at sites with more regeneration or at early successional phase.

Table 5.4: Measures of species richness estimates and inventory completeness for each habitat type for moth assemblage. Richness estimator values (Chao 1 & Jacknife2) represent the mean of 100 randomizations of sample order. Ratio of estimated and observed richness represents inventory completeness. All values rounded to the nearest integer.

	Chir Pine	Agriculture Mix	Mixed Riverine	Broadleaf	Conifer	Alpine Scrub	Regional
No. of specimens	259	424	561	312	238	198	1992
Observed richness	190	161	261	137	146	118	784
No. of singletons	109	34	63	23	19	18	153
No. of doubletons	39	45	29	17	13	7	83
Chao 1	329	188	294	245	221	167	873
Jackknife 2	349	196	262	234	238	184	891
Percent completeness	58	86	89	56	66	71	90

5.3.1.5 Moth Diversity across Forest Types of Different Maturity Level

Alpha diversity (Fisher's alpha) of entire moth ensembles in the Isreagad-Changsil gradient, in relation to elevation at forest sites of different maturity level were regressed, with secondary disturbed forests at the lowest elevations, secondary forest with medium disturbance around 2000m and mature forest above 2200m. The lines result from separate linear regression analyses for the secondary forest and mature forest plots, respectively.

Forest habitats were subdivided into secondary forests, represented by the disturbed secondary forests of Chir Pine mix at the very base of the transect and closed secondary forests at elevations below 2200 m, and mature forests at elevations above 2200 m. Both secondary and mature forests showed significant, but diverging changes in alpha diversity with elevation (**Fig. 5.10**). While in secondary forests, moth diversity significantly decreased with increasing elevation (Pearson's r^2 = 0.63, P = 0.0001) and at a much stronger rate than in open habitats with 24 units/1000 m, values of Fisher's alpha showed a positive correlation with elevation in mature forest sites (Pearson's r^2 = 0.55, P = 0.002), with an increase of diversity of 8 units per 1000 m increase in elevation, hence somehow mirroring the decrease in open habitats.

The contrasting patterns observed in closed-canopy secondary and mature forest can also be related to the different conditions in these two habitat types. Moth ensembles in secondary forest widely follow the negative correlation observed as an overall trend in the ectothermic insects along the transect.

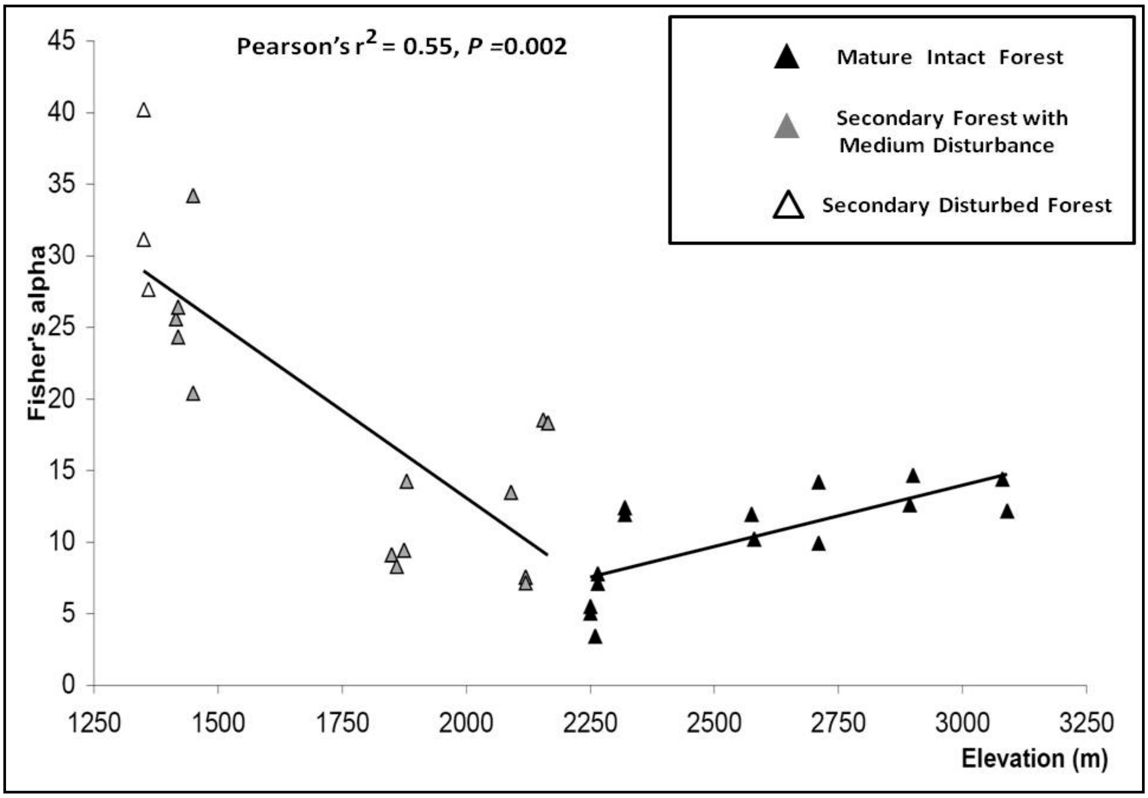


Figure 5.10: Alpha diversity (Fisher's alpha) of entire moth ensembles of all taxa recorded in relation to elevation at forest sites of different maturity level

The steep diversity decrease in secondary forests may be attributed to climatic factors like decreasing temperatures at higher elevations in the open secondary forests with a generally poorly developed shrub layer, in connection with a decrease in host plant diversity. The opposing pattern of slightly increasing diversity in mature forest from mid- to high elevations is ascribed to the extremely perhumid conditions prevailing in the mature forests at mid-elevations.

This low moth diversity is particularly remarkable since the diversity of vascular plants in the respective mature forests is relatively high, especially when compared to forest gaps and the secondary forest plots at slightly lower elevations (Axmacher et al., 2004). Another factor potentially contributing to the diversity minimum encountered in the mature forests at mid-elevation could be boundary effects at the upper forest margin enhancing diversity in mature forest sites at high elevations, where moth species associated with *Rhododendron companulatum* woodlands mix with forest species. Finally, the monotonic decrease in diversity of moth in open habitats, similar to the decrease observed in secondary forest, can be both related to a decrease in food plant diversity as well as to increasingly harsh environmental conditions at upper portions of the transect. As there is no tree covers at these open sites to dampen oscillations in temperature and humidity, both daily and seasonal fluctuations in ambient conditions are much more pronounced as compared to forest. This is particularly true for elevations above 3000 m, where sub-zero temperatures regularly occur at night in the *Rhododendron companulatum* woodland, and main flight activity of a number of moth species shifts to periods shortly before sun-set.

5.2.1.6 Sites and Zones Clustering Based on Moth Community Composition

Although fine level discrimination was not visible at the site level (**Fig 5.11a**) in the Bray-Curtis similarity coefficients, seven broad communities were visible. (i) All the agricultural scrublands, both high and low altitude, along with three Mixed Riverine Forest sites and Pine Forest sites, were clustered together. (ii) The Broadleaf Mixed Forest sites were separate altogether. (iii) Juniper scrubs and (iv) pure Conifer Forest sites formed two separate groups. The Conifer Mixed Forest sites formed two separate groups: (v) one with *Rhododendron campanulatum* scrub sites and (vi) another with alpine grasslands. (vii) Disturbed grassland sites, which were interspersed into Broadleaf Forest patches, formed a completely separate group. At the zone level (**Figure 5.11b**), the communities were well separated and made a gradient according to the elevational zones. While Pine Forest, Agricultural Scrub and Riverine Mixed Forest from the lower elevation band (1400 to 2200 m altitude) were clustered together, the higher elevational communities (2600 to 3500 m altitude) such as the Conifer Forest community and Alpine Scrubland community made separate clusters. Moreover, the Conifer Forest community and the Alpine Scrubland communities were the most closely related, with a similarity greater than 75% between them. The Broadleaved Mixed Forest, which lies from 2100 m to 2600 m in the study area, had a distinct community intermediate between the other two elevational clusters.

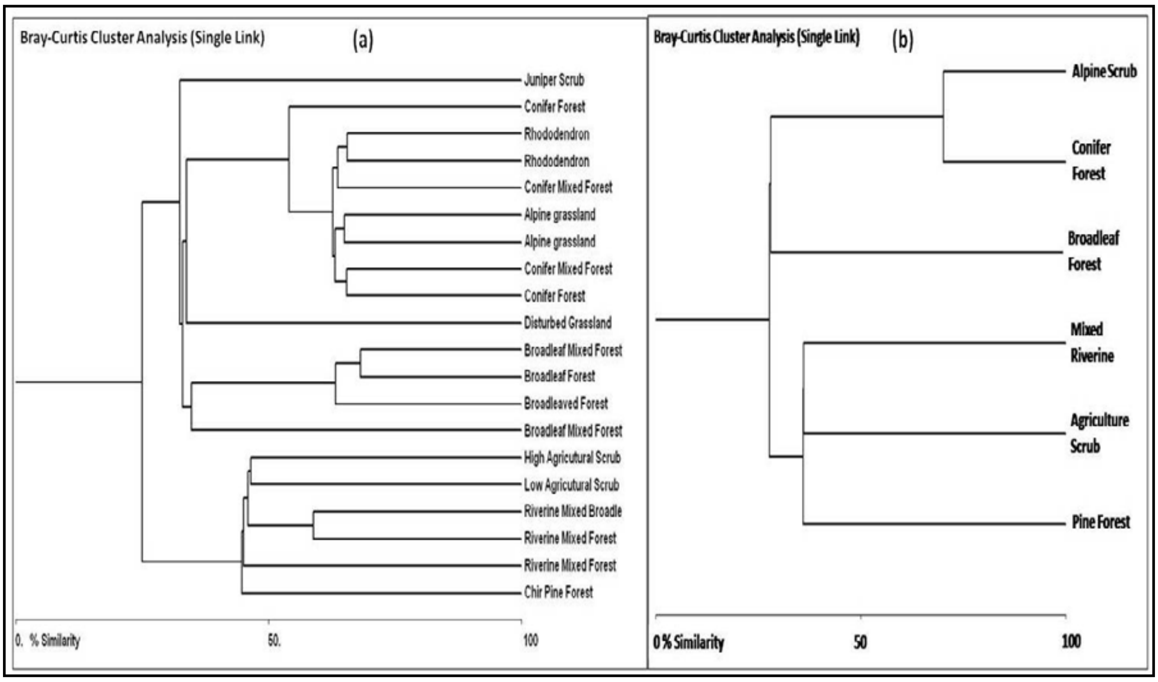


Figure 5.11: (a) Sites and (b) zone cluster from Bray-Curtis similarity coefficients: six major vegetation zones were identified from 20 sampling sites. At the zone level, the communities were well separated and made a gradient according to the elevation.

5.3.2 Discussion

The present study, a systematic inventory of moths, is the first of its kind in Gangotri Landscape and is one of the few studies on moth communities in India. As there is no previous species list available for this area, it is difficult to know precisely what proportion of the actual local and regional species richness the study captured. However, based on the estimated richness, the inventory was almost complete at the regional scale (90%). In spite of the relative success of this study, it still cannot be described as comprehensive – undoubtedly species were missed at local scales. Sampling additional sites or using different methods would capture more species. Additionally, lacking access to the modern equipments for light-trapping, we restricted our sampling to the understory layer. Thus, species that predominantly or exclusively occur in the canopy were under-sampled. Moreover, the sampling efficiency was reduced in the dense forest vegetation. Therefore, capturing cryptic species in the dense vegetation zone is probably less complete compared with open zones. However, using a sample-size independent diversity measure such as Fisher's alpha (Hayek & Buzas 1997) should minimize distortions of between-zone comparisons. Nevertheless, the inventory protocol utilized here provided sufficiently thorough samples of local and regional moth species to permit an accurate comparison of species richness of different vegetation zones. Overall, the moth assemblages varied among zones and revealed a pattern of assemblage response in relation to altitude and the related microclimatic regime of zones.

The moth diversity found was not similar in the different vegetation zones. Comparatively, Chir Pine and Mixed Riverine forests exhibit highly diverse assemblages, possibly due to their higher structural complexity. The relatively open and diverse overstory and understory structure of the Mixed Riverine forest supported the highest number of species, while the closed canopy Broadleaf Forest and agricultural sites supported relatively few species. In our study the proportion of unique singletons was 21%, but the fractions of local singletons mostly ranged around 30%. Singletons were more prevalent in the mature forest understorey. One plausible explanation for this high proportion is that species represented as singletons are "true forest species", which occupy special niches and occur at low densities. The moth composition in agricultural sites showed the most dissimilar assemblage in comparison with those of other vegetation zones. Possible reasons may be the scarcity of understorey vegetation, single species dominance, less complexity in vegetation structure and isolation from the nearest forest habitat, affecting the amount of different microhabitats available to moths. In conclusion, despite the small distances between the vegetation zones studied, the local ecological processes were strong enough to allow differentiation between moth species assemblages from mature forests and naturally disturbed sites. At disturbed sites the moth assemblages retained considerable diversity, even higher than in the mature forest, suggesting that landscape mosaics at the edge of nature reserves may support the survival of many of the more common species. Such areas could play an important role as buffer zones around protected areas (Schulze, 2000).

5.4 Conclusion

In conclusion, it was observed that despite small differences in geographic distance the landscape was able to support a high amount of Lepidopteran diversity and the processes involved with landscape heterogeneity were strong enough to support a unique Lepidopteran assemblage between forests. Despite enormous pressure from the local communities on these habitats they supported considerably high (64% of butterfly species expected to be found in Uttarakhand state) butterfly diversity in such a small area. As there is no previous species compilation of moths for the state of Uttarakhand or Western Himalaya as such, success of the study cannot be assessed. Although with a list of 468 species and lots more to be identified in future, the study can be regarded as exhaustive. This only shows the potential of the area in harboring exceptionally high diversity of Lepidopteran assemblage. The landscape along with three protected areas (Gangotri NP, Govind WLS and NP) and their adjoining habitats are important for long term conservation of entomofauna as well as biodiversity as a whole in Uttarakhand, Western Himalaya.

CHAPTER 6
PATTERNS OF LEPIDOPTERA DISTRIBUTION ALONG ELEVATION GRADIENT IN GANGOTRI LANDSCAPE

6.1 Introduction

Biodiversity on earth is not uniformly distributed, and understanding these patterns and underlying mechanisms has been central theme in biogeography, macroecology and conservation biology during in recent times. Latitudinal gradient in species diversity is perhaps the best studied, documented and most consistent ecological pattern in spatial ecology (Gaston & Blackburn, 2006), in which the species richness declines (for most of taxa) with increase in distance from equator (Rosenzweig, 1995; Hillebrand, 2004), although there are a few exceptions. Differences in patterns in species richness along elevational gradients may vary among taxa, geographic regions, unit of sampling and spatial scale and disturbance (Kattan & Franco, 2004; Rowe & Lidgard, 2009; Sanders et al., 2003). Elevational patterns in species richness exhibit four general patterns: mid-elevation peak, decreasing, low plateau and low plateau with a mid-elevational peak (McCain, 2009).

Hypothesized factors that are assumed to shape these patterns can be grouped majorly as: Climate (temperature and rainfall), space (area and mid-domain effect), evolutionary and biotic factors (niche conservationism, isolation, speciation, endemism and evolutionary processes) (McCain and Grytnes, 2010). To document elevational pattern of Lepidoptera species richness in Gangotri landscape, we aimed to answer the following questions: (1) What is the pattern of species richness along elevation; (2) What factors are correlated with richness?

6.2 Butterflies

6.2.1 Pattern of Species Richness along Elevational Gradient

A total of 174 species of butterflies were recorded over the course of the study sampled across 520 transects at 26 sampling sites. Non parametric estimators

(Chao1) yielded higher value compared to observed species richness (**Figure 6.1**). Overall inventory completeness was 95% considering highest estimate (Chao1) of species richness for compete dataset (**Table 6.1**).The mean butterfly species richness was 57.6 species (N = 26), with a minimum of 5 species (recorded at 3400 – 3500 m elevation zone) and a maximum of 110 species (recorded between 1200 – 1300 m elevation zone). In general butterfly species richness was highest in 1200 – 2100 m elevation while lowest in between 2900 – 3500 m elevation zones of the study area (**Figure 6.3**).

Table 6.1: Species richness estimates of butterflies across study area in Tons valley.

