Diversity of Moths (Lepidoptera: Heterocera) and their Potential Role as a Conservation Tool in Different Protected Areas of Uttarakhand





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Department of Science and Technology
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Project Completion Report

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CONTENTS

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Project Summary

Moths have long been regarded as the “poor cousins” of butterflies in Lepidoptera conservation, and have lagged well behind butterflies in popularity and in the attention given to their conservation status and needs. Only rarely do they gain greater prominence, despite the enormous taxonomic and biological variety they display. Forest moth species have important functional roles as selective herbivores, pollinators, detritivores, and prey for migratorial passerines. Furthermore, they have shown promise as forest indicator taxa. Keeping in view of these various roles of moths in ecosystem, the present study is proposed to be undertaken in the Western Himalayan Landscape of Uttarakhand, in 12 protected areas: Corbett NP, Rajaji NP, Gangotri NP, Govind NP, Nanda Devi NP, Valley of Flowers NP, Askot Musk Deer WLS, Binsar WLS, Govind Pashu Vihar WLS, Kedarnath WLS, Mussoorie WLS and Sonanadi WLS.

The objective of this study was to document rich moth fauna of Uttarakhand. The study was an interesting attempt to make an inventory of moth species in various sites and to see diversity and richness with respect to different vegetation structure and composition and measure different habitat covariates. The influence of climatic, topographic and anthropogenic effect on moth assemblages were studied. The study expects to establish moth assemblage as surrogate for entire insect community and use them as indicator taxa in rapid habitat-quality assessment program.

The study was conducted in some Protected Areas of Uttarakhand: 1) Nanda Devi Biosphere Reserve 2) Gangotri National Park 3) Govind Wildlife Sanctuary 4) Askot Wildlife Sanctuary The study area was stratified on the basis of elevation & vegetation types to explore the moth diversity along the gradient. Each site will was selected randomly at a particular elevation band so that the vegetation types are included in them. The number of trap sites were selected at each stratum so that comprehensive representation of the moth diversity can be accounted. The trap sites were situated in the centre of plots with a homogeneous vegetation cover, so that moth catches at weak light sources should largely reflect the local communities. The minimum distance between neighbouring sites were 50 m, with lamps not being visible from neighbouring sites, so that cross-habitation sampling does not occur. At each site 2-3 night sampling were done for 3-4 hours from dawn. The moths were trapped by their attraction to weak light sources. 5days prior to and after full moon were not sampled.

Among five subfamilies of Geometridae sampled across different elevation and forest types, Ennominae was the dominant (92 species), followed by Larentiinae (37 species), Geometrinae (28 species), Sterrhinae (11 species) and Desmobathrinae (1 species). Altitudinal distribution of the four major subfamilies (Figure 3) showed that the subfamily Larentiinae was exceptionally distributed towards higher altitude while the other three were diverse in lower and middle elevation zones.

We documented 36 species which were previously unrecorded from Uttarakhand. Among them 19 species were of subfamily Ennominae: *Anonychia violacea, Biston falcata, Psilalcis inceptaria, Medasina interruptaria, Medasina cervina, Erebomorpha fulguraria, Ourapteryx convergens, Arichanna tenebraria, Gnophos albidior, Hypomecis ratotaria, Loxaspilates hastigera, Odontopera heydena, Odontopera lentiginosaria, Plagodis inustaria, Psyra debilis, Opisthograptis sulphurea, Opisthograptis tridentifera, Sirinopteryx rufivinctata and Tanaoctenia haliaria;* 3 species of subfamily Geometrinae: *Chlorochaeta inductaria, Chlorochaeta pictipennis, Pingasa rubicunda;* and 13 species were of subfamily Larentiinae: *Photoscotosia multilinea, Photoscotosia metachryseis, Cidaria aurata, Electrophaes recta, Eustroma chalcoptera, Hydrelia bicolorata, Stamnodes pamphilata, Trichopterigia rufinotata, Triphosa rubrodotata, Perizoma albofasciata, Euphyia stellata, Xanthorhoe hampsoni and Heterothera dentifasciata*. One species *Rhodostrophia pelloniaria* of subfamily Sterrhinae was also the first record from Western Himalaya.

In Nanda Devi Biosphere Reserve species of Geometridae family were found to be most abundant in both Joshimath (0.71) and Lata (1.15) gradient across all the sampling plots. The second most prominent family is Noctuidae with high abundance in Lata (0.65) but low abundance in Joshimath. The temperate forest type showed the maximum species richness in both Joshimath (243) and Lata (150) gradient. The extent of temperate forest type was the most within our sampling altitude range (2000-3800m) and is more heterogenous in vegetation structure with mixed coniferous tree species diversity (Pine-Fir) in the lowest reaches and oak and deodar species in the mid-altitudes. The highest elevation band in Joshimath gradient was 3200m, so there was no sampling in the alpine scrubland forest type in this gradient

In Gangotri National Park and Govind Wildlife Sanctuary the diversity was maximum in lower altitude zone and decreased gradually in three subsequent zones (Fig 7a). Fisher's alpha was highest, 85.37±3.31 in 1400m-1900m, and lowest 48.02±1.75 in 2900-3400m. Simpson's Index was 112.14±4.56, 93.27±3.84, and 76.04±4.73, 65.89±2.74 in 1400-1900m, 1900-2400m, 2400-2900m and 2900-3400m respectively. Observed species richness and estimated species richness (Fig. 7b) was 271, 293.54±9.37 for 1400m-1900m, 193, 196.76±3.07 for 1900m-2400m, 203, 217.8±8.26 for 2400m-2900m and 203, 211.09±5.17 for 2900m-3500m. The percent completeness, represented as ratio between observed species richness and estimated species richness was 92%, 98%, 93%, and 96% respectively for the four altitudinal zones studied.

Alpha diversity (Fisher's alpha) and Simpson's index were highest (Fig 8a) in Subtropical Pine Broadleaved Mix forest (80.89±3.56, 105.18±7.56) and Western Mix Coniferous forest (82.66±2.84, 108.23±2.4) and lowest in Subalpine forest (47.47±1.9, 62.36±2.94). Almost similar diversity patterns were recorded in Moist Temperate Deciduous forest (48.21±2.51, 71.43±5.74) and Western Himalayan Upper Oak forest (56.69±2.24, 70.97±3.38). At habitat level also, relatively, sampling success was achieved with no major difference in observed species richness and estimated species richness using Chao 1. Observed and estimated species richness was highest (Fig. 8b) in Western Mixed Coniferous forest (294, 306.99±6.11) and lowest in Moist Temperate Deciduous forest (152, 156.26±3.24). The values for observed and estimated species richness for other vegetation classes were like 237, 264.84±11.56 for Subtropical Pine Broadleaved mix forest, 210, 226.13±8.29 for Western Himalayan Upper Oak forest and 187, 193.86±4.67 for Subalpine forest.

In conclusion, despite gradual and small distances between various habitat types studied, each one had significant resources to support its own characteristic moth assemblage. Overall, local diversity among moth communities were high all through the gradient signifying enough resource availability at every altitude and vegetation zones studied. The high diversity documented for the first time of a major herbivorous insect community in this typical Western Himalayan altitudinal gradient can be instrumental enough to ascertain its conservation significance. The results confirm that unless sampled extensively over a large temporal scale, the recorded species number is an unreliable measure of diversity because of its dependence on the number of specimens collected. Use of a set of sample size independent diversity measures like Fisher's alpha, Chao I and Jackknife should complement each other in different aspects of diversity as well as mathematical assumptions underlying their usage. Concordant diversity picture yielded by all these different measures should also minimize the possible risk of misinterpretations.

This study has covered an elevational range from 600m-3800m spread across different protected areas of Uttarakhand. Still there is a gap in moth samples between 1000m-1500m, which is mainly due to the absence of suitable natural sites in this range which are free from human disturbance. The sampling of entire elevational gradient would generate a more discernible pattern with relevant ecological explanations. Although our data is still scattered and more intensive sampling can result in more addition to this species record of Geometridae, future research on this current database should benefit the conservation of entire moth assemblage and their habitats in Western Himalayan Biogeographic province.

PROJECT COMPLETION REPORT

1. **Project Title:** Diversity of moth (Lepidoptera:Heterocera) assemblages and their potential role as a conservation tool in different protected areas of Uttarakhand (SERB NO: SR/SO/AS-23/2011)

2. **Project Investigators:**

   Principal Investigator: **Dr. V.P. Uniyal, Scientist-F**

   Date of Birth: 30th December, 1962

   Co-Principal Investigator: NIL

3. **Implementing institution:** Wildlife Institute of India
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4. **Date of commencement:** August 2012

5. **Planned date of completion**: November 2015

6. **Actual date of completion:** April 2016

7. **Approved objectives of the Proposal:**

1. Documenting and prepare taxonomic inventory of rich moth fauna of Protected Areas of Uttarakhand.

2. To assess and analyse diversity and distribution of moth assemblages among different elevations and vegetation types and the influence of anthropogenic disturbance factors on moth assemblages in different protected areas of Uttarakhand.