Estimator/Model	Estimate	SE (±)	95% Confidence interval
Observed species richness	174	-	-
Chao1 (Chao, 1984)	184.6	16.9	(161.0 - 232.8)
ACE (Chao and Lee, 1992)	178.6	6.6	(177.5 - 203.8)
1st order jackknife	177.0	7.7	(165.2 - 196.4)

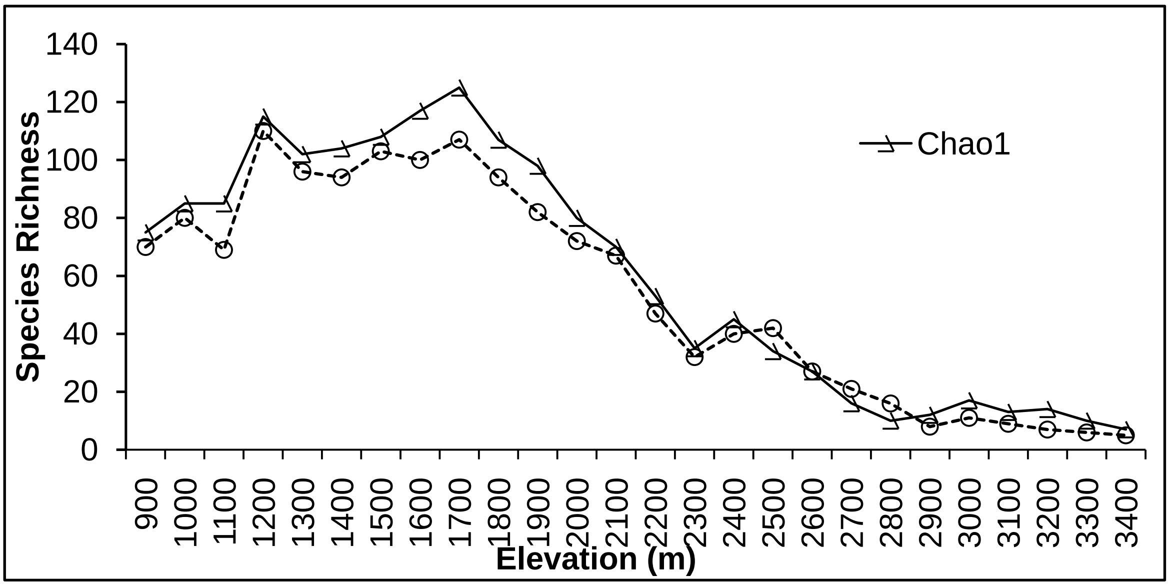


Figure 6.1: Line curves to compare observed species richness with estimated species richness to evaluate sample adequacy at each site along elevation.

The butterfly species richness increases and reaches its peak at 1200 m and shows a hump shaped pattern at middle elevations ranges from 1200 – 1700 m, with the maximum value observed at 1200 m. This value accounted for 68.9% of total number of butterfly species recorded during study in Tons valley. A second peak was also observed at 1700 m, accounting for total 61.4% of species. Butterfly species richness shows a linear decreasing pattern between elevation ranges from 1700 – 3500 m. Regression analysis showed a highly significant negative correlation (r = -0.81, N = 26, *P* < 0.01) between elevation and observed species richness of butterflies. Thus butterfly species richness pattern along elevation gradient falls within general pattern of an initial increase in species richness, followed by a peak and then a decline with no further increase in species richness along increasing elevation. The observed and estimated species richness showed strong positive correlation with each other (r = 0.99; N = 26; P > 0.01).

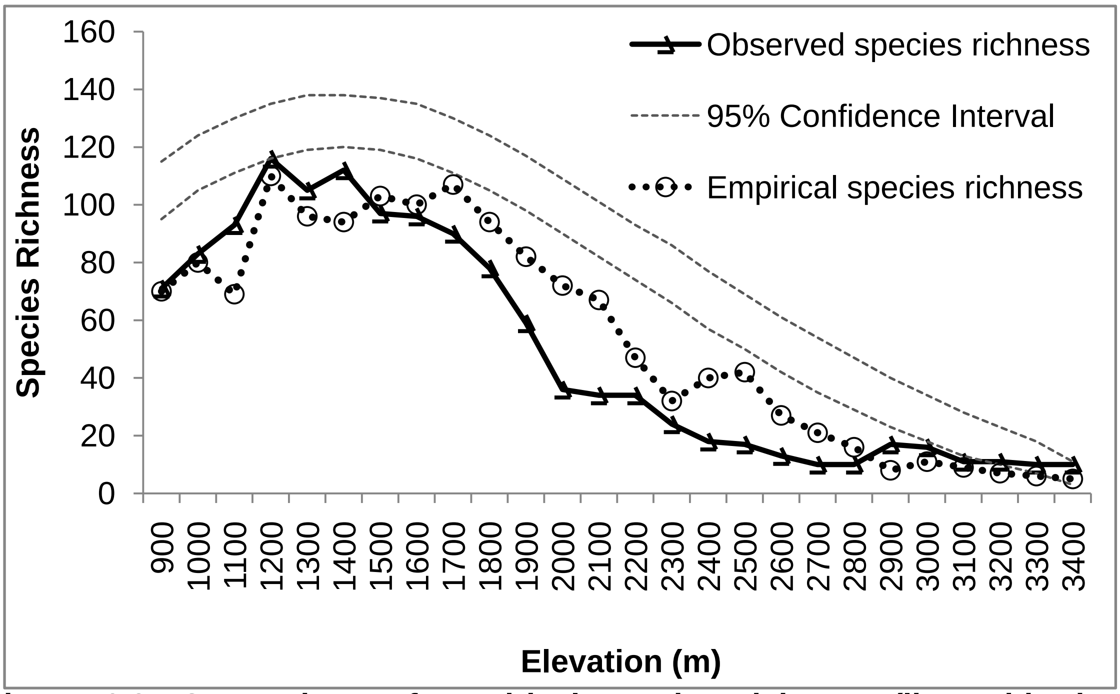


Figure 6.2: Comparison of empirical species richness (line with data points) with 95% prediction curves sampled without replacements from program Mid-domain null (McCain, 2004)

Support for mid-domain effect was found in current study. The curves were nearly symmetrical and thus not differed from mid-domain predictions (Figure 6.2). A comparison of the empirical data with the 95% prediction curves obtained from the 50,000 simulations using range sizes showed that more than 80%

(22/26) occurred outside the predicted range of null model (**Figure 6.2**). Empirical species richness was significantly correlated with the mean of the predicted richness (r = 0.92; N = 26; $P > 0.01$).

6.2.2 Role of Area, Temperature, Rainfall and NDVI

With increasing elevation the area of each elevation band first increased steeply from 900 - 2000 m and then after 2000 m increased very slowly, but a significant correlation was found between area available under each 100 m elevation band and elevation(r = 0.90, $p < 0.0001$) (**Figure 6.3**). Highest area was available between 3000 - 3100m elevation bands. Finally the area of each point above 3100 m gradually decreased upto 3500 m. The correlation between the species richness of butterflies and the area was significant but negative (r = -0.58, $p < 0.02$).

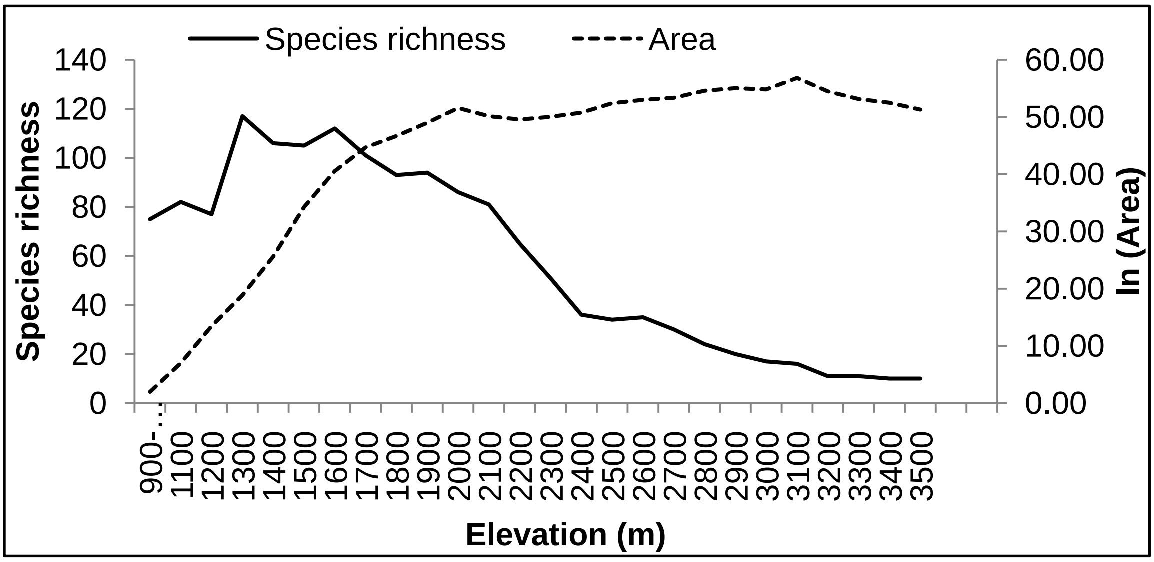


Figure 6.3: Relationship between area of 100 m elevational band and species richness of butterflies

Butterfly species richness increases initially upto 1300 m and was symmetrical with an increase in area. After 1300 m species richness of butterflies gradually decreased with no further increase upto 3500 m while area available under each elevation band increased.

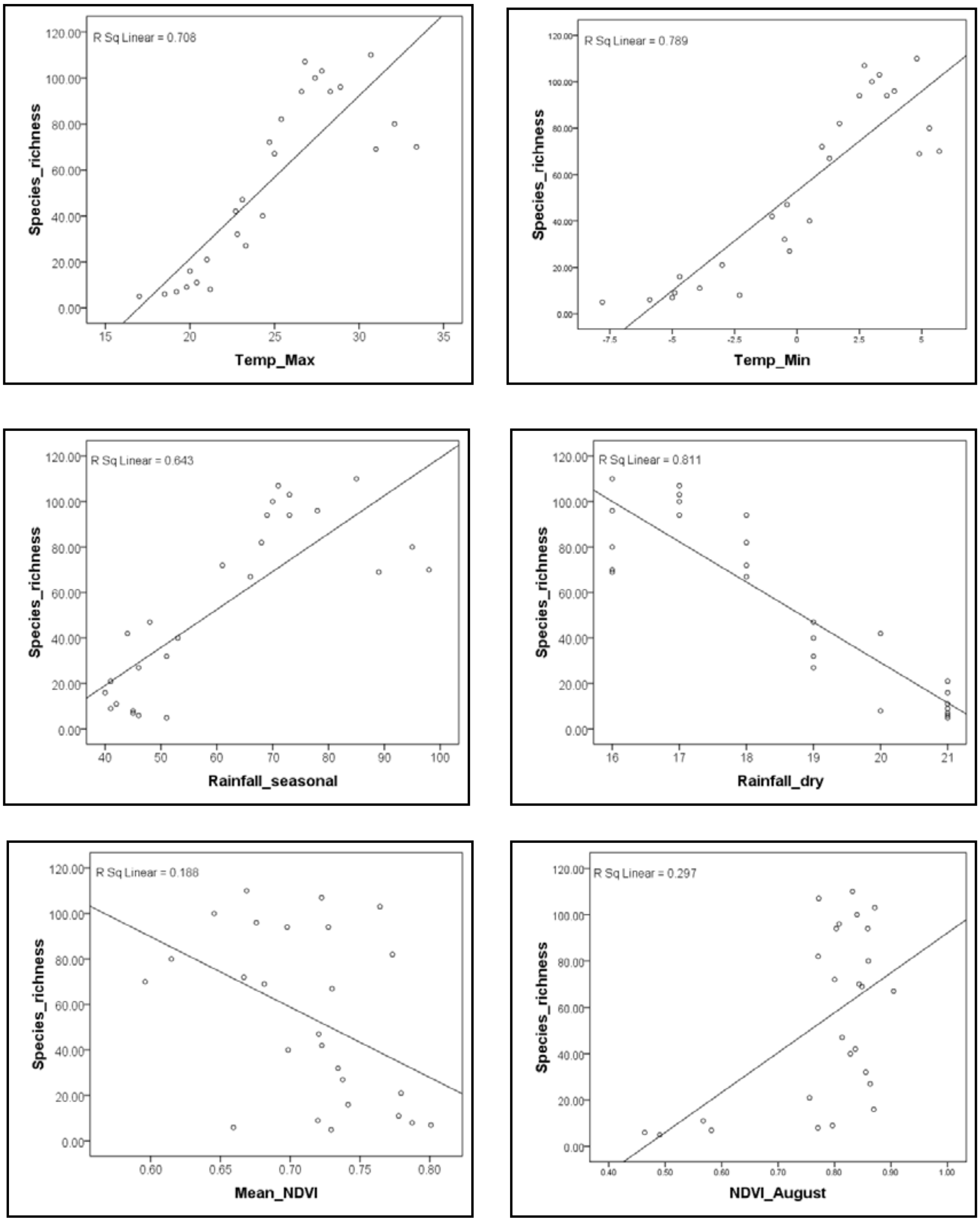


Figure 6.4: Scatterplots showing relationships between butterfly species richness and climatic and primary productivity variables along elevational gradient in Tons valley (N = 26)

The butterfly species richness was found to be significantly positively correlated with maximum (r = 0.70, $p < 0.01$) and minimum (r = 0.78, $p < 0.01$) temperature. While, species richness was found to be correlated with seasonal (r = -0.64, $p < 0.01$) and dry quarter rainfall (r = 81, $p < 0.01$). We used NDVI as a surrogate for productivity, surprisingly butterfly species richness was found to be poorly associated but significant with mean NDVI ($r = 0.18$, $p < 0.01$) and NDVI of August month ($r = 0.29$, $p < 0.01$) (**Figure 6.4**).

6.2.2.1 Effect of Habitat Attributes and Microclimatic Variables at Plot Level

Microclimatic variables, such as temperature, had significant positive influence on species richness ($r = 0.69$, $N = 42$, $P < 0.01$) and abundance ($r = 0.74$, $N = 42$, $P < 0.01$). Relative humidity had a slight negative influence on butterfly species richness ($r = -0.35$, $N = 42$, $P < 0.05$) and a negative association with abundance ($r = -0.20$, $N = 42$, $P > 0.05$). Wind speed did not contribute significantly to either variation in butterfly species richness ($r = 0.20$, $N = 42$, $P > 0.05$) or abundance ($r = 0.27$, $N = 42$, $P > 0.05$) across sampling locations (**Table 6.2**).

Elevation was an important factor in accounting for variation in butterfly species richness ($r = -0.81$, $N = 42$, $P < 0.01$) and abundance ($r = -0.55$, $N = 42$, $P < 0.01$) across sampling locations. The other cardinal variables that were associated with butterfly species richness and habitat specificity involved vegetation cover. Plant species richness was positively associated with butterfly species richness ($r = 0.87$, $N = 42$, $P < 0.01$) and abundance ($r = 0.65$, $N = 42$, $P < 0.01$). Variation in butterfly abundance and species richness across sampling plots was highly predicted by herb density (Abundance: $r = 0.95$, $N = 42$, $P < 0.01$; Butterfly species richness: $r = 0.74$, $N = 42$, $P < 0.01$) and shrub density (Abundance: $r = 0.82$, $N = 42$, $P < 0.01$; Butterfly species richness: $r = 0.69$, $N = 42$, $P < 0.01$), but poorly predicted by canopy cover (**Table 6.2**).

Fire and livestock abundance were negatively associated with butterfly species richness (Fire signs: $r = -0.36$, $N = 42$, $P < 0.05$; Livestock abundance: $r = -0.33$, $N = 42$, $P < 0.01$) and abundance (Fire signs: $r = -0.49$, $N = 42$, $P < 0.05$; Livestock abundance: $r = -0.31$, $N = 42$, $P < 0.05$). Surprisingly, logging activities were positively correlated with butterfly species richness ($r = 0.32$, $N = 42$, $P < 0.05$) (Table 6.2).

Table 6.2: Relationship of butterfly species richness and abundance with microclimatic, vegetation, disturbance variables across sampling sites in Tons valley: table presents correlation values (Pearson's *r*) and a level of significance (* < 0.05, ** < 0.01: two tailed)

	Butterfly	
	Species Richness	**Abundance**
Altitude	-0.816**	-0.553**
Temperature	0.693**	0.749**
Relative humidity	-0.359*	-0.208
Wind speed	0.209	0.270
Plant species richness	0.871**	0.659**
Canopy cover	0.538**	0.187
Shrub density	0.693*	0. 823**
Herb density	0.745**	0.999**
Logging	0.328*	0.227
Fire signs	-0.366*	-0.337*
Livestock abundance	-0.493**	-0.312*

6.2.3 Discussion

We found that the species richness of butterflies in western Himalaya demonstrated a mid-elevation peak in species richness. Such a pattern is frequently documented in birds (Acharya et al., 2011; McCain, 2009), small mammals (Heany, 2001; McCain, 2004), herpetofauna (Hofer et al., 1999; Fu et al., 2007), invertebrates and plants (Kluge et al., 2006; Sanders et al., 2003; Oommen and Shanker, 2005; Grau et al., 2007). Other taxa in Himalaya and nearby regions also exhibit mid-elevation peaks in species richness: bird diversity in Eastern Himalaya, plant diversity in Central Himalaya, Nepal and Western Himalaya and small mammal diversity in Mt. Qilian, China. The question of importance is then what produces this pattern. In literature, the influence of area on species richness has been explained by the theory of island biogeography (MacArthur, 1972) or by the habitat diversity hypothesis. However, these concepts are not mutually exclusive and theoretically may even be complementary because area and habitat diversity are correlated. It has been widely mentioned that larger space can accommodate more species and species richness increases as a function of area (Rahbek, 1997). The influence of area in determining species richness has been shown for different taxa (Kattan and Franco, 2004; Fu et. al., 2006). For butterflies, the area seems to support species richness upto 2100m after which species richness gradually decrease and area increase. This may be possible that temperature and other factors became stronger in explaining butterfly species richness at higher elevation as butterflies are ectotherms and need more energy to support themselves at these higher elevations.

At local plot level, we found a more obvious association of butterfly species richness with vegetation parameters such as plant species richness, herb and shrub density and canopy cover at plot level. Herb and shrub density were major predictors of butterfly abundance. Anthropogenic factors such as logging were found to be positively associated with butterfly species richness and abundance. While forest fire and livestock abundance found to have significant negative influence on butterfly species richness as well as on abundance. As logging create open patches and these patches also maintain relatively high temperature, which may be important for thermoregulation requirements. Similar results were found by Devi and Davidar (2001), Ghazoul (2002), Cleary (2004) and Akite (2008) studying effect of logging on butterfly diversity. On the other hand, forest fire and livestock grazing directly impacts shrub and herb abundance and shrub and herb abundance was found to be significantly correlated with butterfly abundance and species richness. Precipitation and temperature emerges as a significant determinant of butterfly species richness in Tons valley at the regional scale.

6.3 Moth

The analysis for moth diversity along altitudinal gradient was performed in two different taxonomic levels. Alpha diversity of all the moth species and individual recorded were plotted along elevational gradient to see the overall trend in elevational pattern. Moreover, as different groups of taxa behave differently along altitudinal gradient, one major family, the Geometridae was chosen for separate analysis to see the elevational pattern of diversity. The reasons for selecting Geometridae were: their taxonomy is advanced compared to other families like Noctuidae, for which the subfamily level classification is still confusing. Moreover the Geometrids are a relatively habitat specific group, their diversity parallels their main food resource, vascular plants. They inhabit predominantly forested rather than open habitats and understory vegetation is well documented as the best predictor of geometrid diversity. Above all, they react very sensitively to subtle changes in habitat modification. The geometrids are already a well established group for comprehensive statistical analyses of diversity patterns.

6.3.1 Diversity pattern of all the moth species sampled

In total, 8,408 specimens representing 302 morphospecies of moths were regressed to see the alpha diversity pattern along altitudinal gradient. Numbers of moths caught on the entire elevational transect studied strongly varied with weather conditions, habitat and elevation. Hence, differences in sample size rendered the number of species sampled from each location a highly inaccurate measure of diversity. To overcome these limitations, alpha diversity was expressed as Fisher's alpha, a robust index widely employed in investigations of tropical moth communities (e.g. Schulze & Fiedler 2002; Axmacher et al. 2004) which is also relatively insensitive to under-sampling (Magurran 2004). A comparison of Fisher's alpha values including all habitats along the complete transect (**Figure 6.5**) shows that overall, diversity decreases highly significantly with increasing elevation from the base of the mountain to 3700 m (Pearson's r^2 (log-transformed) = 0.53, $P < 0.0001$). However, over a sizeable proportion of the gradient between 1800 and 3100 m, alpha diversity shows no correlation with elevation (Pearson's r^2 (logtransformed) = 0.0001, $P = 0.94$).

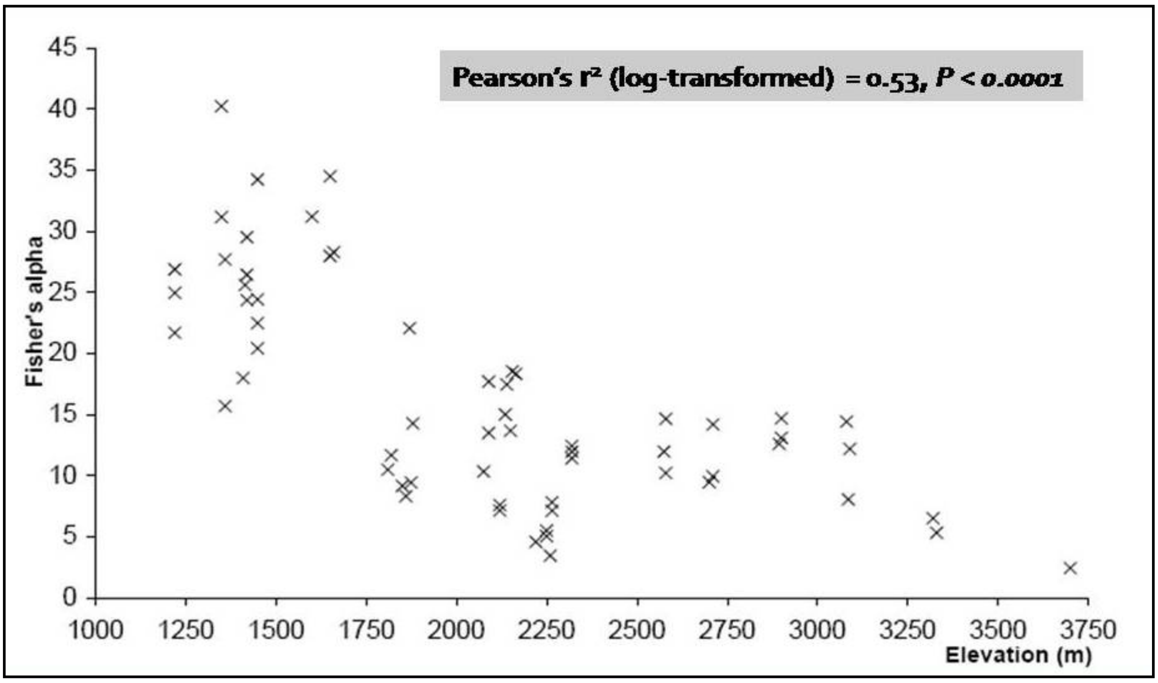


Figure 6.5: Overall change in species diversity (measured as Fisher's alpha) of all the moth species recorded along elevational transect in Gagngotri Landscape Area

Our results clearly indicate that patterns in the species diversity of all the moths along the extensive elevational transect are habitat-specific. This somehow contrasts with earlier findings (Axmacher et al. 2004), which indicated that elevation and related changes in climatic conditions was the dominating factor relating to both local diversity and species turnover. Nonetheless, along the extensive gradient investigated here, which stretched over a range of about 2700 m, local habitat conditions do seem to strongly modify the overall negative relationship between elevation and diversity. Reasons for these deviations from the common theme of decreasing diversity at higher elevations with their cooler climate must be inherent in the specific local conditions of the different habitats.

6.3.2 Diversity pattern of Family Geometridae

A total of 1,052 specimens representing 200 species of Geometridae were sampled. Among 8 subfamilies of Geometridae worldwide, 6 have been recorded from the study area. Ennominae was the largest subfamily representing 108 species. The subfamily Larentiinae which is mostly abundant in temperate region of the world is represented by 51 species. 23 species of Geometrinae, commonly known as Emerald moth, and 14 species of Sterrhinae were recorded. The two smallest subfamilies were Desmobathrinae (3 species) and Oenochrominae (only 1 species). The most interesting feature which came out along the entire elevational transect was the structural changes in faunal composition of different subfamilies within Geometridae (**Figure 6.6**). While the subfamilies Ennominae (squares), Sterrhinae (triangles) and Geometrinae (crosses) decrease in the proportion of species numbers, the subfamily Larentiinae (circles) increases with increasing altitude. Proportional changes in all four subfamilies are highly significant.

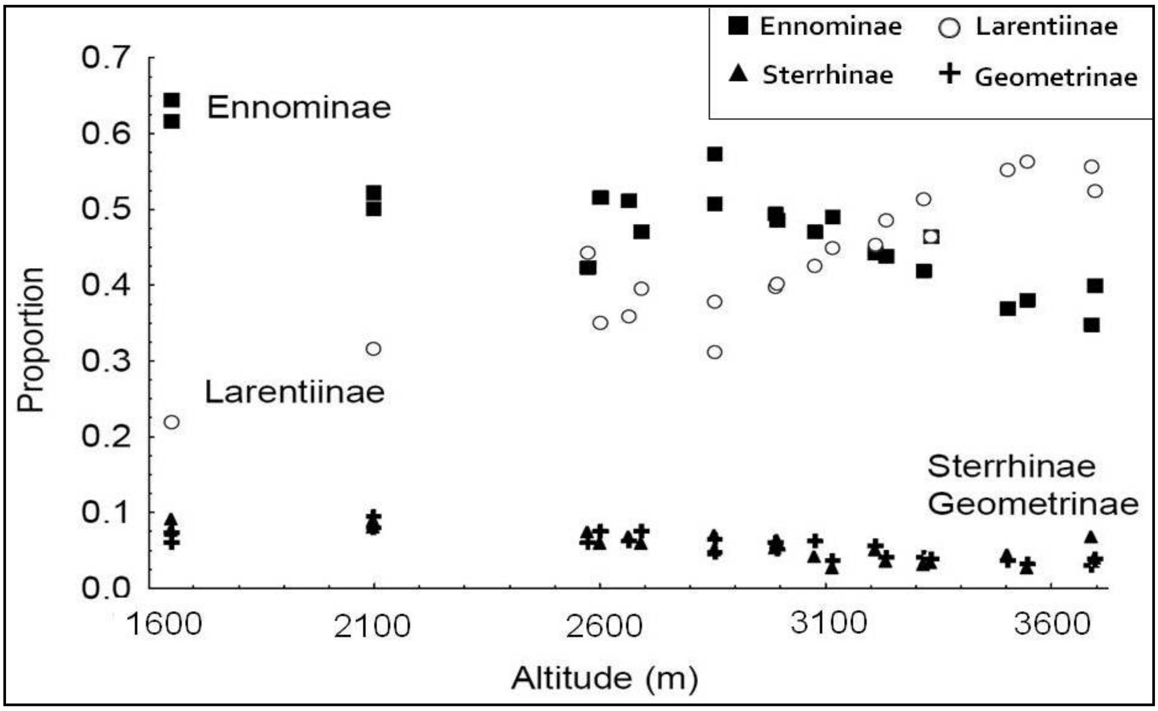


Figure 6.6: Structural changes in the Faunal Composition of Geometrid Moths along the Elevational Gradient in Gangotri Landscape

Species of the subfamily Ennominae clearly dominated at low elevational level (**Figure 6.7**), whereas, the ratio of Larentiinae increases towards high altitudes. Proportion of Sterrhinae and Geometrinae steadily decrease along altitude.

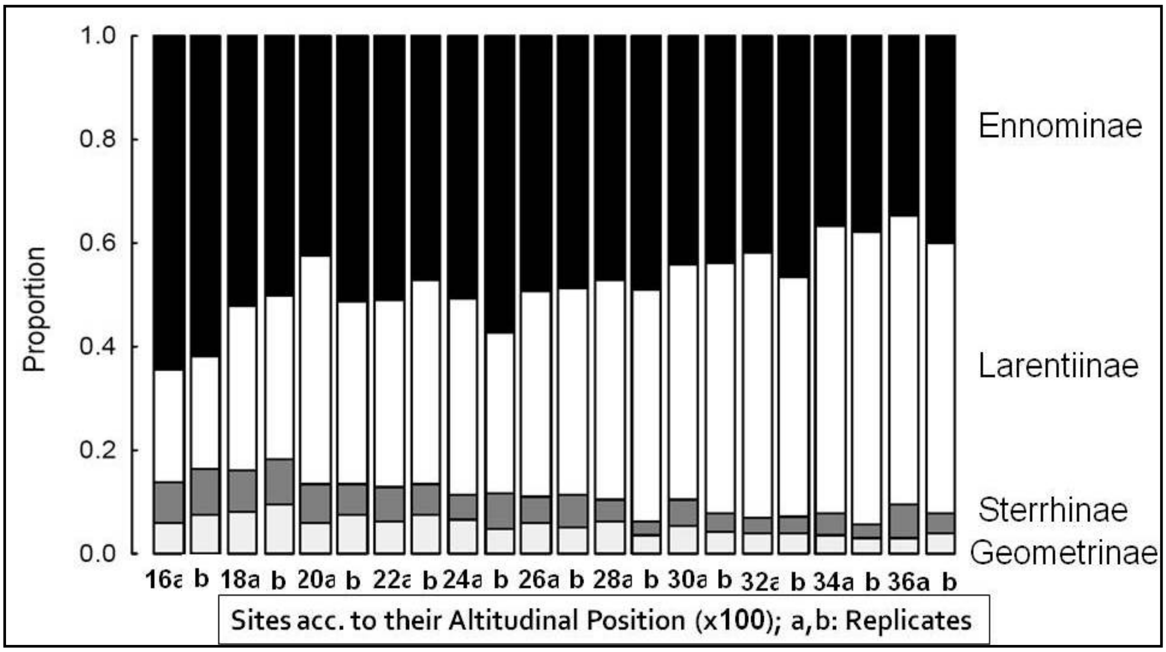


Figure 6.7: Proportion of subfamilies of Geometridae along increasing altitude based on species number

Table 6.3 shows Spearman rank correlation coefficients between four subfamilies and altitude. Species proportion and altitude are all highly significantly correlated. Very similar pattern occurs when number of specimens are analysed. Strongest positive correlation of Larentiinae with altitude is evident, i.e. their proportions are definitely increasing with altitude. On the other hand, strongest negative correlation of Ennominae with altitude is evident, that means, the proportion of this subfamily is strongly decreasing with altitude.

Table 6.3: Spearman rank correlation coefficients between proportion of four subfamilies of Geometridae moth with altitude

* p<0.05, *** p<0.001	Ennominae	Larentiinae	Geometrinae	Sterrhinae
Species number	-0.84 ***	0.92 ***	-0.79 ***	-0.84 ***
Specimen number	-0.84 ***	0.89 ***	-0.45 *	-0.52 *

Extrapolated species numbers at the individual sites are on average 70-80% larger than the observed number in all three taxa. For Geometridae as a whole and Ennominae, there doesn't seem to be any relationship between altitude and extrapolated number of species **(Figure 6.8)**. Whereas in case of Larentiinae, the extrapolated species number tends to increase with increasing altitude.

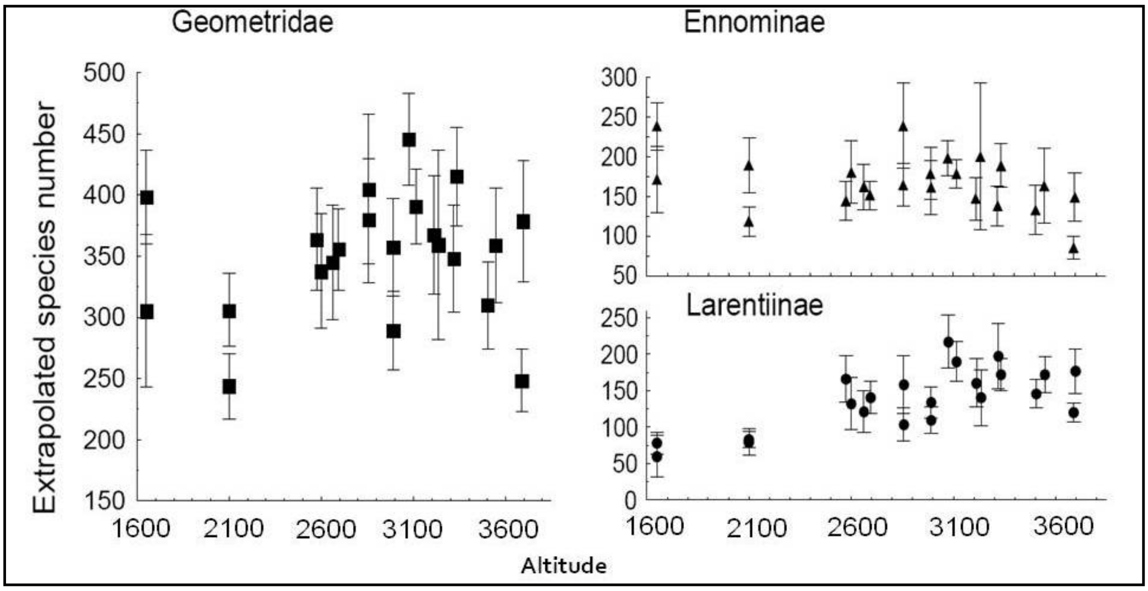


Figure 6.8: Diversity of Geometridae moths measured by extrapolation with estimator Chao 1 along increasing altitude

Figure 6.9 shows alpha values of Geometridae measured by Fisher's alpha at all 22 sites along altitudinal gradient. The values range from 69 to 130 and are amongst the highest values ever measured for local moth ensembles. There is no significant consistent change in Fisher's alpha along the altitudinal gradient. However in the subfamily Larentiinae, significant differences occur between the lowest and medium sites.