3. To establish moth assemblage as surrogate for entire insect community and use them as indicator taxa in rapid habitat-quality assessment program.

8. **Deviation made from the original objectives if any, while implementing the project reasons thereof: NONE**

9. Details of experimental work

9. 1: GENERAL INTRODUCTION

9.1.1 Insect conservation outline

One of the major crises we face today is the ever-growing mass extinction of living beings caused by human activities. Our knowledge of global biodiversity and extinction is very limited, but of the 5 to 50 million species believed to exist, conservative estimates points to about 17500 being lost each year, that is, 2 species every hour (Wilson, 1988; Stork, 1994). Of these, the vast majority belongs to understudied groups like invertebrates, "the little things that run the world" (Wilson, 1987). Despite their fundamental roles in nature and potential in the definition of conservation priority areas, invertebrates have been systematically ignored in conservation studies (Franklin, 1993; Kremen et al. 1993). But how do we conserve species when we have very limited knowledge of which species are endangered or even how many species there are? Estimates of the number of insect species thought to exist globally vary widely (Stork, 1988), but there are probably 4-6 million (Novotny et al. 2002). We have perhaps named only 23-35% of these (Hammond, 1992). As for their ecology and habitat requirements, the chances of elucidating even a small fraction of the myriad life histories and species interactions that exist within the invertebrate world are remote, especially in the hyper diverse tropics. This is despite the widely appreciated importance of arthropods to the diversity and function of terrestrial and freshwater ecosystems, at least among entomologists. The limitations associated with invertebrate conservation efforts are clearly manifested in the literature. Clark and May (2002) found deep taxonomic bias in conservation research, with vertebrate studies dominating (69% of papers versus 3% of described species) over plants (20% of papers versus 18% of species), and with invertebrates lagging far behind (11% of papers versus 79% of species).

The described taxonomic richness of insects is distributed unevenly among the higher taxonomic groups. Five orders stand out for their high species richness: the beetles (Coleoptera); flies (Diptera); wasps, ants and bees (Hymenoptera); butterflies and moths (Lepidoptera); and the true bugs (Hemiptera). Insects play a central role in all terrestrial ecosystems as herbivores, pollinators, for nutrient cycling, and as food and host organisms (Summerville *et al.*., 2004; Summerville & Crist, 2004). Due to their sheer numerical preponderance herbivorous insects comprise a significant fraction of any insect fauna (Ødegaard, 2000; Basset et al.., 2001; Novotny et al.., 2002). Herbivorous insects are also expected to respond sensitively to deforestation and subsequent forest regeneration, since they have a close functional relationship with the vegetation they live in.

9.1.2 Lepidoptera conservation

Lepidoptera are important herbivores, pollinators, and serve as food and hosts for multiple other organisms at higher trophic levels (Summerville & Crist, 2004; Summerville et al.. 2004). They are the most diverse order of insects associated primarily with angiosperm plants and, with some 160,000 named species. Powell et al (1999) 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 (such as Noctuidae: 35,000 species; Geometridae: 21,000 species) each thus include more species than the whole of the butterflies. Another "working division" of the Lepidoptera, of considerable relevance to conservation, is that of so-called "macrolepidoptera" and "microlepidoptera". The former includes the butterflies and larger moths and is by far the better documented group, largely because it includes the taxa which have traditionally attracted most attention from collectors and hobbyists. Nevertheless, the smaller moths are relatively poorly known, comprise a substantial proportion of most local lepidopteran assemblages, and in contrast with macrolepidoptera in that very few species have been considered widely as targets for conservation. In general, the amount of information available on distribution and decline is limited, and substantial taxonomic difficulties remain in virtually all regional faunas. This division by size tends to mirror the "bridging role" of moths in practical conservation considerations- from the ability to focus constructively on single target species (mainly macrolepidoptera, for which the ecology of many species is reasonably well understood) to the twin topics of assemblage diversity and its changes in relation to patterns of land use or disturbance. The last usually involve either macrolepidoptera or all Lepidoptera, so using moths as indicators of environmental condition and possible surrogates of wider changes in biodiversity. Thus, many studies of moth assemblages include only macrolepidoptera. In many parts of the world this limitation simply reflects taxonomic expediency, because knowledge of most microlepidoptera does not yet enable them to be incorporated with equivalent confidence in many surveys where species-level determination is needed. However some microlepidoptera groups are very diverse and thus have potential to yield much relevant information on interest to land managers.

9.1.3 Definition of the Problem

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, fauna of considerable conservation importance. Inventory of insects in Western Himalayan landscape is still fragmentary and incomplete which makes monitoring and conservation of insect biodiversity an impractical thing for the protected area managers. Instead of studying the entire insect community the attention should be given to identify and select an easy-to-monitor assemblage that serves as surrogate for entire insect community and act as indicator of changes in habitat quality. Order Lepidoptera comprising butterfly and moth can easily serve this purpose as they are taxonomically well known and critical to the functioning of many ecosystems being strongly associated with vegetation structure and composition. The butterfly taxonomy and distribution is relatively well studied in Western Himalayan perspective. But the moth study lacks significant addition in this particular landscape since the "*Fauna of British India*" series published in 1892 to 1896, although sampling moths are relatively easy as they are readily attracted to light traps and they are sufficiently speciose and diverse to offer powerful discrimination in detecting ecosystem level impact. In this context, current study proposes to document moth diversity and distribution in the Protected Area Network of Uttarakhand. An attempt will also be made to correlate moth diversity as surrogate for overall insect diversity so that by sampling this subset of fauna, protected area managers can have an overall picture of insect diversity in a particular landscape and work towards their conservation oriented management practices.

9.1.4 Literature Review

a) International Status

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 behaviour. Ian Kitching 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. He did a preliminary assessment of the diversity of geometrid moths within different types of rain forest in Peninsular Malaysia (2001). E.C. Zimerman has worked on Macrolepidoptera of Hawaii Island. Dr. Roger Kendrick has been documenting the moth fauna of Hong Kong.

Apart from Taxonomic study most prominent works on ecology of Moth are done by: Jan Beck and Chey Khen (2007) who worked on beta diversity of Geometrid moth from northern Borneo and effect of habitat, time and space on moth assemblages, Gunnar Brehm and Konrad Fiedler (2004) 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.

In Europe and North America moths have now been regularly used as indicator taxa in ecological studies assessing the impact of fragmentation (Summerville & Crist 2004), selective logging (Holloway & Chen 1992), Grazing (Poyry et al. 2005), Fire (Fleishman, 2000), Invasive Plants (Fleishman et al.. 2005). K. Summerville and T.O. Crist (2002, 2004) assessed suitability of forest moth taxa as an indicator of Lepidopteron richness and habitat disturbance. R.L. Kitching established moth assemblages as indicator of environment quality in upland Australian rainforest. In a pilot study in Sydney's Cumberland Plain Woodland, Boris Lomov et al. (2006) tried to assess moth assemblages as useful indicators for restoration monitoring. In overall scenario, there is plenty of International resources available using moths as indicator taxa in various ecological impact assessment program.

b) National Status

The Indian scenario is little different with very few, if not a single one, study addressing ecological questions behind the diversity and distribution pattern of moth assemblages. Not a single study has so far addressed Indicator properties of moth assemblages in assessing habitat quality. All the work has been addressing the taxonomy of moth; still the inventory of these taxa for a single state is not complete.

The earliest faunistic records of Lepidoptera from India are by Linnaeus (1758-68), Cramer (1775-82), Fabricius (1775-98), Kollar (1844-1848), Butler (1879-86), Donovan (1800), Swinhoe (1885-1902). The lists and catalogue were published by Walker (1854-

1866), Moore (1857-88), 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. Hampson (1892, 1894, 1895, and 1896) published four volumes of the "*Fauna of British India*". He (1903, 1908, and 1919) further published supplementary paper and studied of new moths collected by Mons. Bell and Scott (1937) published "*Fauna of British India*" to family Sphingidae. Warren (1888, 1893, 1896, 1910, 1911, 1913, and 1914) and Rothchild (1914, 1915, 1920, and 1933) 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). Arora (1997, 2000) published some moth species from the Nanda Devi Biosphere Reserve and some Indian pyralid species of Economic Importance respectively. Arora and 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. Moth 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 been 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.

9.1.5 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.