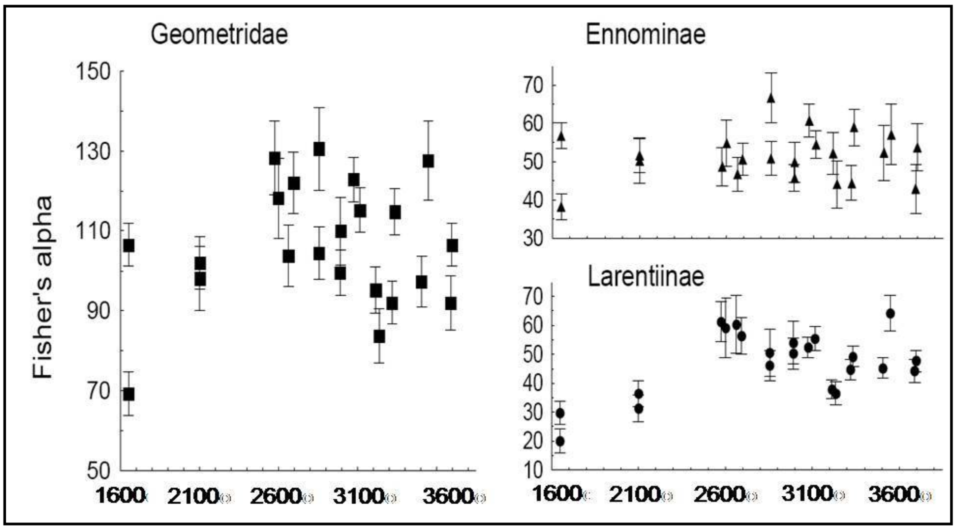


Figure 6.9: Diversity measured with Fisher's alpha for Geometridae and two subfamilies Ennominae and Larentiinae

Table 6.4 shows Spearman rank correlations between four measures of alpha diversity and specimen number and altitudes. Recorded species number is strongly correlated with the number of specimens collected in all three taxa. Therefore we must reject "species number" as reliable measure of alpha diversity. Significant strong positive correlation between Larentiinae and altitude occurs. So an increase in species number for this subfamily with altitude is evident.

	Geometridae	Ennominae	Larentiinae
Correlations between **specimen number** and			
species number	**0.91** ****	**0.93** ****	**0.94** ****
Fisher's alpha	0.15 ns	0.29 ns	0.11 ns
rarefied species number	-0.07 ns	-0.09 ns	0.32 ns
level [1]	350	100	50
extrapolated species number (Chao 1)	**0.58** ***	**0.54** **	**0.83** ****
Correlations between **altitude** and			
species number	0.13 ns	-0.39 ns	**0.78** ****
Fisher's alpha	0.08 ns	0.11 ns	0.16 ns
rarefied species number	0.01 ns	0.57 **	0.31 ns
extrapolated species number (Chao 1)	0.18 ns	-0.30 ns	**0.65** ***

Table 6.4: Spearman rank correlations between four measures of alpha-diversity and (1) specimen number, and (2) altitude. ns not significant, ** p<0.01, *** p<0.005, **** p<0.001. In bold are results that remain significant after sequential Bonferroni correction.

6.3.3 Effect of Microclimate Variables and Tree species Richness on Moth assemblage

We collected data on several environmental parameters like relative humidity, temperature, mean monthly rainfall and tree species richness in every altitudinal belt where moths were sampled. **Figure 6.10** shows these four environmental parameters along altitudinal gradient. While relative humidity was recorded maximum at medium elevation, temperature dropped significantly with increasing altitude, mean monthly rainfall first increased with altitude and took a sharp decline from 2400m and reached almost minimum level around 3400m. The precipitation in higher altitude is by means of snowfall mainly. Tree species richness reached its peak around 2000m and then declined gradually.

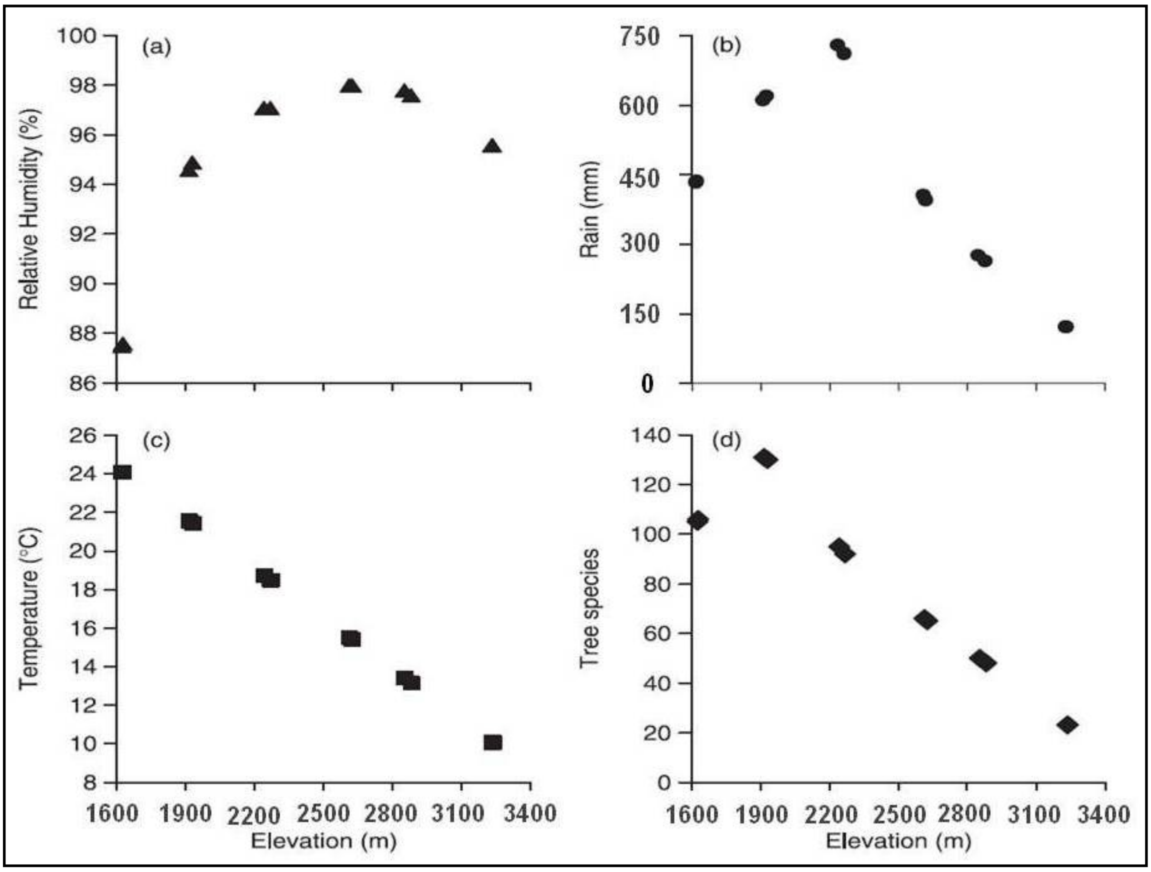


Figure 6.10: Environmental factors (relative humidity, temperature, rainfall and tree species richness) used for regression analysis on alpha diversity of moths

The regression between alpha values of geometrid and mean monthly rainfall indicates higher diversity at sites of lower rainfall. This is in contrary to the general idea that high rainfall translates into high primary production which in turn translates into high species diversity. Possibly water availability is not the limiting factor in the gradient studied. Regression with temperature (**Figure 6.11**) shows higher diversity at warmer areas, but our data suggests this relationship is valid only above a certain threshold elevational level.

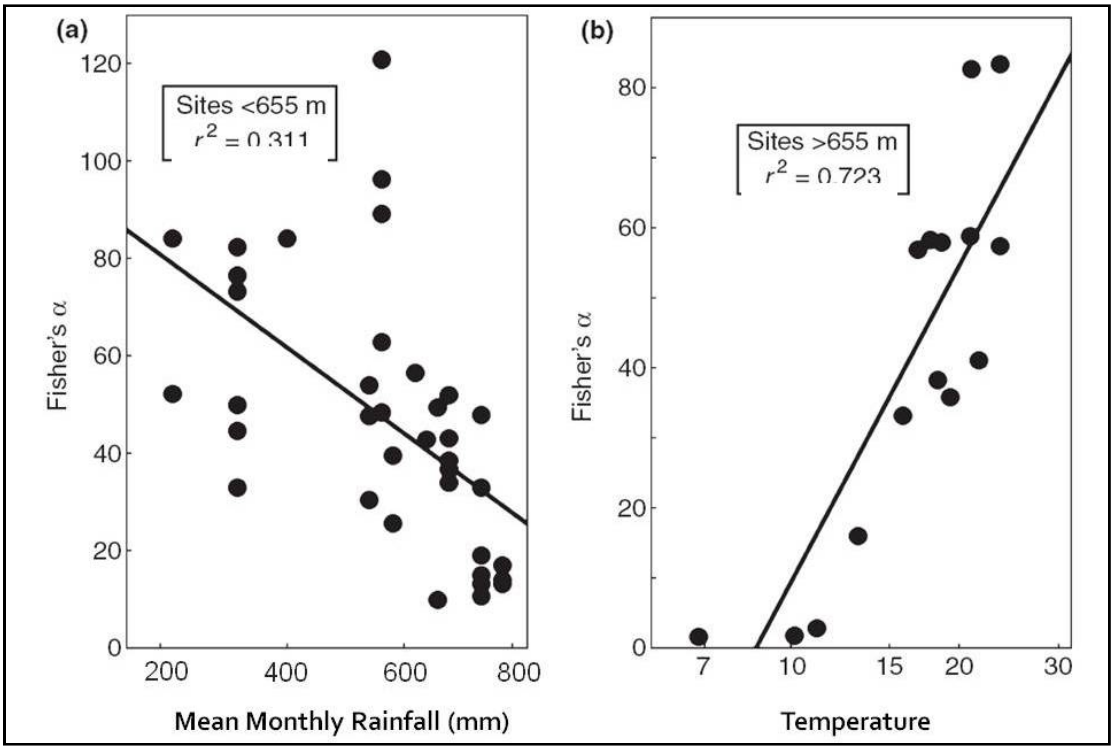


Figure 6.11: Regression analysis of Geometrid species diversity with mean monthly rainfall (mm) and temperature

Rarefied plant species richness was positively correlated with Geometrid diversity (**Figure 6.12**). Plant data were not normally distributed. Species richness remained high upto 2400m, above which it declined steeply. At lower elevation, Geometrid diversity showed high variability, whereas plant data didn't. So the plant species richness partially explained observed pattern in Geometrid diversity.

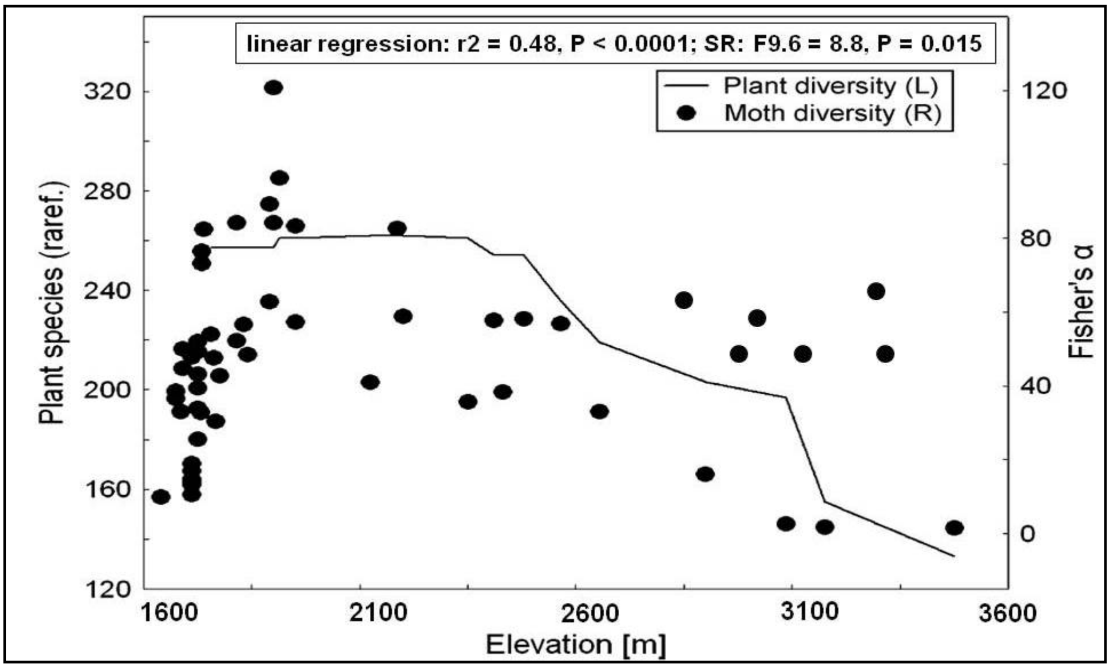


Figure 6.12: Elevational pattern of plant diversity (rarefied species richness) and Geometrid species diversity (Fisher's alpha at 22 sites)

6.3.4 Discussion

The number of geometrid species and morphospecies collected in this study (1,010) is by all standards among the highest ever counted in a single study on such a small spatial scale. The true species richness is even larger because the ensembles are not completely sampled and the extrapolated number is 16% higher. Values of Fisher's alpha up to 131 per site are also among the highest ever measured in the world, and the order of magnitude of gamma-diversity of 250 (Fisher's alpha) has never been documented before. All diversity measures reveal overall similar results along the altitudinal gradient for Larentiinae, whereas the patterns in Ennominae and Geometridae differ slightly depending on the selected measures. All observed patterns are remarkable since a decline in insect diversity towards higher altitudes was expected as shown in many other studies (Wolda 1987, Hanski & Niemelä 1990, McCoy 1990 with a review, Brühl et al. 1999). However, there is growing evidence that diversity often does not decrease linearly along elevational gradients, but peaks at medium elevations (Janzen et al. 1976, Holloway 1987). The diversity of the family Geometridae remains high along the whole gradient, but in particular one of the lowest sites (site 1a) tends to be lower in diversity than all other sites. This is probably due to the low diversity of Larentiine moths. Subfamilies like Geometrinae and

Sterrhinae tend to be more diverse and increase in their proportion towards lower altitudes. Ennominae show a uniformly high level of diversity measured by Fisher's alpha and extrapolated species numbers across all sites, whereas a more asymptotic pattern like in Larentiinae is indicated by rarefied species numbers. Larentiine moths definitely increase from low diversity at the lowest sites (1,040 m) and reach an approximately constant level of diversity from 1,800 m onwards. A low level of diversity of larentiine moths in lowlands has also been found in several studies in other regions, such as South East Asia (Holloway 1987, Schulze 2000). The diversity pattern of Larentiinae in the study area can best be described as a very broad medium to high elevation hump. The underlying mechanisms for this most exceptional distribution of Larentiinae are uncertain. One reason could be the better availability of specific host-plants that are more diverse at high altitudes.

Temperature, mean monthly precipitation and plant species richness all predicted the geometrid diversity pattern well. This study shows that many species of the family are able to resist the unfavourable cold and humid weather conditions at high altitudes. The monthly average temperature decreases linearly by approximately 10 K throughout the gradient. While alpha-diversity is virtually independent of this great change in abiotic conditions, beta-diversity (species turnover) is strongly associated with ambient temperature. Other factors such as primary productivity are also known to decrease along altitudinal gradients.

This chapter provided evidence that the Gangotri landscape area is a hotspot in Western Himalayan context with regard to one large taxon of herbivorous insects. Despite the enormous diversity of geometrid moths, analyses were manageable at a high taxonomic resolution and allowed ecological interpretations at a relatively fine scale. Geometrids are predestined to serve as study organisms for further ecological studies in other parts of the world. The diversity patterns that emerged in this study are unique and raise a number of questions, e.g. how the extremely high diversity can be achieved despite increasingly unfavorable climatic conditions. Investigations along comparable altitudinal gradients in other parts of Himalaya will offer an excellent opportunity to learn more about the generality of the patterns uncovered here and the mechanisms that are responsible for the diversity of herbivorous insects. Such investigations could also reveal patterns of large-scale beta-diversity of a species-rich arthropod group and the association between altitudinal and latitudinal gradients. The results provided in this chapter also emphasize the enormous importance of Himalayan temperate ecosystems from conservation point of view.

6..4 Conclusion

We found that the species richness of butterflies in western Himalaya demonstrated a mid-elevation peak in species richness. Butterfly species richness is also found to be a function of nearly same set of environmental variables (temperature, precipitation and habitat heterogeneity) in Tons valley. Our study also found support for ‘water energy balance’ hypothesis of species richness gradients which states that the temperature limits the number of species at higher latitude/altitude and rainfall determines species richness at warmer lower latitudes/altitudes. Although the alpha-diversity of geometrid moths remains at a consistently high level throughout the investigated gradient, the faunal composition changes significantly at all taxonomic levels regarded. The patterns are remarkably clear and are very parallel to those found at latitudinal gradients and other altitudinal gradients investigated at other parts of the world. Only the subfamily Larentiinae shows a significant increase in its proportion as altitude and latitude rise. Larentiine moths are obviously better adapted to climates that are characterized by low temperatures and high precipitation than all other groups of Geometridae. Himalayan high altitude temperate habitats not only hold a very high diversity of geometrid moths, but also a significantly higher proportion of locally restricted species than adjacent habitats at lower altitudes. Furthermore, the results clearly indicate the potential pitfalls of diversity estimations which rely on constant ratios between taxa, because such ratios might change rapidly and profoundly along environmental gradients. Given the high richness and small ranges of species, the area needs to be given more protection for the conservation of butterflies and other insect fauna.

CHAPTER 7
APPLICATIONS OF LEPIDOPTERA IN INSECT MONITORING AND CONSERVATION

7.1 Utility of Indicators

Conservation managers must be supported with quick and cost effective monitoring techniques and protocols. The use of indicator and surrogate taxa to monitor entire community has evolved a good option to save money, effort and time. Lepidoptera constitute a model system for large sample, long term monitoring studies to quickly survey biodiversity. A full inventory of diversity of any area would require nearly impossible amounts of time, effort, and money (Lawton et al., 1998). To avoid the logistically impossible task of sampling entire communities, past efforts have concentrated on performing rapid inventories (Roberts, 1991), utilizing focal taxa approach (Noss, 1990; Pearson & Cassola, 1992; Pearson, 1994), and developing extrapolation techniques to estimate diversity in different habitats (Colwell & Coddington, 1994; Hammond, 1994; Kiester et al., 1996). Conservation biologists should include insect diversity in planning conservation in tropical forests (Kremen et al., 1993; Clark & May, 2002; Leather et al., 2008). Insects are appropriate because they represent a major proportion of animal species in tropical forests (Godfray et al., 1999; Putz et al., 2001; Lewis & Basset, 2007). Assuming that carefully selected focal taxa can serve as a proxy for overall biodiversity (Kerr et al., 2000; Uniyal et al., 2007), several insect taxa have been tested for their utility as indicators in various ecosystems at multiple spatial scales (McGeoch, 1998).

It is extremely difficult to sample biodiversity in a given area, as time and money is limited. The appeal of using indicator taxa is one of saving time, effort, and money. By focusing on one set of species in a location rather than all of the species, considerable time and limited resources can be saved (Gardner et al., 2008). The purpose of this chapter was to demonstrate the importance of rapid assessment studies for selecting areas important for insect conservation and to select indicator species for habitat monitoring in the Gangotri Landscape in Western Himalaya. We used an integrated approach by sampling across multiple habitats and land use types and by using multiple data collection techniques. We determined how much sampling effort was required for an adequate assessment of butterfly communities in the Western Himalayan landscape.

7.2 Lepidopteran Assemblage as Indicator for Habitat Monitoring

Indicator species for all groups at the different habitat cluster (came from Bray-Curtis clustering) were calculated with the Indicator Species Analysis (ISA) (Dufrêne & Legendre, 1997). With this methodology, an indicator value is calculated for a species in each habitat group. ISA is a non-parametric technique in which indicator value of a species is calculated as a product of "faithfulness" (proportion of sites/samples within the habitat in which the species is present) and the "exclusivity" (inverse of the total number of habitat in which species occurs), expressed as percentage. The values range from zero (poorest indicator) to 100% (perfect indicator). The statistical significance of indicator values is estimated by means of Monte Carlo Randomizations (999 permutations). At each level of cluster (species group), indicator values (IndVal) and their associated *P*-values of all moth species were calculated. Cluster analysis and ISA were performed using Program PC- ORD Version 4.2 (McCune & Mefford, 2007).

7.2.1 Butterflies and moths

Indicator values of all moth species were computed for each habitat types and only those species with statistically significant values ($P < 0.001$) were regarded as suitable indicator for a particular habitat and are presented here (**Table 7.1**). Out of 234 species (unidentified morphospecies were not taken into consideration in presenting here), only 15 species performed well for their respective habitat categories. Of all habitats, Riverine forest and Conifer forest were characterized by species with high indicators score; 6 species from riverine habitat, *viz. Scopula pulchellata, Euproctis scintillans, Prodenia littoralis, Spirama retorta, Aletia medialis and Gazalina apsara* and 4 species from conifer forest habitat, *viz. Epicrocis hilarella, Spilarctia obliqua, Gluphodes crithealis, Gonirhynchus signatalis* came out as good indicator of their respective habitats. While less homogenous habitats like Pine forest, agriculture scrubland and broadleaved forest showed generally low mean Indicator values and only single species or two remained “faithful” or “exclusive” to their respective habitat. Alpine scrubland was characterized by a single species, *Diarsia dahlii* with high Indicator score.

Table 7.1: Indicator moth species group for different habitats

Species	Family	Ind Val	Significance (*P*)	Habitat
Psyra indica	Geometridae	57.5	0.001	Pine Forest
Lymantria concolor	Lymantridae	66.7	0.001	Agriculture Scrub
Terastia egialealis	Crambidae	66.7	0.002	Agriculture Scrub
Scopula pulchellata	Geometridae	100	0.001	Mixed Riverine
Euproctis scintillans	Noctuidae	100	0.001	Mixed Riverine
Prodenia littoralis	Noctuidae	100	0.002	Mixed Riverine
Spirama retorta	Noctuidae	100	0.001	Mixed Riverine
Aletia medialis	Noctuidae	100	0.001	Mixed Riverine
Gazalina apsara	Notodontidae	81.8	0.001	Mixed Riverine
Eoophyla peribocalis	Crambidae	66.7	0.002	Broadleaf Forest
Epicrocis hilarella	Pyralidae	100	0.001	Conifer Forest
Spilarctia obliqua	Arctiidae	100	0.001	Conifer Forest
Glyphodes crithealis	Crambidae	100	0.001	Conifer Forest
Pyrausta signatalis	Crambidae	83.3	0.002	Conifer Forest
Diarsia dahlia	Noctuidae	100	0.001	Alpine Scrub

The moth assemblages were structured among a gradient from lower elevational sites to high altitude alpine pastures. Two main moth assemblages were identified, which showed characteristic sets of indicator species for Mixed Riverine forest and Conifer forest. The other vegetation zones were characterized by only one or two indicator species, and no assemblage could be found for them. Though Pine forest was amongst the most species-rich zones in our study area in terms of both observed and estimated richness, the inventory completeness for this zone was only 58% (**Table 7.1**). It was also the zone where the second highest numbers of singletons and doubletons were recorded. This implies that there is still a good chance of recording more species here. This zone is characterized by open and high canopy forests with almost no undergrowth vegetation due to frequent burning events and low flowering plant diversity except some scrubs at the edge. The openness of this zone may be the reason for cross-attraction of species from nearby habitats such as Agriculture Scrubland and riverine patches, which also signify the presence of only a single indicator species of moth, *Psyra indica* Butler 1889, with a low indicator score from this zone. The species of the genus *Psyra* are known to feed on the plant family Rosaceae (Robinson et al., HOSTS, Database of World's Lepidopteran Hostplants) which were abundant at the edges of the forest on frequently burnt slopes where there was plenty of shade and underground moisture. Agricultural zones are those with the maximum human interference and are characterized by complex resource availability from an influx of rich minerals from anthropogenic activity. These are again open kinds of habitats where light trapping had a high chance of attracting species from adjoining habitats, and the species assemblages were dominated by common agricultural pests such as *Spilarctia obliqua* Walker 1855, *S. sagittifera* Moore 1888, *S. strigatula* Walker 1855, *Spilosoma erythrozona* Kollar 1844, *Argina multiguttatum* Hampson 1894, *S. sangaicum* Hampson 1894, *S. unifascia* Walker 1855 and *Helicoverpa armigera* Hübner 1827. Two species of moth, *Lymantria concolor* Walker 1855 and *Terastia egialealis* Walker 1855, were identified with a medium indicator score for this zone. These three species from Pine forest and agriculture land can be considered as detector species, rather than indicator species, which are defined by moderate levels of fidelity and specificity. Changes in the abundance of these species may provide information on the direction of ecological change (McGeoch et al., 2002). In the Western Himalaya, climate change and human disturbance are causing the lower elevation Oak forests to be gradually degraded and invaded by the drought-resistant Chir Pine (*Pinus roxburghii*). So, long term monitoring of the increasing or decreasing abundance of these detector species of moth can be of great help for predicting the future direction of changes in forest structure in this fragile but ecologically important landscape.

Five species of moth of the highest possible indicator score (absolute indicator) and another with a considerably high score were identified from the Mixed Riverine forest zone. The assemblage structure of this forest type is dominated by these species, and as a result of the variation in their optima, the relative abundances of these five species changed gradually along the main ecocline. Therefore, the composition of the assemblages changes principally according to the dominance structure of these species. The other species were in general more widespread, generalist or ubiquitous. The assemblage is characterized by the strong abundance of *Scopula pulchellata, Euproctis scintillans, Prodenia littoralis, Spirama retorta, Aletia medialis* and, to a lesser extent, by *Gazalina* *apsara*. This assemblage is typical of shady, dampy sites of primarily Oak forest (*Quercus incana* and *Q. galuca* contributing to the main canopy), with *Rhododendron arboreum* and *Lyonia ovalifolia* contributing to the second storey. The forest is currently facing considerable threat from lopping for fuel wood collection and extreme overgrazing, with grass patches developing due to the loss or breaking up of the canopy. The second assemblage, essentially consisting of Western Himalayan Coniferous Forest stands, is characterized by high numbers of *Epicrocis hilarella, Spilarctia obliqua, Glyphodes crithealis* and *Gonirhynchus signatalis*. These were both diverse assemblages and showed a lesser dominance structure in the distribution of species abundances. The vegetation of these sites is dominated by Blue Pine (*Pinus wallichiana*), Chilgoza Pine (*Pinus gerardiana*), Fir (*Abies spectabilis*), Silver Fir (*Abies pindrow*) and Spruce (*Picea smithiana*).These categories seem to be clearly structured along a vegetation gradient, showing various intermediate vegetation zones such as pure Fir forest (*Abies spectabilis*), mixed Oak-Fir forest (*Quercus semecarpifolia* and *Abies spectabilis*), mixed Rhododendron, Fir and Birch forest (*Rhododendron campanulatum, Abies spectabilis* and *Betula utilis*), and mixed coniferous forest (*Abies spectabilis, Pinus wallichiana,* and *Picea smithiana*). All along this gradient, the composition of the moth assemblage changes gradually from sites dominated by *E. hilarella* and *G. crithealis* to sites dominated by *G. signatalis*. The ecological niches of the four indicator species are probably confined to a medium canopy with interspersed open, grassy patches, and they are rarely observed elsewhere.

Interspersed between Riverine Forest and Coniferous Forest lies the Western Himalayan Broadleaved Forest, which is characterized by both evergreen broadleaved forest, dominated by *Quercus semecarpifolia, Q. dilatata* and *Q. lamellosa* and deciduous broadleaved forest, dominated by *Ilex,* sometimes mixed with conifers such as *Abies, Picea and Cedrus* spp. It also has a dense understorey with mosses, ferns and several epiphytes on the trees. No true indicator species could be found here, with a single detector species, *Eoophyla peribocalis* Walker 1859, with a medium indicator score. Under-sampling with only 56% of the inventory completeness in this zone can be the probable reason. The alpine meadows of our study site were generally of a xerophytic formation, with the predominance of dwarf shrubs and under tremendous pressure from livestock grazing. These meadows were composed mainly of perennial mesophytic herbs, with very little grass on drier slopes. Conspicuous among the herbs were *Primula, Anemone, Fritillaria, Iris* and *Gentiana*, with Dwarf Juniper and *Rhododendron campanulatum* scrubs on the edges. The single and most faithful indicator species from here was *Diarsia dahlia*, and the assemblage structure was characterized by an over-abundance of this species. The larva of this species primarily feeds on *Primula*, which can be cited as the most important reason for this assemblage pattern.

Although seasonal variations in the population size of an indicator species often hinder its use in monitoring habitat conditions, the use of only presence/absence data in our analysis resulted in unambiguous identification of true indicators that are always present (independent of their yearly abundance). Besides, year-to-year fluctuations, species assemblages can vary as a function of habitat conditions and landscape structure. The present analysis is based on an extensive data set from six zones representing different vegetation compositions so the determined indicator species can be used as bio-Indicators for future monitoring purposes. Our results suggest that the set of six moth assemblages identified as indicators may constitute a useful tool for conservation purposes. Focusing conservation efforts on the habitat requirements of these species may be beneficial in protecting a significant proportion of the Gangotri Landscape. These six groups are more or less specialized as ecological indicator species of the main gradient and are indicators of particular vegetation zones. Therefore, if we preserve and manage refuge sites for these species, we are likely to be providing protection for other organisms living in the same biotopes. Concentrating management practices on these six moth assemblages will also result in cost-effective administration of time and funding resources. The six sets of indicator species show features that make them ideal candidates for focal species. They may be assessed quickly using cheap and standard methods. Moreover, some of these species show narrow tolerances, and so they may be particularly sensitive to environmental changes (Oostermeijer & Van Swaay, 1998). By using a multi-species approach, we are covering a long gradient of environmental conditions. These six sets of indicator species encompass the entire range of the studied biotopes. The simultaneous presence of many of these species may be an indicator of habitat heterogenity. The concepts of indicator and umbrella species may not be equivalent, and they may be interesting complementary tools for conservation practices (Fleishman, 2000). However, some particular species may constitute indicator as well as umbrella species. For example, the six sets of species identified as indicators have some characteristics that suggest they may be candidates for a suite of umbrella species. They are easily recognizable, show an intermediate degree of rarity, are moderately sensitive to human disturbance and encompass a large range of habitats (Fleishman et al., 2000; Maes, 2004). However, to be considered as umbrella species, they must show a high pattern of co-occurrence with many other typical species, and that was not tested in the present study.

Species	Family	Ind Val	Significance (*P*)	Habitat
Himalayan Jester (*Symbrenthia hypselis*)	Nymphalidae	66.7	0.003	Pine Forest
Chocolate Pansy (*Junonia iphita*)	Nymphalidae	87	0.004	Agriculture Scrub
Plain Tiger (*Danaus chrysippus*)	Nymphalidae	66.7	0.002	Agriculture Scrub
Common Mime (*Papilio clytia*)	Papiolinidae	65.2	0.002	Agriculture Scrub
Pea Blue (*Lampides boeticus*)	Lycaenidae	84.2	0.001	Riverine Forest
Common Sailer (*Neptis hylas*)	Nymphalidae	79.2	0.004	Riverine Forest
Common Beak (*Libythea lepita*)	Nymphalidae	72.7	0.005	Riverine Forest
Bath White (*Pontia daplidice*)	Pieridae	60	0.003	Riverine Forest
Green Sapphire (*Heliophorus tamu*)	Lycaenidae	60	0.001	Riverine Forest
Large Tortoiseshell (*Nymphalis polychloros*)	Nymphalidae	75	0.001	Broadleaf Forest
Eastern Comma (*Polygonia comma*)	Nymphalidae	75	0.002	Broadleaf Forest
Western Courtier (*Sephisa dichroa*)	Nymphalidae	59.2	0.003	Broadleaf Forest
Common Meadow Blue (*Cupidopsis cissus*)	Lycaenidae	55.6	0.002	Conifer Forest
Queen of Spain Fritillary (*Issoria lathonia*)	Nymphalidae	65.5	0.003	Conifer Forest
Pale Clouded Yellow (*Colias hyale*)	Pieridae	53.8	0.001	Conifer Forest
Common Blue Apollo (*Parnassius hardwickii*)	Papiolinidae	63.1	0.004	Alpine Scrubland

Table 7.2: Indicator butterfly species group for habitat monitoring of habitat quality in different habitats.

To conclude, because of the many advantages described above, we propose that these butterfly and moth assemblages can be used as indicators of vegetation zones and as surrogate species for conservation efforts. These species are habitat specialists of small size, and so they represent interesting tools at small spatial scales. The use of species assemblages as indicators may be considerably improved by extending the approach to organisms that are taxonomically and functionally different (Maes, 2004). Future research should be oriented to integrate over larger spatial scales by incorporating knowledge from other taxonomic groups such as butterflies, beetles and birds.