9.1.6 Importance of the proposed project in the context of current status

In the context of above literature review for Indian studies on moth, it can be said that there is still plenty of lacking for even faunistic inventory for a particular state or landscape. The proposed study will enrich knowledge about the moth biodiversity in Uttarakhand which has a unique landscape pattern of Western Himalaya, the meeting point of Oriental and Palaearctic faunal elements. An initial database of moth fauna and checklist will be produced based on the ground level sampling. The sampling protocol can be established for forest moth survey and monitoring in temperate and alpine zone of Himalaya which is so far poorly studied for this particular group. Study will be able to evaluate the diversity and distribution of moth assemblages among different elevations and vegetation types of Protected Areas of Uttarakhand. The influence of climatic, topographic and anthropogenic effect on moth assemblages will be understood. It will be possible to identify groups of indicator species with correspondence to intact or disturbed patches in given landscape. This will have a conservation implication by depicting the habitat condition of the landscape which is very important repository for unique Himalayan flora and fauna. In short the study will promote moth as model terrestrial insect group for concurrent conservation management target.

9.1.7 Aims & Objectives of the study

1. Documenting and prepare taxonomic inventory of rich moth fauna of Protected Areas of Uttarakhand.
2. To assess and analyse diversity and distribution of moth assemblages among different elevations and vegetation types and the influence of anthropogenic disturbance factors on moth assemblages in different protected areas of Uttarakhand.
3. To establish moth assemblage as surrogate for entire insect community and use them as indicator taxa in rapid habitat-quality assessment program.

9. 2 MATERIALS AND METHODS

9.2.1 Study Area

9.2.1A Nanda Devi Biosphere Reserve

Nanda Devi Biosphere Reserve (NDBR), (30º 08'-31º 02'N, 79º 12'- 80º 19'E) ,which includes both the Nanda Devi National Park (NDNP) and Valley of Flowers National Park (VoFNP) (Negi,2002), is located in the northern parts of the Western Himalaya in the biogeographically classified zone, 2B (Rodgers et al., 2000). It covers an area of 6,407.03 km² (core area: 712.12 km2, buffer zone: 5148.57 km2 and transition zone: 546.34 km2), with an altitudinal range of 1800m-7816m asl. The entire area of NDBR lies within the Western Himalayas Endemic Bird Area (EBA) (Islam and Rahamani, 2004). NDBR comprises parts of Chamoli district in Garhwal, Bageshwar and Pittoragarh districts in Kumaun in the state of Uttarakhand. NDBR is bordered by the upper catchments of river Saraswati and Malari-Lapthal area in the north; village Khati in the south, Kala glacier and catchment of river Girthi Ganga in the east; and the upper catchment of river Alaknanda, Nanda Ghunti peak, and Roop Kund in the west (Fig.-1).

In 1988, the NDNP (30°16' to 30° 32'N and 79° 44' to 80° 02'E) formed the core zone with the surrounding areas as the buffer zone of NDBR (2,237 sq.km) and was declared a biosphere reserve under the Man and the Biosphere (MAB) Programme of UNESCO. This was later amended in 2000 to cover a total area of 5,860 km2 to include the VOFNP (30° 41' to 30° 48'N and 79° 33' to 79° 46'E) as part of the core zone (88 km2). NDNP and VOFNP were designated as 'World Heritage Sites' during the years 1988 and 2004 respectively. NDNP is located in the high mountain ranges of Chamoli district in the upper catchments of the river Alakananda, the eastern tributary of the river Ganga. Nanda Devi peak lies within the core area of NDNP and is the second highest peak within Indian territory (7,816 m). It is considered the world's second toughest peak to climb (Kaur, 1982). VOFNP is located in the west of NDNP harbouring a rich and diverse floral and faunal assemblage in a small area of about 88 sq.km. These two core zones have the distinction of being the only two PAs in the Western Himalaya that have not been subjected to extensive livestock grazing since 1983 (Sathyakumar, 2004). They are considered to be the least disturbed areas of the entire BR. They remain intact primarily due to their inaccessibility on account of the surrounding high mountain peaks (UAFD, 2004).

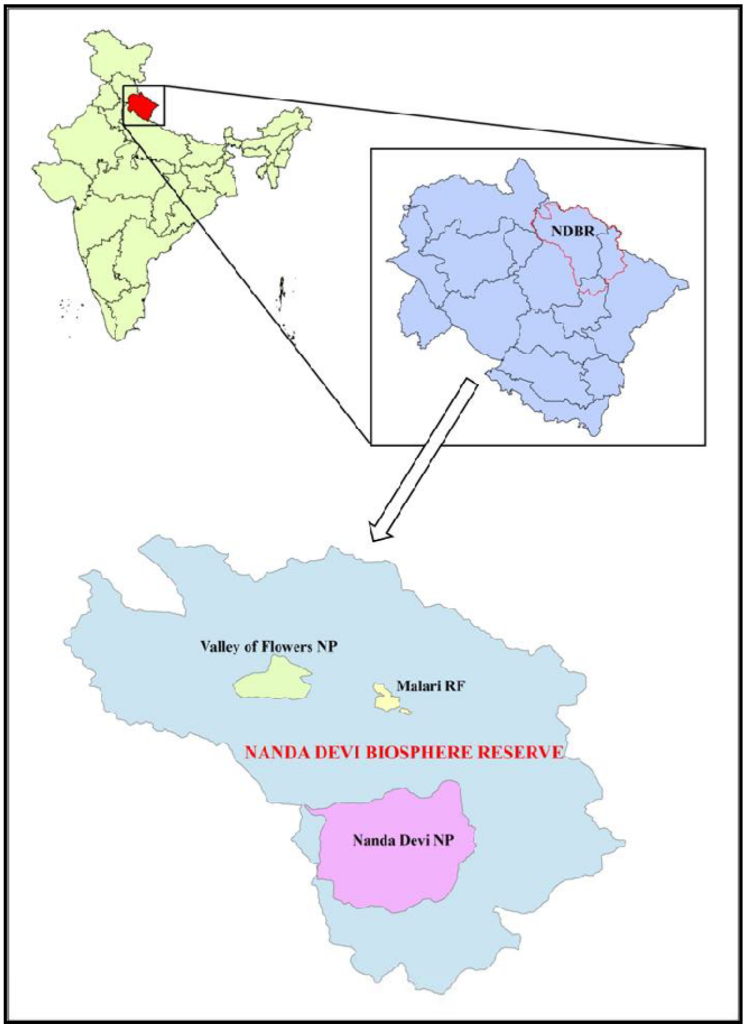


Figure 1: Map of Nanda Devi Biosphere Reserve (Quasin,2011)

9.2.1A.1 Topographical Features

The terrain of the entire region is highly undulating. About 90% of the total area in the NDBR region (from 3500m and above) is covered in snow and alpine meadows and 52.7% of the reserve has slopes of 20° to 40° (Kandpal, 2010; WII-GIS lab). The rocks are highly metamorphosed crystalline type of the Vaikrita group (Marou 1979). The core zones of the biosphere have been divided into four geological formations *i.e.* Lata, Ramani, Kharpatal and Martoli. The geological succession varies from the Shiwalik formations in the fringe areas to the lesser Himalayan formations (Negi, 2000). Most of the NDNP falls within the central crystalline, a region of young granites and metamorphic rocks. The Tethys sediments form Nanda Devi peak along with many of the surrounding peaks, displaying spectacular folds and evidence of thrust movements, while other mountains like Changbang are made up of granite. The basin displays an array of periglacial and glacial forms covering a wide range of phases of their growth. The combinations of normal and perched glaciers on different rock types form interesting features in the basin (Reed, 1979). Geologically VOFNP falls in the Zanskar range (Wadia, 1966). The rocks are primarily sedimentary with mica schist and shale. The soil is acidic in nature (pH 3.8 – 6.1).

9.2.1A.2 Climate

The Nanda Devi Basin has a microclimate. The climate is dry with low yearly precipitation. It has heavy rainfall during the monsoon season, which is from late June to the beginning of September. There are four main seasons that are experienced by the BR: (i) winter: December to March with heavy snowfall in the months of December - February (ii) spring: April to mid June (iii) summer: mid June to September (iv) autumn: October to November. The major portion of the biosphere area remains under a thick carpet of snow during winter, and is accessible only for a limited period from late June to early October. Generally, the snow cover is thicker on the northern slopes than on the southern slopes (Lavkumar, 1979; Lamba, 1987). About 60% of the buffer zone and 81% of the core zone remain snow bound or covered by glaciers throughout the year (Sahai & Kimothi, 1996). During rainy season, the climate as a whole is dry, with low annual precipitation. Average annual rainfall is 928.81mm. About 47.8% of annual rainfall occurs over a short period of two months (July-August) (Quasin, 2011). This contributes to the lush vegetation. The Valley of Flowers shares this similar climate pattern. These two areas are usually snowbound for six to seven months from late October and March. The snow is deeper at lower altitudes on the south side than on the north side of the valleys. The temperatures range from 10° - 23° C from April to June, and from 7° - 22° C from July to October. The elevation of the Trans-Himalayan region ranges from 4400 to 5500 msl. It receives very scanty rainfall and exhibits all the characteristics of typically cold-arid conditions (Rawat, 2005)

9.2.1A.3 Floral & Faunal Diversity

The vegetation in the study area are mainly dominated by *Quercus* and *Abies* species forming the climax communities at various altitudinal zones. According to Champion and Seth (1968) forests of NDBR is divided into four major categories:

(a) Temperate forests (2000–2800m): This type has two sub categories:

(i) Deciduous forests and (ii) Coniferous forests. Deciduous forests are dominated by *Acer caesium, A. pictum, Celtis australis, Betula alnoides, Alnus nepalensis* and other associated species such as *Rhododendron arboreum, Aesculusindica,* and *Juglans regia.* Coniferous forests are dominated by *Abies pindrow, A. spectabilis, Picea smithiana, Pinus wallichiana, P. roxburghii, Cedrus deodara* and *Taxus wallichiana.* Shrubs such as *Rubus* sp., *Desmodium elegans, Viburnum continifolium, Deutzia staminea and Sinarundinaria falcata* occupy the middle layer.