7.3 Implications of Rapid Assessment

We conducted a rapid survey for 20 days during March and April in Govind NP and WLS. We sampled approximately 50% of the estimated butterfly species richness in 20 days of sampling during April – May 2010 in the Tons valley. Despite the difficulties of sampling such a diverse group in such a short period of time, we were able to find significant differences in diversity across sites and were able to provide estimates of butterfly species richness in the area (**Table 7.3**). Sampling for more time would have improved the estimates of species richness. For this, we sampled again during May – July 2010 to account for seasonality effects and recorded 44 more species (a total 123 species) from the Tons valley. Using the non-parametric species richness estimates, inventory completeness was approximately 77% in the study area. It can be considered as comprehensive sampling, as Cardoso (2009) recommended 80% of inventory completeness as comprehensive sampling for arthropod inventories. Gupta (2004) documented 48 species from the Govind NP and WLS, while we recorded 94 (75% of the species encountered in whole study area) species from the same region.

Istragad and Kedarkanta had the highest species richness (**Figure 7.1a**). The 95% confidence intervals for species richness at lowest number of individuals (rarified at lowest number (98) of individuals, found at Har-ki-Dun) of sites Istragad (19–28 species) and Kedarkanta (20–27 species) were higher than Jakhol (20–25 species) and Tuni (16–23 species). Species richness intervals were significantly lower for Har-ki-Dun (14–17 species). Non-metric multidimensional scaling (NMDS) analysis showed that Istragad and Kedarkanta were grouped together and Har-ki-Dun and Jakhol were grouped together (**Figure 7.2**). Tuni did not group with any of the sites and showed a different assemblage pattern from the other four sites (**Figure 7.2**). We wanted to determine whether our sampling period was sufficient to detect butterfly compositional differences between sites. Kedarkanta and Har-ki-Dun differed significantly, well before the last 30–40 individuals were sampled in rarefaction plot (**Figure 7.1b**). Thus, we confirmed that we were able to determine the butterfly composition of sites in short sampling time. We were also able to differentiate between Har-ki-Dun and Jakhol though there were fewer differences in their species richness in the given short sampling period.

A positive cross-taxon correlation was found in species richness and abundance of butterflies, moths, and beetles (**Table 7.4**).Patterns of species turnover were correlated for lepidoptera, indicating that the butterfly and moth species richness and abundance shifts similarly across sites. In the absence of data for more insect communities, we could use this assessment as an indicator of biodiversity because insect species patterns may follow similar patterns as the butterflies. This may result from overlap in the location of host plants, degree of disturbance, or similarity of thermal tolerance. Although correlations between species richness, abundance, and diversity of butterflies and other insect groups are imperfect (Ricketts et al., 2002; Schulze et al., 2004; Singer & Ehrlich, 1991), but in the absence of more complete insect data, we suggest that Istragad and Jakhol are likely to be important sites for general insect conservation in Govind NP and WLS and Nilang valley in Gangotri NP. Jakhol and Istragad are currently managed under different degrees of protection regimes (under Govind NP and Govind WLS respectively), and were the most promising sites, supporting a large number of unique forest species and high butterfly, moth, and beetle diversity. Thus, management practices should be revised so as to give protection to these sites. Our study also confirms the importance of natural and semi-natural habitats for butterflies in the Tons valley. It is extremely difficult to sample biodiversity in a given area, as time and money is limited. Butterflies constitute a model system for large sample, long term monitoring studies to quickly survey biodiversity.

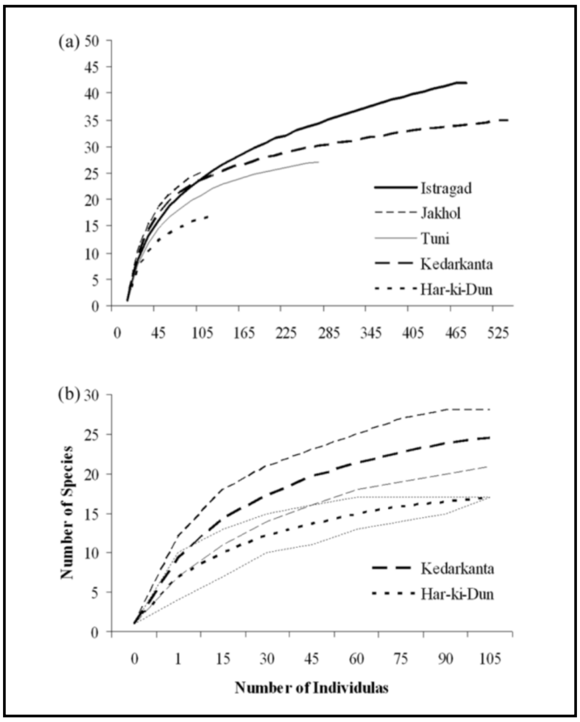


Figure 7.1(a) Individual based rarefaction curves for five sampling sites and (b) with 95% confidence intervals for sites Kedarkanta and Har-ki-Dun to show that sampling was enough to differentiate habitats though having short sampling period

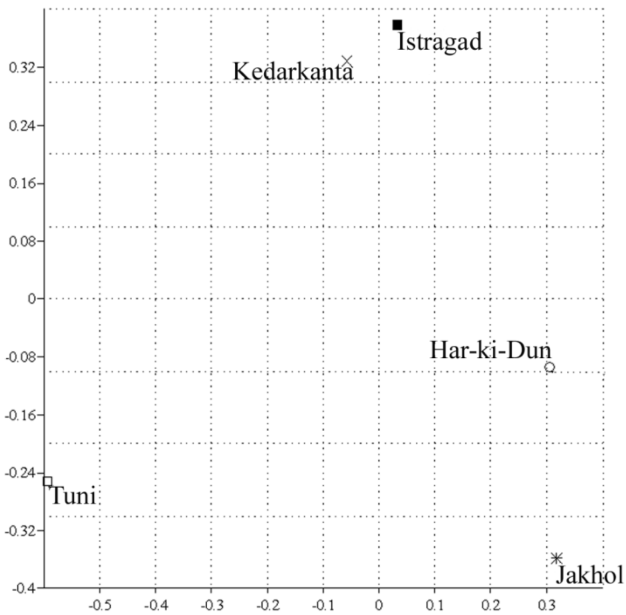


Figure 7.2: Nonmetric multidimensional scaling (NMDS) ordination plot showing similarities in butterfly composition between five sampling sites at Tons valley. Sites managed under similar protection category grouped together. Site Tuni, is managed under very low protection category (reserve forest), and separates apart showing a unique butterfly assemblage than other sites

Table 7.3: Survey details, disturbance characteristics, butterfly species richness, abundance, diversity and unique species recorded, for the five sampling sites in Tons Valley during March-April 2010

	Istragad	Jakhol	Tuni	Kedarkanta	Har-ki-Dun
Protection category	Govind WLS	Govind NP	Reserve Forest	Govind WLS	Govind NP
Logging intensity	Low	Low	High	Medium	Medium
Fire signs	Low	Medium	High	Medium	High
Livestock abundance	Low	Low	High	High	Medium
Human habitations	Very low	Medium	High	High	Medium
Altitude sampled(m)	1500 - 3500	1800 - 3500	900 - 2400	1250 - 3000	1800 – 3500
Habitats sampled*	6	6	6	6	6
No. of transects/trails	20	16	16	16	16
Effort (km)	6	4.8	4.8	4.8	4.8
Species richness	51	27	27	35	17
Genera richness	40	24	21	26	14
Individuals	488	100	259	540	117
Fisher's alpha	11.17	10.84	7.59	8.37	5.47
Unique species	19	4	11	5	1

** Six butterfly habitats were sampled uniformly across all five sites (e.g. Agriculture land, Mix riparian forest, Mix broadleaf forest, Pine forest, Conifer forest and Alpine meadows).*

Table 7.4: Cross taxa correlation with moths (Lepidoptera) and beetles (Coleoptera) across sampling sites in the Tons valley: table presents correlation values (Pearson's r) and a level of significance (*P<0.05, **P<0.01)(N=26)

	Butterfly	
	Species Richness	Abundance
Moths species richness	0.825**	0.732*
Beetles species richness	0.673**	0.785*

7.4 Conclusion

To select and prioritize areas for biodiversity conservation, rapid assessments of biodiversity indicator taxa can be an important, helpful, quick, and cost effective tool for conservation managers. We also propose that butterfly and moth assemblages can be used as indicators for monitroing vegetation zones and as surrogate species for conservation efforts. These observations were also supported by the significant positive cross-taxon congruency between butterflies, moths, and beetles species richness and abundance across sites. Efforts are needed to check or minimise anthropogenic activities (e.g. grazing, logging, looping (collection of leaves for fodder), herb collection, wood cutting, forest fire, etc.) that lead to habitat degradation and fragmentation. There have been very few studies on the biogeographical distribution of the Himalayan butterfly fauna in the last 50 years. As the Himalayan forests are under large threats of habitat degradation and forest fragmentation, there is an urgent need to perform such studies on butterflies, especially for species which are endemic to the Himalayan region and subregions. The conservation issue must be carefully considered before butterflies are used as a surrogate for insect biodiversity because differences in distribution of rare species of butterflies, moths, and beetles across sites have not been measured. The global scale and rapidity of biodiversity destruction (Wilson, 1988) forces most ecologists to accept the practical need for quick surveys of biodiversity in conservation planning and management (Roberts, 1991). However, these can ultimately be justified only by testing their accuracy against large samples and long term studies that partition diversity into spatial and temporal dimensions. It is our expectation that the results presented and discussed here will help conservation planners and managers by aiding them in the selection of biodiversity rich areas and by giving attention to remaining fragmented habitats facing human alterations, which will increase biodiversity conservation efforts in the area.

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APPENDICES

Appendix 4.1: Butterfly documented on 29 transects in Gangotri NP during 2008.

S.no	Species name	Relative abundance
	Hesperiidae	
1	*Choaspes benjaminii* (Guerin-Meneville)	0.12
2	*Tagiades litigosa* Möschler	0.06
	Papilionidae	
3	*Parnassius hardwickii* Gray	0.92
4	*Parnassius epaphus* Oberthür	2.93
5	*Papilio machaon* Linnaeus	2.38
N	**Pieridae**	
6	*Gonopteryx rhamni* (Linnaeus)	5.67
7	*Catopsilia pomona* (Fabricius)	4.64
8	*Colias fieldii* Ménétriés	5.43
9	*Pieris brassicae* (Linnaeus)	0.61
10	*Pieris canidia* (Sparrman)	11.96
11	*Pontia daplidice* (Linnaeus)	2.32
12	*Dellaias belladona* (Fabricius)	0.06
	Lycaenidae	
13	*Esakiozephyrus mandara* dohertyi de Nicévillle	0.06
14	*Spindasis vulcanus* (Fabricius)	0.12
15	*Lycaena phlaeas* (Linnaeus)	2.07
16	*Heliophorus tamu* (Kollar)	0.12n
17	*Heliophorus sena* Kollar	3.36
18	*Actyolepis puspa* (Horsefield)	7.57
19	*Polyommatus eros*	3.66
	Nymphalidae	
20	*Libythea lepita* Moore	0.12
21	*Danaus chrysippus* (Linnaeus)	1.95
22	*Lasiaommata schakra* Kollar	3.66
23	*Aulocera swaha* (Kollar)	0.43
24	*Paralasa mani* de Nicéville	0.06
25	*Fabriciana adippe* Denis and Schiffermüller	0.92
26	*Issorea lethonia* (Linnaeus)	4.09
27	*Neptis hylas* (Linnaeus)	0.12
28	*Neptis mahendra* Moore	2.87
29	*Symbrenthia hypselis* (Godart)	0.06
30	*Vanessa indica* (Herbst)	8.66
31	*Vanessa cardui* (Linnaeus)	11.53
32	*Aglais cshmiriensis* (Kollar)	10.25
33	*Polygonia egea* (Cramer)	0.06
34	*Kaniska canace* (Linnaeus)	1.16

Appendix 4.2: Butterfly species occurrence (Presence/absence) in different habitat types sampled in Govind NP and WLS and adjoining area of Gangotri landscape. The status in Indian Wildlife (Protection) Act, 1972 is also provided.

S. No.	Species Name	MRSF	PF	BF	CAF
	Papilionidae				
1	*Paranassius epaphus*	0	0	0	1
2	*Paranassius hardwickii*	0	0	0	1
3	*Graphium sarpedon*	1	0	1	0
4	*Graphium cloanthus*	1	1	0	0
5	*Graphium doson*	1	1	0	0
6	*Graphium* sp.	1	0	1	0
7	*Graphium eurous*	1	0	0	0
8	*Chilasa agestor*	1	0	1	0
9	*Chilasa clytia*	1	1	0	0
10	*Papilio polytes*	1	1	0	0
11	*Papilio helenus*	0	0	1	1
12	*Papilio protenor*	1	1	1	0
13	*Palpilio alcemenor*	0	0	1	0
14	*Papilio demoleus*	1	1	0	n0
15	*Papilio machaon*	1	0	1	1
16	*Papilio polyctor*	0	1	1	0
17	*Atrophaneura polyeuctes*	0	0	1	0
18	*Atrophaneura dasarada*	0	0	1	0
19	*Atrophaneura aristolochiae*	1	1	0	0
20	*Troides aeacus*	1	0	1	0
	Pieridae				
21	*Eurema blanda*	1	1	1	0
22	*Eurema brigitta*	1	1	0	0
23	*Eurema laeta*	0	1	1	0
24	*Eurema hecabe*	1	0	1	1
25	*Gonepteryx rhamni*	1	1	1	1
26	*Catopsilia pomona*	1	1	0	0
27	*Catopsilia pyranthe*	1	1	1	0
28	*Colias fieldii*	0	0	1	1
29	*Colias erate*	1	0	1	1
30	*Parenonia valeria*	1	1	1	0
31	*Pieris brassicae*	1	1	1	0
32	*Pieris napi*	1	0	1	0
33	*Pieris canidia*	1	1	1	1
34	*Pontia daplidice*	1	1	1	1
35	*Aporia leucodice*	0	0	1	0

S. No.	Species Name	MRSF	PF	BF	CAF
36	*Aporia agathon*	1	0	1	0
37	*Delias belladonna*	1	0	1	1
38	*Delias Sanaca*	1	0	0	0
39	*Belenois aurota*	1	1	1	1
	Lycaenidae				
40	*Poritia hewitsoni*	1	0	1	0
41	*Curetis bulis*	0	0	1	0
42	*Loxura atymnus*	1	0	1	0
43	*Chliaria kina*	1	0	1	0
44	*Deudorix perse*	0	1	1	0
45	*Deudorix epijarbas*	1	0	0	0
46	*Rapala jarbas*	1	0	1	0
47	*Rapala varuna*	0	0	1	0
48	*Spindasis vulcanus*	1	0	0	0
49	*Lycaena phlaeas*	1	0	1	1
50	*Lycaena pavana*	1	1	0	0
51	*Lycaena kasyapa*	1	0	0	0
52	*Heliophorus brahma*	1	0	0	0
53	*Heliophorus androcles*	1	0	0	1
54	*Heliophorus tamu*	0	0	1	0
55	*Heliophorus sena*	1	0	1	1
56	*Castallius rosimon*	1	0	0	0
57	*Jamides celeno*	1	0	1	1
58	*Lampides boeticus*	1	1	0	0
59	*Zizeeria karsandra*	1	0	1	0
60	*Pseudozizeeria maha*	1	1	1	1
61	*Everes argiades diorides*	1	0	0	0
62	*Acytolepis puspa*	1	1	1	1
63	*Celastrina argiolus*	1	1	1	1
64	*Celastrina huegelii*	1	1	1	1
65	*Aricia astrarche*	0	0	1	0
66	*Chilades pandava*	1	0	0	0
67	*Polymmatus eros*	1	0	0	1
68	*Abisara echirius*	1	0	0	1
69	*Dodona eugenes*	1	0	1	0
70	*Dodona durga*	1	0	1	0
	Nymphalidae				
71	*Libythea lepita*	1	1	1	1
72	*Libythea myrrha*	0	0	1	0