(b) Subalpine forests (2800–3500m) are dominated by *Abies spectabilis, Taxus wallichiana, Betula utilis* forms the transition zone between subalpine forest and alpine meadow near the treeline. Shrub species such as *Juniperus communis, J. indica, Rhododendron campanulatum, R. anthopogon, Cotoneaster* spp., *Rosa sericea, R. macrophylla* are present as dominant
understory vegetation.

(c) Alpine scrublands (3800–4500m) are dominated by *Rhododendron anthopogon, R.lepidotum, R. campanulatum, Juniperusindica.*

(d) Alpine meadows and moraines (>3500m) are dominated by herbs and shrubs *viz*., *Juniperus indica*, *Rhododendron anthopogon, Cassiope fastigiata,Danthonia cachemyriana, Salix elegans, S. denticulata, Carex nubigena, C.stenophylla, Bistorta* spp. and *Anaphalis* spp.

There are over 1,000 species of plants including bryophytes, fungi and lichens (Samant, 2001). About 620 species of flora has been reported for NDNP and the list comprises of 531 Angiosperms, 11 Gymnosperms and 33 Pteridophytes. Smythe (1938) surveyed VOFNP and the adjacent areas and reported 262 plant species. Later, Kala (1998) made a floral inventory of vascular plants exclusively, inside the NP and recorded 521 species of vascular plants (Angiosperms, Gymnosperms and Pteridophytes) belonging to 72 families and 248 genera. The vegetation comprises mainly of temperate, sub alpine and alpine types. The alpine meadows are locally known as 'bugyals' which harbour high value medicinal plants such as *Aconitum* spp. *Dactylorhiza hatagirea, Podophyllum hexandrum,Nardostachys jatamansi, Jurinea dolomiaea, Trillium govanianum, Gaultheria trichophylla* and aromatic plants *viz.*, *Nardostachys jatamansi, Angelica glauca, Saussurea gossypiphora, Skimmia anquitilia, Geranium wallichianum, Artemisia nilgirica*, *A. gmelinii* supporting over several alpine faunal communities. The reserve also supports large numbers of other native, endemic, rare, endangered and charismatic floral species *viz., Saussurea obvallata, Meconopsis aculeata, Dactylorhiza hatagirea, Angelica glauca, Podophyllum hexandrum*. (Quasin 2011)

Over 518 faunal species including mammal, birds, fishes, reptiles, amphibians, molluscs, annelids and invertebrates are found in NDBR. The vertebrate and invertebrate faunal groups comprise of 29 mammals, 228 birds, 3 reptiles, 8 amphibians, 6 annelids, 14 molluscs and 229 species of arthropods (Kumar et al. 2001). Snow leopard (*Uncia uncia*), musk deer (*Moschus chryogaster*), bharal (*Pseudois nayaur*), Himalayan tahr (*Hemitragus jemlahicus*), serow (*Captricornis sumatraensis*) Himalayan black bear (*Ursus ursus*) and Himalayan brown bear (*Ursus arctos*) are found in NDBR (Dang, 1967; Khacher, 1978; Kandari, 1982; Lamba, 1987; Uniyal, 2004; Sathyakumar, 1993, 2004; Bhattacharya et al. 2006, 2009 and Kandpal, 2010). Nearly 200 species of birds are reported from the BR (Shankaran, 1993). Some of the birds like Himalayan golden eagle (*Aquila chrysactos daphancea*), eastern steppe eagle (*Aquila rapax nipalensis*), black eagle (*Ictinaetus malayensis perniger*), Himalayan bearded vulture (*Gypaetus barbatus*), and Himalayan snowcock (*Tetragullus himalayensis*) (Shankaran 1993; Tak & Kumar 1987; Reed 1979 and Sathyakumar 2004) have been reported from NDBR. Galliformes like the Himalayan monal pheasant (*Lophophorus impejanus*), koklass (*Pucrasia macrolopha*) and satyr tragopan (*Tragopan satyra*) are found in this region (Sathyakumar, 2004).

However, very little information is available on the invertebrate fauna of the BR. Kumar et al. (2001) reported 218 forms of invertebrates from NDBR: 15species of Mollusca, 6 species Annelida, 17 species of Arachnida, 1 species of Thysanura, 2 species of Collembola, 6 species of Odonata, 14 species of Orthoptera, 7 species of Dermaptera, 13 Hemiptera, 4 species of Neuroptera, 80 species of Lepidoptera, 2 species of Trichoptera, 24 species of Diptera, 24 Hymenoptera and 3 species of Chilododa. There is a rich diversity of butterflies in the BR; some of the butterflies found in these areas are common yellow swallowtail (*Papilo machaon*), common blue apollo (*Parnassius hardwickei*), dark clouded yellow (*Colias electo*), Queen of Spain fritillary (*Issoria Iathonia*), and Indian tortoiseshell (*Aglais cashmirensis*) (Baindur 1993 and Uniyal 2004).

9.2.1A.4 Concern

Unorganized mountaineering activities threatened the biological integrity of the National Park. Pollution is one of the biggest problems caused by tourists. The camping sites on the trails become polluted with garbage from hikers not cleaning up after they leave. Rivers and streams also become contaminated with leftover garbage, causing harm to the animals living in them and drinking from them. Deforestation and forest fires are also environmental problems that the Nanda Devi Biosphere needs to control. Forest fires are the result of irresponsible fire building when out in the campsites of the park. Human impact in this biosphere reserve appears to have harmed, more than benefited, the national park.

One case where human impact helped the biosphere reserve was the Chipko movement when village women saved forests of the area (Nanda Devi Campaign). They stopped deforestation from occurring in their local forests one year. The residents of Nanda Devi want to do anything they can to help save their environment and keeps it flourishing for as long as possible.

9.2.1B **Gangotri Landscape and Askot 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 km2 harboring the Gaumukh Glacier, the origin of the River Ganges, and Govind National Park covers an area of 953.12 km2 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.

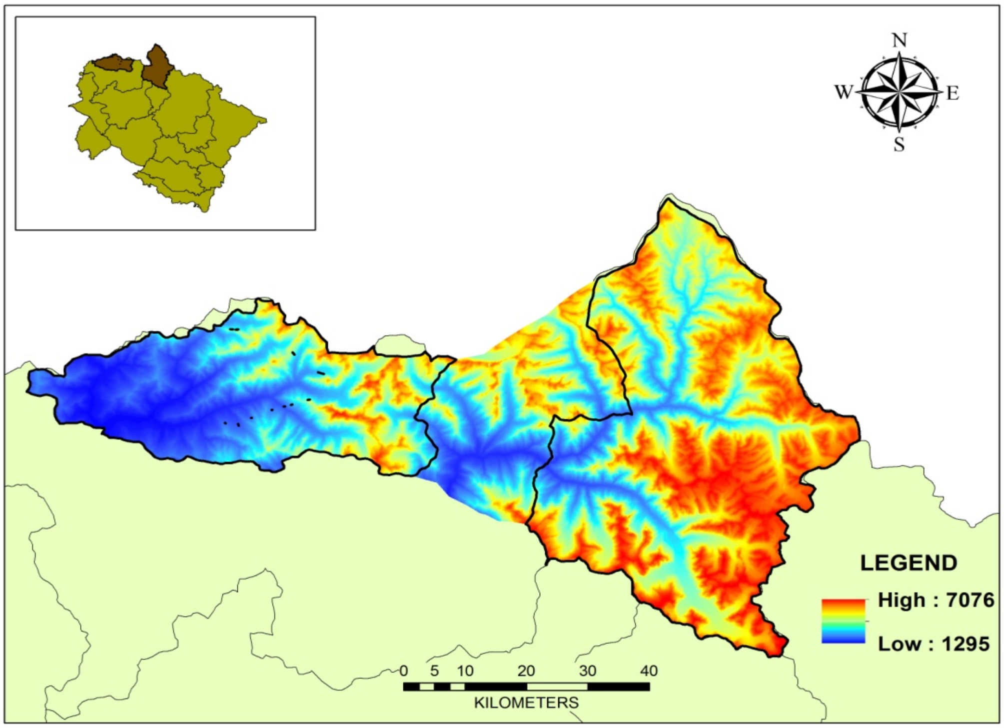


Figure 2: Digital Elevation Model of study area, Gangotri Landscape Area showing the boundary of Govind WLS & NP in the west and Gangotri NP in the east

9.2.1B.1 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. 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.

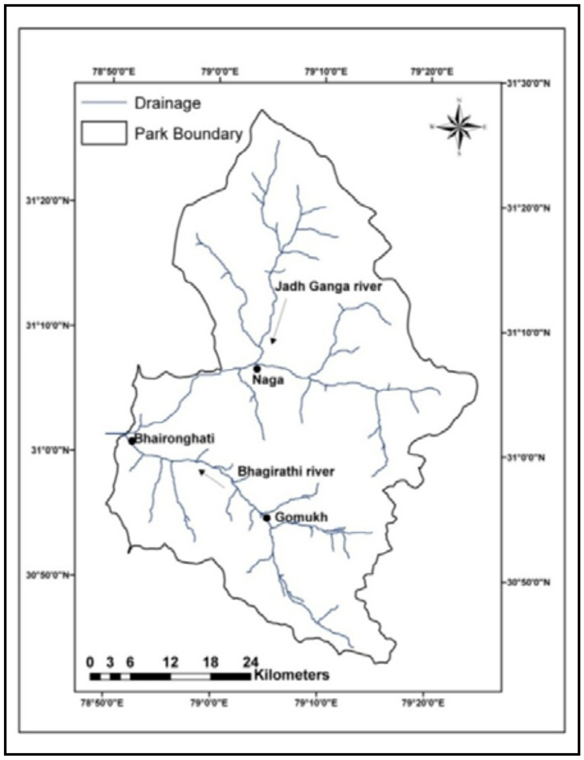


Figure 3: Map of Gangotri National Park

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*).

9.2.1B.2 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 km2 of which 472.08 km2 have been demarcated as National Park encompassing the upper catchment of river Tons.

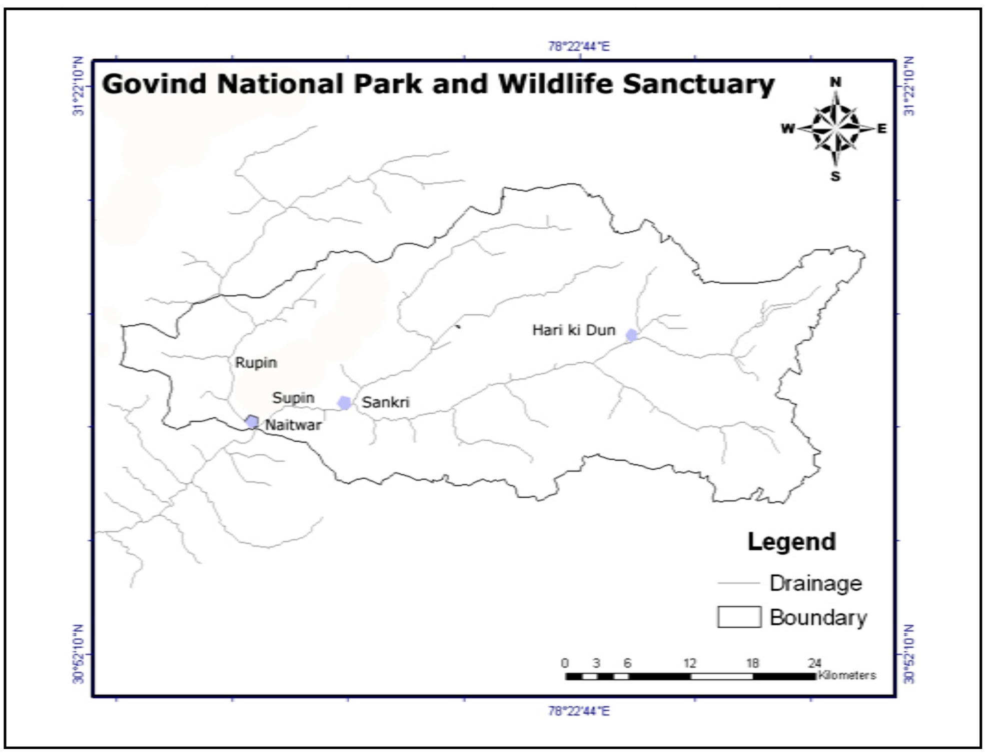


Figure 4: Map of Govind National Park and Wildlife Sanctuary

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.

9.2.1B.2.1 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.

9.2.1B.2.2 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.

9.2.1B.2.3 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.

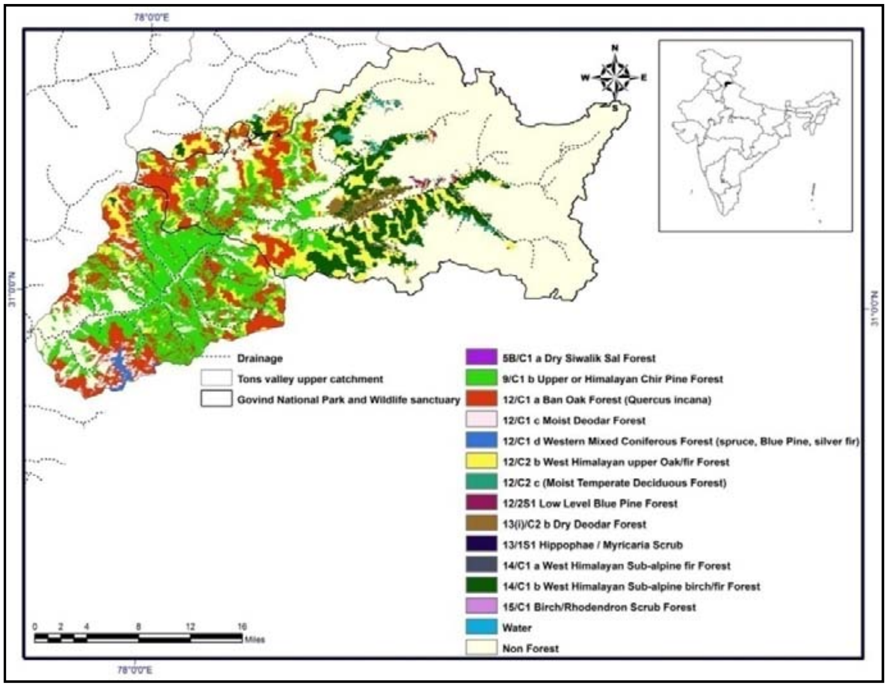


Figure 5: Forest types in the Govind NP and WLS and adjoining area of Tons valley, according to Champion and Seth (1968)

9.2.1B.2.4 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 chrysogaster*), 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).

9.2.1B.2.5 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

9.2.1C Askot Wildlife Sanctuary

The Askot landscape in the eastern Kumaon of Uttarakhand state lies in the conjunction of the western and eastern Himalayas and contains biodiversity elements of both these regions. The great vertical altitudinal gradients, from 560 m at the banks of the Gori in the township of Jauljibi to over 7000 m at the Panchachuli's summits yield an exceptionally high habitat diversity that ranges from subtropical shorea robusta, to alpine meadows and in between fourteen major vegetation types have been identified in the landscape like Pine Mix Forest, Sub-tropical Riverine Forest, Banj Oak Forest, Moru Oak, Kharsu Oak, Alder Forest, Cypress Forest, Temperate Secondary Grasslands, Hemlock or Tansen Forest, Temperate Secondary Scrub including Berberis, Prinsepia, Rubus, Temperate Broadleaf Forest including Acer, Betula, Juglans, Aesculus, Blue Pine, Sub-alpine Forest including Birch-Fir and Birch-Rhododendron forest, Alpine Scrub consisting Dwarf Rhododendron and Juniper scrub. About 58% of the landscape also falls under alpine conditions that are characterized by moist alpine habitats in the Greater Himalaya and dry alpine habitat in the Trans Himalaya sections of the landscape. In spite of this great diversity in the landscape there have been few intensive studies on the floral and faunal elements in the region except for inventorying plants (2607 species of tracheophytes), birds (265 species) and mammals (37 species). The Askot landscape, encompassing 3326 square kilometers, links the Nanda Devi National Park and the

Askot Wildlife Sanctuary and shares international boundaries with the Tibetan Autonomous region in the north and Nepal on the South East; large swathes of wilderness also exist between and in the upper reaches of both the international boundaries. While the landscape shows a predominance of typical west Himalayan forest communities like Chir pine and West Himalayan Oaks, the special location of the landscape in the east to west (longitudinal) transition enables it to also represent the western-most limit for the occurrence of East Himalayan communities such as Tsuga and Macaranga.