S. No.	Species Name	MRSF	PF	BF	CAF
73	*Tirumala limniace*	1	1	1	0
74	*Tirumala septentrionis*	1	0	1	1
75	*Danaus genutia*	1	1	1	1
76	*Danaus chrysippus*	1	1	1	0
77	*Parantica aglea*	1	0	0	0
78	*Parantica sita*	1	0	1	0
79	*Euploea mulciber*	1	1	1	0
80	*Euploea core*	1	1	1	0
81	*Polyura athamus*	1	0	1	0
82	*Melantis leda*	1	1	0	0
83	*Melantis zitenius*	1	1	0	0
84	*Lethe rohria*	1	0	1	0
85	*Lethe europa*	1	0	1	0
86	*Lethe insana*	1	0	0	0
87	*Lethe verma*	1	0	1	0
88	*Lethe sidonis*	1	0	0	0
89	*Lethe goalpara*	1	0	0	0
90	*Lasiommata schakra*	0	0	1	0
91	*Elymnias hypermnestra*	1	0	1	0
92	*Mycalesis francisca*	1	0	1	0
93	*Mycalesis perseus*	1	0	0	0
94	*Mycalesis myneus*	1	1	1	0
95	*Aulocera padma*	0	1	1	1
96	*Aulocera swaha*	1	0	1	0
97	*Aulocera saraswati*	1	0	0	1
98	*Callerebia ananda*	1	1	0	0
99	*Callerebia nirmala*	0	1	1	0
100	*Callerebia scanda*	1	1	0	0
101	*Ypthima asterope*	1	1	1	0
102	*Ypthima baldus*	1	1	0	0
103	*Ypthima sakra*	1	0	1	0
104	*Cethosia cyane*	1	0	1	0
105	*Acraea violae*	1	0	1	0
106	*Argynnis pandora*	0	0	1	1
107	*Arggyres hyperbius*	1	1	0	0
108	*Fabriciana adippe*	0	0	0	1
109	*Fabriciana kamala*	1	0	1	0
110	*Speyeria aglaja*	0	0	0	1
111	*Issora lathonia*	1	0	1	1n

S. No.	Species Name	MRSF	PF	BF	CAF
112	*Cupha erymanthis*	1	0	0	0
113	*Palanta phalantha*	1	0	0	0
114	*Limentis trivena*	0	0	1	1
115	*Athyma perius*	1	0	1	0
116	*Athyma opalina*	1	0	1	1
117	*Pantoporia hordonia*	1	1	0	0
118	*Neptis nata yerburyii*	1	0	1	0
119	*Neptis hylas*	1	1	0	0
120	*Neptis ananta*	0	0	1	0
121	*Neptis Mahendra*	1	0	1	1
122	*Neptis sankara*	1	0	1	0
123	*Neptis narayana*	0	1	1	0
124	*Euthalia aconthea*	1	0	0	0
125	*Euthalis nais*	1	1	0	0
126	*Cyrestis thyodamas*	1	0	1	0
127	*Pseudergolis wedah*	1	0	1	0
128	*Stibochiona nicea*	1	0	1	0
129	*Ariadne merione*	1	0	1	0
130	*Apatura ambica*	0	0	1	1
131	*Dilipa morgiana*	0	0	1	0
132	*Hestina nama*	1	0	1	0
133	*Sephisa dichroa*	1	1	1	0
134	*Symbrenthia hypselis*	1	0	1	0
135	*Symbrenthia hippoclus*	1	1	1	0
136	*Vanessa indica*	1	1	1	1
137	*Vanessa cardui*	1	1	1	1
138	*Aglais cashmiriensis*	1	0	1	1
139	*Nymphalis xanthomelas*	1	0	1	1
140	*Polygonia agea*	1	0	1	1
141	*Kaniska canace*	1	1	1	0
142	*Junonia orithiya*	1	1	1	1
143	*Junonia hierta*	1	1	0	0
144	*Junonia iphita*	1	1	1	0
145	*Junonia atlites*	1	0	0	0
146	*Junonia almana*	1	0	0	0
147	*Junonia lemonias*	1	0	0	0
148	*Hypolimnas misippus*	1	0	0	0
149	*Hypolimnas bolina*	1	0	1	0
150	*Kallima inachus*	1	0	0	0

S. No.	Species Name	MRSF	PF	BF	CAF
	Hesperiidae				
151	*Hasora chromus*	1	0	0	0
152	*Choaspes benjaminii*	1	0	1	0
153	*Celaenorrhinus leoucocera*	1	0	1	0
154	*Pseudocoladenia dan*	1	0	0	0
155	*Tagiades japetus*	1	0	0	0
156	*Tagiades japetus*	1	1	0	0
157	*Oriens goloides*	1	1	0	0
158	*Potanthus dara*	0	1	1	1
159	*Pelopidas mathias*	1	0	1	0

Appendix 4.3: List of moths (Lepidoptera: Heterocera) identified to species in various superfamilies, families and subfamilies in Gangotri Landscape Area

S No	Superfamily	Family	Subfamily	Species
	Pyraloidea			
1		Pyralidae	Phycitinae	*Epicrocis hilarella Ragono*
2				*Diloxia fimbriata Hampson*
3				*Endotricha olivacealis Bremer*
4				*Dichocrocis nigrilinealis Walker*
5				*Zinckenia fascialis Cramer*
6				*Dichocrocis definita Butler*
7				*nOrybina flaviplaga Walker*
8				*Phostria ocellea Haworth*
9		Crambidae	Scopariinae	*Heliothela ophideresana Walker*
10			Crambinae	*Ancylolomia sp.*
11				*Euchromius sp.*
12			Spilomelinae	*Dysallacta sp.*
13				*Glyphodes sp.*
14				*Glyphodes indica Saund.*
15				*Glyphodes crithealis Walker*
16				*Glyphodes bivitralis Guenee*
17				*Pygospila tyres Cramer*
18				*Goniorhynchus signatalis Hampson*
19				*Lamprosema commixta Butler*
20				*Nomophila noctuella Denis & Schiffermüller*
21				*Pachynoa sabelialis Guenee*
22				*Botyodes asialis Guenee*
23				*Cirrhochrista brizoalis Walker*
24				*Sameodes cancellalis Zeller*
25			Pyraustinae	*Phryganodes noctescens Moore*
26				*Pleuroptya ruralis Scopoli*
27				*Herculia ignifualis Walker*
28				*Terastia egialealis Walker*
29			Nymphulinae	*Eoophyla peribocalis Walker*
30	Pterophoroidea	Pterophoridae		*Buckleria paludum Zeller*
31				*Deuterocopus socotranus Rebel*

32				*Diacrotricha fasciola Zeller*
33	Zygaenoidea	Zygaenidae		*Pnhauda flammans Walker*
34				*Brachartona quadrimaculata Moore*
35				*Artona Zebraica Butler*
36				*Pidorus glaucpis Drury*
37				*Chalcosia pectinicornis Linnaeus*
38				*Epizygaena cashmirensis Kollar*
39	Cossoidea	Cossidae		*Zeuzera coffeae Nietner*
40				*Zeuzera multistrigata Moore*
41				*Cossus cadambae Moore*
42				*Xyleutes strix Linnaeus*
43		Limacodidae		*Scopelodes unicolor Westwood*
44				*Chalcoscelides castaneipars Moore*
45				*Altha subnotata Walker*
46				*Denmonarosa rufotesselata Moore*
47				*Miresa inornata Walker*
48				*Cania himalayana Holloway*
49				*Aphendala tripartita Moore*
50				*Phocoderma velutina Kollar*
51	Totricoidea	Totricidae		*Isodemis serpentinana Walker*
52				*Homona encausata Meyrick*
53				*Lopharcha rapax Meyrick*
54				*Costosa rhodantha Meyrick*
55	Uraniodea	Uraniidae	Microniinae	*Pseudomicronia aculeata Guenee*
56				*Micornia aculeata Guenee*
57			Epipleminae	*Orudiza protheclaria Walker*
58				*Warreniplema fumicosta Warren*
59				*Dysaethria rhagavata Walker*
60				*Scmwaria restricta Hampson*
61				*nPangteyia ocusta Swinhoe*
62				*Himaplema pectinicornis Dudgeon*
63				*Dysaethria reticulata Moore*
64	Geometroidea	Geometridae	Ennominae	Abraxas sylvata Scopoli
65				*Abraxas peregrina Inoue*
66				*Anonychia grisea Butler*
67				*Anonychia violacea Moore*
68				*Campaea haliaria Walker*

69				*Ectropis bhumitra Walker*
70				*Elphos pardicelata Walker*
71				*Heterolocha falconaria Walker*
72				*Heterolocha phaenicotaeniata Prout*
73				*nLomographa sp.*
74				*Odontopera kanchai Yazaki*
75				*Oxymacaria temeraria Swinhoe*
76				*Percnia belluaria Guenée*
77				*Phthonandria artilineata*
78				*Pseudomiza sp.*
79				*Psilalcis inceptaria Walker*
80				*Psyra angulifera Walker*
81				*Psyra cuneata Walker*
82				*Psyra indica Butler*
83				*Semiothisa avitusaria Walker*
84				*Semiothisa sufflata Guenée*
85				*Urapteryx sciticaudaria Walker*
86				*Uranpteryx clara Butler*
87				*Thinopteryx crocoptera Kollar*
88				*Lomographa deletaria Moore*
89				*Nothomiza dentisignata Moore*
90				*Plutodes transmutata Walker*
91				*Scardamia metallaria Guenee*
92				*Peratophyga hyalinata Moore*
93				*Hypochrosis hyadaria Guenee*
94				*Eurymene inustata Moore*
95				*Plagodes reticulata Warren*
96				*Opisthograptis moelleri Warren*
97				*Corymica arnearia walker*
98				*Corymica deducta Walker*
99				*Corymica specularia Moore*
100				*Luxiaria phyllosaria Walker*
101				*Luxiaria amasa Butler*
102				*Luxiaria acutaria Snellen*
103				*Zamarada scriptifasciata Walker*
104				*Zeheba lucidata Walker*
105				*Godonela frugaliata Guenee*
106				*Godonela pluviata Fabricius*
107				*Godonela effusata Guenee*
108				*Godonela perfusaria Walker*
109				*Hyposidra violescens Hampson*
110				*Hypephyra terrosa Butler*
111				*Hyperythra lutea Cramer*
112				*Fascellina chromataria Walker*

113				*Fascellina plagiata Walker*
114				*Leptomiza calcearia Walker*
115				*Mimomiza cruentaria Moore*
116				*Biston regalis Moore*
117				*Biston suppressaria Guenee*
118				*Biston recursaria Walker*
119				*Biston cognataria Guenee*
120				*Gnophus accipitrarius Guenee*
121				*Gnophus eolarius Guenee*
122				*Opthalmitis herbidaria Guenee*
123				*Boarmia subplagiata Walker*
124				*Boarmia ochrifasciata Moore*
125				*Ectropis crepiscularia Hubner*
126				*Alcis decussata Moore*
127				*Alcis semiclarata Walker*
128				*Hypomecis transcissa Walker*
129				*Hypomecis infixaria Walker*
130				*Percnia celluaria Guenee*
131				*Abaciscus tristis Butler*
132				*Medasinna acribomena Prout*
133				*Medasina parisnattei Walker*
134				*Medasina albidaria Walker*
135			Geometrinae	*Comibaena inductaria Guenée*
136				*Comibaena subhyalina Warren*
137				*Comibaena fuscidorsata Prout*
138				*Pingasa rubicaunda Warren*
139				*Pingasa alba Swinhoe*
140				*Pingasa pseudoterpnaria Guenee*
141				*Herochroma cristata Warren*
142				*Lophophlema luteipes Felder & Rogenhofer*
143				*Hipparchus vallata Butler*
144				*Hipparchus vareigata Butler*
145				*Chlororithra fea Butler*
146				*Omphacodes directa Walker*
147				*Agathia hilarata Guenee*
148				*Agathia hemithearia Guenee*
149				*Hemithea tritonaria Walker*
150				*Hemithea distinctaria Walker*
151				*Eucyclodes gavissima Walker*
152				*Diplodesma planata Prout*
153				*Chlorissa gelida Butler*
154				*Episothalnma robustaria Guenee*
155				*Thalassodes veraria Guenee*

156				*Thalassodes goniaria Felder*
157				*Comostola subtiliaria Bremer*
158				*Comostola hauensteini Smetacek*
159				*Hemistola detracta Walker*
160				*Hemistola loxiaria Guenee*
161			Larentiinae	*Aplocera pudicata Walker*
162				*Larentia albofasciata Moore*
163				*Perizoma seriata Moore*
164				*Photoscotosia miniosata Walker*
165				*Trichopterygia rufinotata Butler*
166				*Trichopterigia decorata Moore*
167				*Triphosa rubrodotata Walker*
168				*Xanthorhoe aurata*
169				*Rhodometra sacraria Linnaeus*
170				*Eupithecia rajata Guenee*
171				*Ecliptopera postpallida Prout*
172				*Ecliptopera relata Butler*
173				*Ecliptopera decurrens Moore*
174				*Ecliptopera dentifera Moore*
175				*Ecliptopera fulvotincta Hampson*
176				*Docirava aequilineata Walker*
177				*Craspediopsis bimaculata Warren*
178				*Lobogonodes multistriata Butler*
179				*Electrophaes niveonotata Warren*
180				*Electrophaes aliena Butler*
181				*Electrophaes sp.*
182				*Dysstroma sp.*
183			Sterrhinae	*Scopula pulchellata Fabricius*
184				*Timandra ruptilinea Warren*
185				*Problepsis vulgaris Butler*
186				*Problepsis delphiaria Guenee*
187				*Rhodostrophia stigmatica Butler*
188				*Timandra correspondens Hampson*
189				*Cambogia phoenicosoma Swinhoe*
190				*Organopoda carnearia Walker*
191				*Rhodostrophia meonaria Guenee*
192			Oenochrominae	*Eurnelea rosalia Stoll*
193	Drepanoidea	Drepanidae		*Nordstromia duplicata Warren*
194				*Macrauzata fenestraria Moore*
195				*Auzata superba Walker*

196				*Depana innotata Hampson*
197				*Oreta extensa Walker*
198				*Deroca inconclusa Walker*
199				*Drepana hyalinata Moore*
200				*Deroca hyalina Walker*
201				*Callidrepana argenteola Moore*
202				*Tridrepana flava Moore*
203				*Cyclidia substigmaria Hübner*
204	Bombycoidea	Bombycidae		*Mustilia sphingiformis Moore*
205				*Bombyx huttoni Westwood*
206				*Penicillifera apicalis Walker*
207				*Ocinara albicollis walker*
208		Eupterotidae		*Apona cashmirensis Kollar*
209				*Bhima undulosa Walker*
210		Lasiocampidae		*Lebeda nobilis Walker*
211				*Euthrix laeta Walker*
212				*Arguda flavovittata Moore*
213				*Paralebeda plagifera Walker*
214				*Cyclopragma lineata Moore*
215				*Estigena pardalis Walker*
216				*Trabala irrorata Moore*
217				*Trabala vishnou Lefèbvre*
218				*Gastropacha undulifera Walker*
218		Brahmaeidae		*Brahmidia hearseyi White*
219		Saturniidae		*Samia cynthia Drury*
220				*Dictyoploca simla Westwood*
221				*Anthraea frithi Westwood*
222				*Dictyoploca cachara Moore*
223				*Loepa Katinka Westwood*
224				*Anthraea roylei Moore*
225	Sphingoidea	Sphingidae	Macroglossinae	*Hippotion boerhavie Fabricius*
226				*Hippotion celerio Linnaeus*
227				*Macroglossa bombylans Boisduval*
228				*Macroglossum saga Bulter*
229				*Rhopalopsyche nycteris Kollar*
229			Sphinginae	*Leucophlebia lineata Westwood*
230				*Bryoxena centralasiae Staudinger*

231				*Couservula indica*
232				*Gnophus muscosarius Hampson*
233				*Psilogramma menephron Cramer*
234				*Agrius convolvuli Linnaeus*
235				*Sphinx ligustri Linnaeus*
236				*Ambulyx sericeipennis Butler*
237				*Ambulyx liturata Butler*
238				*Ambulyx ochracea Butler*
239				*Clanis titan Rothschild & Jordan*
240				*Marumba spectabilis Butler*
241				*Marumba dyras Walker*
242				*Cypa decolor Walker*
243				*Cephonodes picus Cramer*
244				*Daphnis hypothous Cramer*
245				*Acosmeryx anceus Stoll*
246				*Acosmeryx socrates Boisduval*
247				*Theretra clotho Drury*
248				*Rhyncnolaba acteus Cramer*
249				*Cechenena minor Butler*
250	Noctuoidea	Arctiidae	Syntomidae	*Syntomoides imaon Cramer*
251				*Amata bicincta Kollar*
252				*Amata cyssea Stoll*
253			Arctiinae	*Trichaeta teneiformis Walker*
254				*Panaxia similis Moore*
255				*Spilarctia obliqua Walker*
256				*Spilarctia sagittifera Moore*
257				*Spilarctia strigatula Walker*
258				*Spilarctia comma Walker*
259				*Spilarctia casigneta Kollar*
260				*Spilarctia neglecta Rothschild*
261				*Spilarctia melanostigma Erschoff*
262				*Spilosoma erythrozona Kollar*
263				*Spilosoma sangaicum Hampson*
264				*Spilosoma unifascia Walker*
265				*Callindra equitalis Kollar*
266				*Utethesia lotrix Cramer*
267				*Nyctemera adversata Schaller*
268				*Nyctemera cenis Cramer*
269				*Argina astrea Drury*
270				*Areas galactina Van der Hoeven*
271				*Areas imperialis Kollar*
272				*Alphaea imbuta Walker*