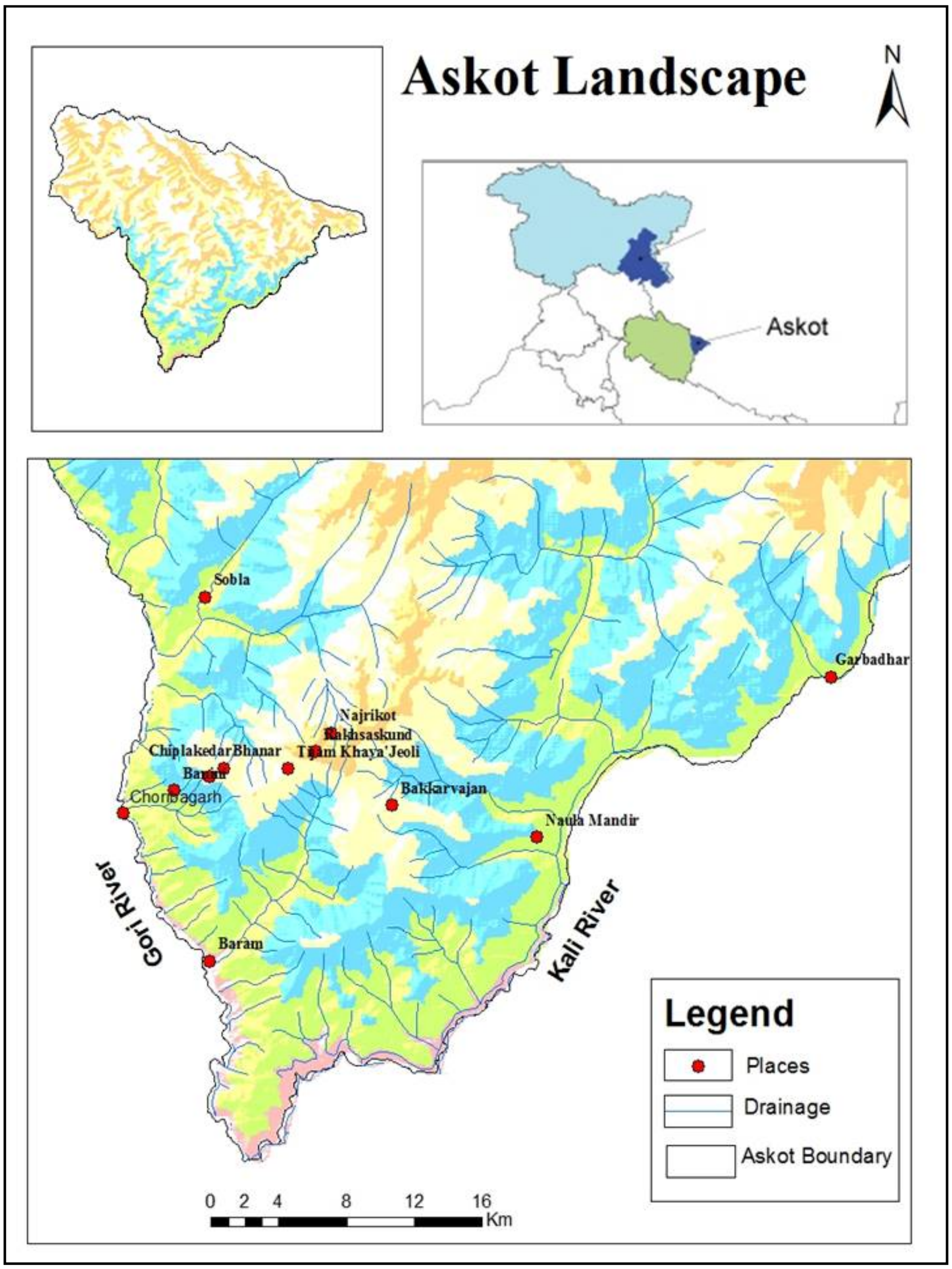


Figure 1: Askot Landscape and the sampling localities

9.2.2 General Study Design

The study area was stratified on the basis of elevation & vegetation types to explore the moth diversity along the gradient. Each site will was selected randomly at a particular elevation band so that the vegetation types are included in them. The number of trap sites were selected at each stratum so that comprehensive representation of the moth diversity can be accounted. The trap sites were situated in the centre of plots with a homogeneous vegetation cover, so that moth catches at weak light sources should largely reflect the local communities. The minimum distance between neighbouring sites were 50 m, with lamps not being visible from neighbouring sites, so that cross-habitation sampling does not occur. At each site 2-3 night sampling were done for 3-4 hours from dawn. The moths were trapped by their attraction to weak light sources. 5days prior to and after full moon were not sampled.

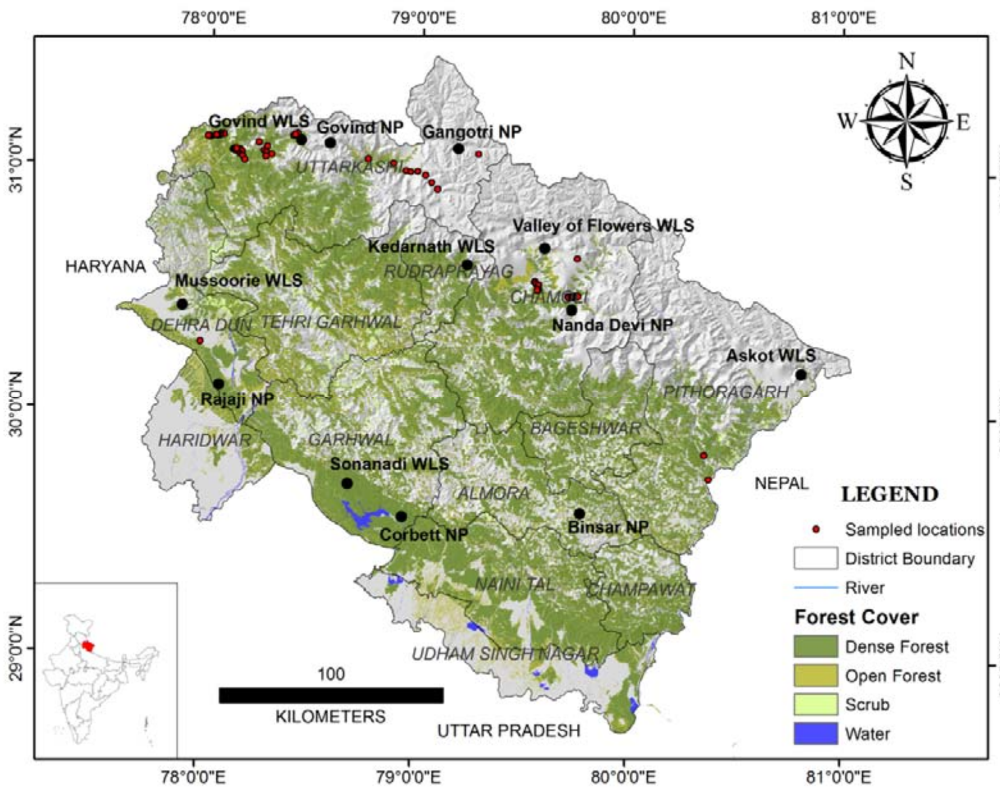


Figure 2: Map showing the sampling sites

9.2.2.1 Preservation of samples:

After collecting, the moths from the field are killed in a killing bottle, which is filled with benzene vapours. For temporary storage in the field, they are kept, in insect envelopes with labels and the envelops are kept in ordinary cardboard boxes. The collection is subsequently exposed to sunlight for warm for some time to avoid growth of fungus. These boxes should also contain sufficient quantity of naphthalene powder. Spreading larger moths in the field is time consuming and quickly leads to bulking up and presenting problem for future transport. However smaller moths can be spread effectively on fine foam plastic in shallow boxes that can be sealed with tape once the specimen is dry. The insects are pinned with micropins through the centre of the thorax such that twice as much pin protrudes below as above, and the angle of the pin is slightly forwards above. The moth is then pinned into the foam with the pin vertical so that the body comes firmly up against the surface. The wings, and the legs if required are then be manipulated on either side into a roughly spread position. Permanent storage were done in larger insect cabinets with glass top drawers and grooved sides for filling the naphthalene powder and then specimens are arranged in proper orientation. Male genitalia will also be dissected out and kept in 10% KOH solution for 12 hours, rinsed in distilled water for several times and are then were preserved in 70% alcohol.

9.2.2.2 Identification:

The collected specimen were identified and classified with the help of all available traditional taxonomic characters for the group. The male genitalia will also help in the process, especially for the discrimination of the species. The moths will then be studied with the help of a camera-lucida and stereoscopic binocular microscope. The specimens were examined thoroughly and classified into different taxa or group. Each taxon is then studied for further segregation on the basis of their general appearance and apparent characters. The identification of the individuals is taken up with the help of literature and the genera and species so identified are compared with the references collection available at the Central Regional Station, Zoological Survey of India, Jabalpur. The traditional characters used for the identification of the moths were as per Hampson (1892) and Common, (1990) and the characters of male genitalia were also studied for distinguishing the species for defining genera and higher categories.