273				*Nannoarctia obliquifascia Hampson*
274				*Creatonotus gangis Linnaeus*
275				*Creatonotus transiens Walker*
276				*Cladarctia quadriramosa Kollar*
277				*Juxtarctia multiguttata Walker*
278				*Lemyra melanosoma Hampson*
279				*Lemyra rhodophila Walker*
280				*Olepa ricini Fabricius*
281				*Amerila astreus Drury*
282				*Asura calamaria Moore*
283			Lithosiinae	*Chrysorabdia bivittata Walker*
284				*Eilema sp.*
285				*Macrobrochis pallens Hampson*
286				*Macrobrochis pracena*
287				*Miltochrista cuneonotata Walker*
288				*Sidyma albifinis Walker*
289				*Hesudra sericeipennis Moore*
290				*Brunia antica Walker*
291				*Cyana puella Drury*
292				*Cyana bianca Walker*
293				*Cyana effracta Walker*
294				*Cyana horsfieldi Roepke*
295				*Cyana detrita Walker*
296				*Cyana bellissima Moore*
297				*Eugoa bipunctata Walker*
298				*Asurna undulosa Walker*
299				*Lyclene dharma Moore*
300				*Barsine gratiosa Guerin-Meneville*
301				*Barsine maculifasciata Hampson*
302				*Cacyparis prunifera Swinhoe*
303				*Barsine linga Moore*
304		Lymantriidae		*Euproctis scintillans Walker*
305				*Euproctis vitellina Kollar*
306				*Euproctis bimaculata Walker*
307				*Euproctis varia Walker*
308				*Euproctis plana Walker*
309				*Euproctis magna Swinhoe*
310				*Euproctis lunata Walker*
311				*Euproctis inconcisa Walker*
312				*Lymantria concolor Walker*
313				*Lymantria albolunulata Moore*
314				*Lymantria obfuscata Walker*

315				*Lymantria mathura Moore*
316				*Lymantria todara Moore*
317				*Dasychira inclusa Walker*
318				*Mardara caligramma Walker*
319				*Calliteara strigata Moore*
320				*Laelia atestacea Hampson*
321				*Leucoma divisa Walker*
322				*Himala argentea Walker*
323				*Gazalina apsara Moore*
324				*Perina pura Walker*
325		Noctuidae	Trifinae	*Xanthia albosignata Moore*
326			Acronictinae	*Nacna malachitis Oberthür*
327				*Cretonia vegetus Swinhoe*
328				*Maliattha vialis Moore*
329				*Maliattha signifera Walker*
330				*Maliattha tegulata Butler*
331				*Oruza divisa Walker*
332				*Amyna octo Guenee*
333			Heliothinae	*Helicoverpa armigera Hubner*
334				*Pyrrhia umbra Hufnagel*
335			Calpinae	*Eublemma ostrina Hubner*
336				*Calesia haemorrhoa Guenee*
337				*Ericeia inangulata Guenée*
338				*Ericeia pertendens Walker*
339				*Lacera nyarlathotepi Zilli & Holloway*
340				*Oraesia emerginata Fabricius*
341				*Oraesia indecisa Walker*
342			Noctuinae	*Chersotis harutai Varga & Ronkay*
343				*Xestia consanguinea Moore*
344				*Xestia renalis Moore*
345				*Diarsia erubescens Butler*
346				*Diarsia dahlii Hübner*
347				*Diarsia nigrosigna Moore*
348				*Axylia sicca Guenee*
349				*Agrotis fraterna Moore*
350				*Euxoa hyperythra Boursin*
351				*Agrotis biconica Kollar*
352			Hadeninae	*Aletia sp.*

353				*Aletia medialis Smith*
354				*Callopistria placodoides Guenee*
355				*Callopistria repleta Walker*
356				*Callopistria rivularis Walker*
357				*Leucania compta Moore*
358				*Mythimna albicosta Moore*
359				*Spodoptera littoralis Boisduval*
360				*Spodoptera litura Fabricius*
361				*Siderides submarginalis Walker*
362				*Tiracola plagiata Walker*
363				*Mythimna decissima Walker*
364				*Mythimna obscura Moore*
365				*Mythimna distincta Moore*
366				*Mythimna fragilis Butler*
367				*Mythimna roseilinea Walker*
368				*Mythimna fasciata Moore*
369				*Mythimna loreyi Duponchel*
370				*Mythimna separata Walker*
371			Plusiinae	*Autographa nigrisigna Walker*
372				*Chrysodeixis acuta Fabricius*
373				*Erythroplusia pyropia Butler*
374				*Thysanoplusia orichalcea Fabricius*
375				*Axylia renalis Moore*
376			Cuculliinae	*Dasypolia atrox Hacker & Peks*
377				*Cucullia albipennis Hampson*
378				*Bornolis niveiplaga Walker*
379				*Acronicta indica Moore*
380				*Acronicta pruinosa Guenee*
381				*Thalatha sinens Walker*
382				*Cymatophoropsis sinuata Moore*
383			Euteliinae	*Eutelia adultaricoides*
384				*Eutelia inextricata Moore*
385				*Chlumetria transversa Walker*
386				*Penicillaria jocosatrix Guenee*
387				*Targalla delatrix Guenee*
388				*Paectes subapicalis Walker*
389				*Penicillaria maculata Butler*
390			Herminiinae	*Polypogon vermiculata Leech*
391				*Progonia kurosawai Owada*
392				*Simplicia robustalis Guenee*

393			Pantheinae	*Tichosea obsolescens Hampson*
394			Chloephorinae	*Trisuliodes caerulea Bulter*
395				*Gabala argentata Butler*
396				*Risoba prominens Moore*
397				*Gabala roseoretis Kobes*
398				*Earias biplaga Walker*
399				*Tyana chloroleuca Walker*
400				*Negeta signata Walker*
401				*Xanthodes albago Fabricius*
402				*Xanthodes transversa Guenee*
403				*Westermannia triangularis Moore*
404				*Westermannia superba Hubner*
405			Hypeninae	*Pterogonia episcopalis Swinhoe*
406				*Perciana marmorea Walker*
407				*Hypena triplicalis Walker*
408				*Hypena quadralis Walker*
409				*Hypena melanica Sugi*
410				*Hypena indicatalis Walker*
411				*Rhynchina abductalis Walker*
412				*Hypena rhombalis Guenee*
413			Amphipyrinae	*Callyna jugaria Walker*
414				*Euplexia distorta Moore*
415				*Euplexia albovittata Moore*
416				*Trachea auriplena Walker*
417				*Conservula indica Moore*
418				*Actinotia intermedia Bremer*
419			Agaristiinae	*Ozarba illosis Hampson*
420				*Sarbanissa albifascia Walker*
421				*Episteme maculatrix Westwood*
422				*Episteme adulatrix Kollar*
423			Catocalinae	*Anomis mesogona Walker*
424				*Anomis figlina Butler*
425				*Arcte coerula Guenée*
426				*Catocala inconstans Butler*
427				*Dysgonia latifascia Warren*
428				*Mocis discios Kollar*
429				*Ophiusa tirrhaka*
430				*Spirama retorta Clerck*

431				*Sypna constellata Moore*
432				*Catocala macula Hampson*
433				*Ophiusa olista Swinhoe*
434				*Thyas juno Dalman*
435				*Thyas coronata Fabricius*
436				*Bastilla crameri Moore*
437				*Dysgonia torrida Guenee*
438				*Bastilla arcuata Moore*
439				*Erebus albicinctus Kollar*
440				*Erebus macrops Linnaeus*
441				*Hypopyra vespertilio Fabricius*
442				*Spirama triloba Guenee*
443				*Serrodes campana Guenee*
444				*Grammodes geometrica Fabricius*
445				*Trigonodes hyppasia Cramer*
446				*Ercheia cyllaria Cramer*
447				*Lyncestis amphix Cramer*
448				*Fodina stola Guenee*
449				*Adrus tyrannus Guenee*
450				*Eudocima phalonia Linnaeus*
451				*Calyptra ophideroides Guenee*
452				*Hypocala rostrata Fabricius*
453				*Hypocala moorei Butler*
454				*Chrysopera combinans Walker*
455				*Erygia apicallis Guenee*
456				*Pandesma robusta Walker*
457				*Capotena truncata Walker*
458				*Bocula microspila Holloway*
459				*Calesia dasypterus Kollar*
460				*Tinolius quadrimaculatus Walker*
461		Notodontidae		*Phalera parivala Moore*
462				*Phalera raya Moore*
463				*Eupydna longivitta Walker*
464				*Eupydna eupatagia Hampson*
465				*Zaranga pannosa Moore*
466				*Hyperaeschra dentata Hampson*
467				*Stauropus limitaris Ebert*
468				*Netria viridescens Walker*
469				*Neostauropus alternus Walker*
470				*Ginshachia gemmifera Moore*

Appendix 4.4: List of beetles (Coleoptera) identified to species in various families across three broad altitude zones in the study area.

Species Account		
S.no	**Family**	**Species name**
	Carabidae	
1		*Catascopus whithilli* Hope
2		*Chlaenius hamifer* Chaud.
3		*Chlaenius laetiusculus* Chaud.
4		*Chlaenius vividus* Chaud.
5		*Dioryche* sp.
6		*Macrochitus trimaculatus* Al.
7		*Omphora duplicatus* Weid.
8		*Omphora pilosa*
9		*Oxycentris parallelus* Chaud.
10		*Pharaopsopus cantorei* Dejan
11		*Scarites indicus,*
12		*Stenolophus* sp.
13		*Triganatoma indica* Beritt.
14		*Trigonetama* sp.
15		*Xenodus diabreeri* Anderson
	Cerambycidae	
16		*Glena* sp.
17		*Lophosterus hugeli* Redtnb
18		*Macrotoma creneta* Fabricius
19		*Rhytidodera boweinia* White
20		*Xylotrechus smei*
21		*Xystocera globosa* Oliv.
	Chrysomelidae	
22		*Altica corulea* al.
23		*Altica cyanea*
24		*Aphthona nigrilabris* Duvivins
25		*Aphthona* sp.
26		*Apophylea crotchi*
27		*Aulacophora abdominalis* Fabricius
28		*Auleris tibialis* Jac
29		*Calaspasoma metallicum* Clark
30		*Calaspasoma semicostatum* Jac

Species Account		
S.no	Family	Species name
	Coccinellidae	
31		*Chilocorus nigritus* F.
32		*Thea cincta*
33		*Veronia* sp.
	Curculionidae	
34		*Amblyrrhinus poricollis* Bohem.
35		*Amblyrrhinus subrocticollis* Marshall
36		*Apion* sp.
37		*Cryptorrhynchus brandisi* Stebb.
38		*Curculio calbum* (Fabricius)
39		*Lepropus indicus*
40		*Mecirtocenus fossatifrons* Marshall
41		*Myllocerus discolor* Bohem.
42		*Myllocerus subfasciatus* Geer
43		*Peltotrachelus himalayensis* Marshall
44		*Peltotrachelus sjöstedti* Marshall
45		*Pycnodactylus hypocrites* Cher.
46		*Tanymecus circumdatus*
47		*Tanymecus hirticeps* Marshall
48		*Tanymecus indicus* Faustus
49		*Tanymecus simplex* Marshall
	Dyticidae	
50		*Caccophils parvulus* Aube.
	Elateridae	
51		*Agrypnus censobrines* (Candeze)
52		*Agrypnus costicollis* (Candeze)
53		*Agrypnus fuscipes* Fabricius
54		*Agrypnus moestus* Caud.
55		*Agrypnus tuberosus* Eshr.
56		*Aphanobius cylindricus* Esch.
57		*Argypnus tostanus* (Candeze)
58		*Camsosternus splendidus* Hrbst.
59		*Heteroderes leris* Caud.
60		*Heteroderus* sp.
61		*Lacon costicollis,* Caud.

Species Account		
S.no	**Family**	**Species name**
62		*Melanotus hirticornis*
63		*Petocera cantorii,* Hope
64		*Singhalinus* sp.
	Lucanidae	
66		*Serrognathus titanus,* Boisduval
67		*Titanus* sp.
	Meloidae	
68		*Cylindrothorax pictus* (Laporte)
69		*Epicanta mannerheimni* M.
70		*Epicanta* sp.
71		*Epicauta* sp. (Redtenbacher)
72		*Mylabris pustulatus*
73		*Sybaris praeustus* (Kollar & Redtb.)
74		*Sybaris testaceus* (Fabricius)
75		*Sybaris testaceus* (Fabricius)
	Melolonthidae	
76		*Adoretus bimarginatus,* Ohaus.
77		*Apogonia blanchardi* Rit.
78		*Autoserica* sp.
89		*Brahminia* sp.
80		*Melolontha funcicauda* Ancey
81		*Brahmina crinicollis* Burmeister
82		*Melolontha cuprescens* Blanchard
	Scarabaeidae	
83		*Hybosorus orientalis* Westwood
84		*Oniticellus cinctus* Fabricius
85		*Liatongus gagatinus* Hope
86		*Anomala* sp.
87		*Anomala cantori* Hope
88		*Aphodius finctarius* Olivier
89		*Aphodius marginellus* Fabricius
90		*Aphodius moestus* Fabricius
91		*Caccobius denticollis* Har.
92		*Caccobius himalayensis* Jek.
93		*Catharcius capucinus* Fabricius

Species Account		
S.no	**Family**	**Species name**
94		*Catharcius sagas* Fabricius
95		*Catharius pithecius* Fabricius
96		*Gmnopleurus assamensis* Waterh.
97		*Gymnopleurus cyaneus* Fabricius
98		*Gymnopleurus miliaris* Fabricius
99		*Onthophagus bifasciatus* Fabricius
100		*Onthophagus cervus* Fabricius
101		*Onthophagus dama,* Fabricius
102		*Onthophagus gazella,* Fabricius
103		*Onthophagus gravis* Walker
104		*Onthophagus politus* Fabricius
105		*Onthophagus ramoselus* Bates
106		*Onthophagus recticornutus* Fabricius
107		*Phaechrous emarginatus* Lap.
108		*Popilia impressipyga,* Ohars.
109		*Popillia cyanea* Hope
110		*Mimela passerinii* Hope
111		*Hilyotrogus holosericeus* Redtenbacher
112		*Holotrichia longipennis* Blanchard
113		*Brahmina crinicollis* Burmeister
114		*Oryctes nasicornis* Linnaeus
	Staphylinidae	
115		*Poderus sondaicus* Ful.
	Tenebrionidae	
116		*Alphitobius piceus*
117		*Caedius induta* Weid.
118		*Calathus pallipes,* Anderson
119		*Egaploa crenulata* Dejan
120		*Seleron retteri* Gebien

Appendix 4.5: List of Publications from present research project

Research Papers

- Abesh Kumar Sanyal, V.P. Uniyal, Kailash Chandra and Manish Bhardwaj. 2013. Diversity and indicator species of moth (Lepidoptera: Heterocera) assemblages in different vegetation zones in Gangotri Landscape, Western Himalaya, India. ENVIS Bulletin: Wildlife and Protected Areas (Eds. V.P. Uniyal & Aseem Srivastava), Vol. 14, Wildlife Institute of India, Dehradun.

- Manish Bhardwaj and V.P. Uniyal. 2013. High-altitude butterfly fauna of Gangotri National Park, Uttarakhand: patterns in species, abundance composition and similarity. ENVIS Bulletin: Wildlife and Protected Areas (Eds. V.P. Uniyal & Aseem Srivastava), Vol. 14, Wildlife Institute of India, Dehradun.

- Sanyal, A.K., V.P. Uniyal, K. Chandra & M. Bhardwaj. 2013. Diversity, distribution pattern and seasonal variation in moth assemblages along altitudinal gradient in Gangotri landscape area, Western Himalaya, Uttarakhand, India. Journal of Threatened Taxa 5(2): 3646-3653; doi:10.11609/JoTT.o2597.3646-53.

- Kailash Chandra, Devanshu Gupta, V.P. Uniyal, Manish Bhardwaj and Abesh K. Sanyal. 2012. Studies on Scarabaeid Beetles (Coleoptera) of Govind Wildlife Sanctuary Garhwal, Uttarakhand, India. Biological Forum - An International Journal 4 (1) : 48-54.

- Manish Bhardwaj, V.P. Uniyal , Abesh K. Sanyal and Arun P. Singh. 2012. Butterfly communities along an elevational gradient in the Tons valley, Western Himalayas: Implications of rapid assessment for insect conservation. Journal of Asia-Pacific Entomology, 15: 207–217.

- Bhardwaj Manish, V.P. Uniyal and Abesh K. Sanyal. 2010. Estimating Relative abundance and Habitat use of Himalayan Blue Sheep (Pseudois nayaur) in Gangotri National Park, Western Himalaya, India. Vth World Conference on Mountain Ungulates - Spain Galemys XX-XX ISSN: 1137-8700.