9.2.2.3 Habitat Variables: Following variables were considered as sites covariates:

Habitat Variables:

1. Canopy Cover
2. Tree Density
3. Shrub Density
4. Litter cover at Ground
5. Bare Soil at Ground
6. Grass cover at Ground
7. Foliage Height Diversity
8. Dominant Flowering Plants (Herbs, Shrubs and Grass)

Microclimatic Variables:

1. Ambient Temperature
2. Relative Humidity
3. Monthly Mean Precipitation
4. Wind Speed
5. Atmospheric Pressure
6. Cloud Cover

Disturbance Variables:

1. Logging & Lopping Signs Present
2. Presence of Felled Trees
3. Presence of Grazing & Livestock
4. Presence of Fire Sign

Vegetation Sampling:

Plant community of each vegetation types were sampled using a series of nested quadrats. Initially, each series were designed such that, within a vegetation type, one set of quadrates were centred on the position of the light trapping station and the remaining two were randomly located 50 m from the centre. 10x10 m quadrats were used to quantify species richness, abundance, and the diameter at breast height of all trees greater than 10cm dbh. Canopy cover was measured using a densitometer at 8 points spaced at 10m intervals along the perimeter of each 10x10 m quadrat. Within 10x10 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 were taken account to measure species richness, abundance, and percent cover of herbaceous layer. Plant data collected from nested quadrat sampling were 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. The relative frequency of a given species is the number of 10x10 m quadrats within a vegetation type in which the species were 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.

10. RESULTS

10.1 SPECIES RICHNESS, DIVERSITY AND COMPOSITION OF MOTH ASSEMBLAGES

10.1.1 Introduction: Importance of moths in biodiversity conservation

Knowledge of insects is uneven across different major taxonomic groups with majority of groups are poorly documented. In contrast, some insect groups like Lepidoptera are accepted as well-known and ‘popular’ and have a special place in human perception, culture and nature appreciation. ‘Big colorful butterflies invoke the ‘vertebrate’ approach to Lepidoptera conservation because they are …. charismatic species that imply ‘heroic’ conservation measures should be taken ….’ (Kitching, 2007). In addition (a) many are themselves targets for individual species conservation and (b) many species or assemblages may be valuable ‘tools’ in being putative surrogates for wider conservation of the biotopes in which they occur. Lepidoptera, as ‘Ambassadors of biodiversity’, fall unevenly into three major functional groups: ‘butterflies’, ‘macromoths’, ‘microlepidoptera’. Butterflies and some groups of macromoths like Saturniidae and Sphingidae are well advocated in biodiversity conservation due to (i) low species richness within a sound taxonomic framework so that many taxa are both recognizable and identifiable reliably; (ii) long history of collector interests based on aesthetic appeal and diurnal activity likely to have led to production of illustrated handbooks facilitating further interests; (iii) reasonable general framework of biological understanding and distributional information. In contrast, majority of other macromoths and microlepidoptera are nocturnal and less accessible and is grossly poorly known to make any detailed case for species conservation need. Two practical problems are associated with moths for their inability to gain flagship status: (i) high numbers of unidentified or difficult to identify species and (ii) flagships are ideally conspicuous - most moths, being crepuscular or nocturnal in activity, are not seen as easily unless they are deliberately sought. But, despite the above-mentioned drawbacks, nocturnal Lepidoptera has certain advantages which make them potential taxa for studying in conservation perspectives. They are closely associated with the vegetation gradient and any subtle change in their immediate habitat is reflected in their abundance pattern. Large dataset for sound quantitative analysis can be obtained through attracting them to light trap. Whereas the butterflies prefer open and sunny habitats, the nocturnal moths are numerous in every suitable habitat in a forest environment and are thus more suitable for habitat monitoring purpose.

Geometrids are one of the most speciose families of Lepidoptera and are distributed in all major biogeographic regions. To date, 23,000 species have been described comprehensively worldwide (Scoble & Hausmann, 2007). Phylogenies at the subfamily and tribe levels are still in dispute, but it has been possible to investigate diversity patterns of Geometrid moths in several tropical regions (Kitching et al. 2000, Brehm & Fiedler, 2005, Brehm et al. 2003 a,b; Axmacher et al. 2004), because a global database and extensive taxonomic revisionary works on tropical geometrids are available. Geometrid moths have been chosen as model group in a number of environmental studies in tropical regions, mainly in South East Asia and Australia (Holloway et al. 1992, Chey et al. 1997, Intachat et al. 1997, 1999, Kitching et al. 2000, Schulze, 2000, Beck et al. 2002), also in South America (Brehm, 2002), and in Africa (Axmacher et al. 2004). Their taxonomy is relatively advanced (Scoble, 1999), and the adults can easily be attracted to light traps. They have been described as a suitable group in which to study the effects of forestry practices because of their weak flight ability and the high habitat fidelity (Thomas, 2002). Available data suggest that geometrid moths are sensitive to habitat alterations. For example, Kitching et al. (2000) showed that the proportion of geometrid moths among Macrolepidoptera decreased with increasing levels of disturbance in Australia. Holloway et al. (1992) detected a considerable loss of lepidopteran diversity due to logging activities in Borneo, and showed that major groups within the Geometridae belonged to the most vulnerable taxa. A loss of geometrid diversity due to anthropogenic disturbance was also confirmed by Beck et al. (2002) in Borneo.

This kind of database certainly lacks in Indian Himalayan Region (IHR) which as part of the world’s largest mountain ecosystem, harbours a diverse and unique assemblage of faunal diversity due to its unique position in the junction of Palaearctic and Oriental realms. The Himalayan system, recognized as a globally important biodiversity hotspot, is characterized by sharp environmental gradients due to rapid geo-climatic variations generating diverse vegetation and community types. A baseline data of the distribution of major families of nocturnal Lepidoptera along the altitude needs to be generated, as little information is available so as to pile on future research addressing the ecological patterns governing the distribution and diversity as well as the effects of climate change. In Western Himalayan landscape, extensive knowledge about Geometrid moth diversity is lacking and major contributions were made over century ago by Hampson and Cotes & Swinhoe. Some local species inventories were made in recent decades by Walia, Smetacek, but none of the dataset were systematically collected so that any inferences can be drawn about their richness and abundance changes in spec and time.

The present study aims to document Geometridae moths across different habitat types, along elevation and vegetation gradient in the Indian state of Uttarakhand located in the Western Himalayan Biogeographic Province. Our primary objective was to prepare a species compilation from primary field data which can be compared with old records as well as to be a baseline for future study. We also investigated how major species groups of this important family are distributed along elevational and vegetation gradients, how different biogeographic elements influence the overall faunal composition and which would be the target species to monitor in future.

10.1.2 Sampling Protocol

As making an initial inventory of particular taxa is an important first step towards any conservation management program, we tried to cover as many as possible different forest and habitat types according to major biomes and selected five heterogeneous landscapes. We sampled in Dehradun-Rajaji Landscape (600m-800m) harbouring Moist Sal forest habitat. Subtropical hill forest habitats were sampled in Askot Wildlife Sanctuary (600m-1000m). This landscape, located along India-Nepal border is also significant as a junction between Western and Central Himalaya, as floral elements from both these biogeographic zones converge here. Himalayan Moist Temperate habitat was sampled in Govind Wildlife Sanctuary ranging from an elevation of 1400m to 3600m including major forest types like Subtropical Pine Broadleaved Mix forest, Moist Temperate Deciduous forest, Western Mix Coniferous forest, Western Himalayan Upper Oak forest, and Subalpine forest (Champion & Seth, 1968). The sampling sites within Gangotri National Park, owing to its special location as great vertical orientation, included habitats similar in the Trans-Himalayan condition of Tibetan Plateau. The Nanda Devi Biosphere Reserve, including Nanda Devi National Park and Valley of Flowers National Park, harbours varied habitats like Himalayan Dry Temperate forest and Alpine pastures. Total 503 sampling nights (Table 1) were performed between 2012 and 2015 in 197 sites across 5 Protected Areas.

Protected Area	Sampling session	Sampling nights	Seasons sampled	Altitudinal range covered (m)
Dehradun (Rajaji NP Landscape)	April-June, July-September, October-November, 2009-2014	67	Pre-Monsoon, Monsoon, Post-monsoon	700-1000
Gangotri NP	October-November, 2008; October, 2012	36	Post-monsoon;	1400-3600
Govind WLS	April-June, July-September, October-November, 2009-2012	168	Pre-Monsoon, Monsoon, Post-monsoon	1400-3600
Nanda Devi Biosphere Reserve	(April-June, Late August-October)2013, 2014,2015	184	Pre-monsoon and post monsoon	2000-3800
Askot WLS	(May-June, September), 2013, 2014	48	Pre-monsoon and post monsoon	600-1000

Table 1: Details of the Light-trap sampling done in the different protected areas in the period 2008-2015 covering different seasons.

10.1.3 Results

Altogether 169 species of Geometridae moths belonging to 99 genera of 5 subfamilies were recorded from different Protected Areas (PAs) of Uttarakhand. The detailed species account with their recorded altitudinal range, past altitudinal record and host plant information is provided here with specimen photographs (Table 2).

We recorded 20 species from Askot Landscape, 42 species from Dehradun-Rajaji Landscape, 112 species from Govind Wildlife Sanctuary, 15 Species from Gangotri National Park and 37

species from Nanda Devi Biosphere Reserve. Among major forest types sampled, maximum numbers of species were recorded from Western Mixed Coniferous forest (55 species) which

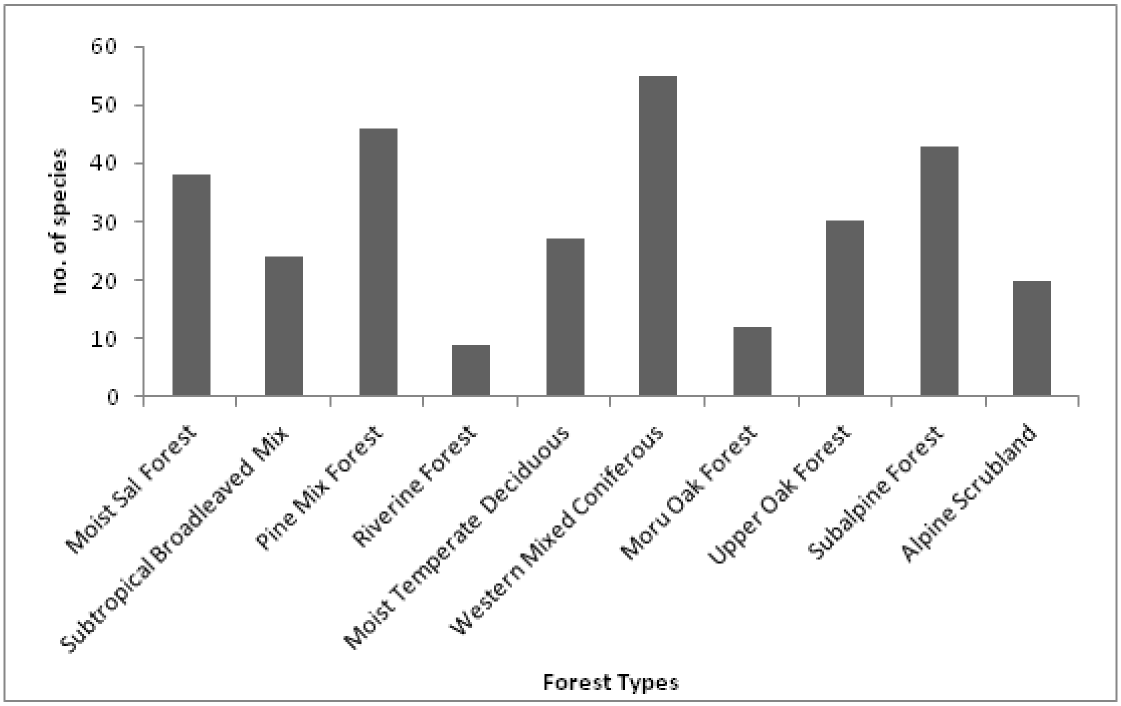


Figure 2: The number of species found in each of the forest type. Western Mix coniferous forest type shows maximum species richness

was mainly the mid-elevation area stretching from 2200m to 2800m altitude zone. Among other species-rich areas were Pine (*Pinus roxburghii*) Mix forests (46 species) extending from 1400m to 1800m and Subalpine forest (43 species) between 3200m-3600m. Riverine forest (9 species) and Moru Oak (*Quercus dilatata*) forest (12 species) were among species-poor regions. The alpine scrubland, the semi-arid altitudinal zone above 3600m beyond tree-line yielded 20 species (Figure 1).

Among five subfamilies of Geometridae sampled across different elevation and forest types, Ennominae was the dominant (92 species), followed by Larentiinae (37 species), Geometrinae (28 species), Sterrhinae (11 species) and Desmobathrinae (1 species). Altitudinal distribution of the four major subfamilies (Figure 3) showed that the subfamily Larentiinae was exceptionally distributed towards higher altitude while the other three were diverse in lower and middle elevation zones. Mean species distribution of the dominant subfamily Ennominae was recorded around 1400m while most of the species were recorded between 600m to 2300m and the species range extended up to 3400m. The mean species distribution of the subfamily Larentiinae was recorded around 2800m while most of the species were recorded between 2500m to 3300m and the species range extended from 1800m to 3600m. The mean species distribution of Geometrinae was around 700m while most of the species were recorded from 600m to 1300m, and the species range extended up to 2500m. For Sterrhinae, the mean species distribution was around 1400m, while most of the species were recorded from 700m to 1700m, and the species range extended up to 2900m (Figure 2).

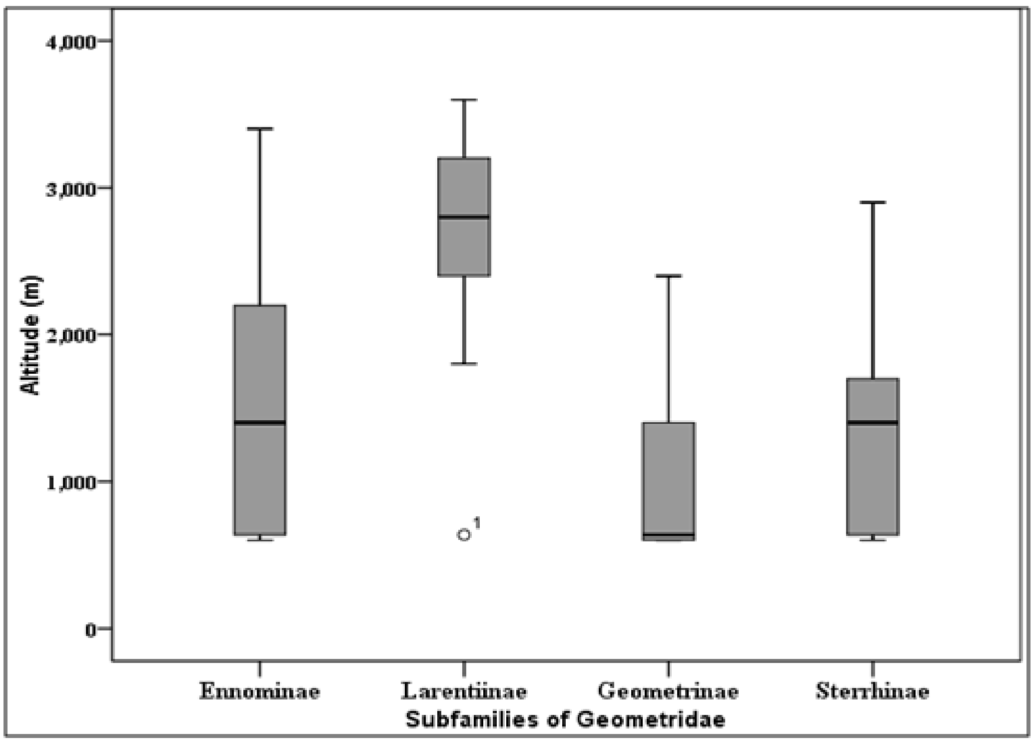


Figure 3: The altitudinal distribution of four major subfamilies of the family Geometridae collected across all sampling sites. While the subfamily Ennominae was widely distributed, species of subfamily Larentiinae had clear preference for higher altitudinal area

The subfamily composition of the Geometridae also changes according to various PAs covered, depending on their elevational position (Figure 3). While there was a dominance of subfamily Ennominae in all the PAs, except Gangotri NP, which being truly a high altitude PA ranging above 3000m, was dominated by Larentiinae. Notably, the lower altitude PAs like Askot and Dehradun (Rajaji Landscape) were almost devoid of Larentiinae species, with no record from Dehradun at all. Whereas, in other PAs, which had significant representation of high altitude forest types, like the Nanda Devi Biosphere Reserve and the Govind Wildlife Sanctuary, Larentiinae species were present in high numbers along with Ennominae species.

Among 12 tribes recorded of the subfamily Ennominae, Boarmiini was the dominant (37.5%) followed by Hypochrosini (12.5%). The other main tribes were Eutoeini, Abraxini, Gnophini, Ourapterygini and Macariini (6.25% each). Nine tribes were recorded of Larentiinae, among which, 30% of the species were from Cidariini, followed by Larentiini, Asthenini and Xanthorhoini (14.81% each). Among Geometrinae, 43% species were recorded of tribe Geometrini, 29% species were of tribe Pseudoterpnini and 23% of Hemitheini. Among Sterrhinae, nearly 50% species were of Scopulini, whose identification up to species level was not very successful.

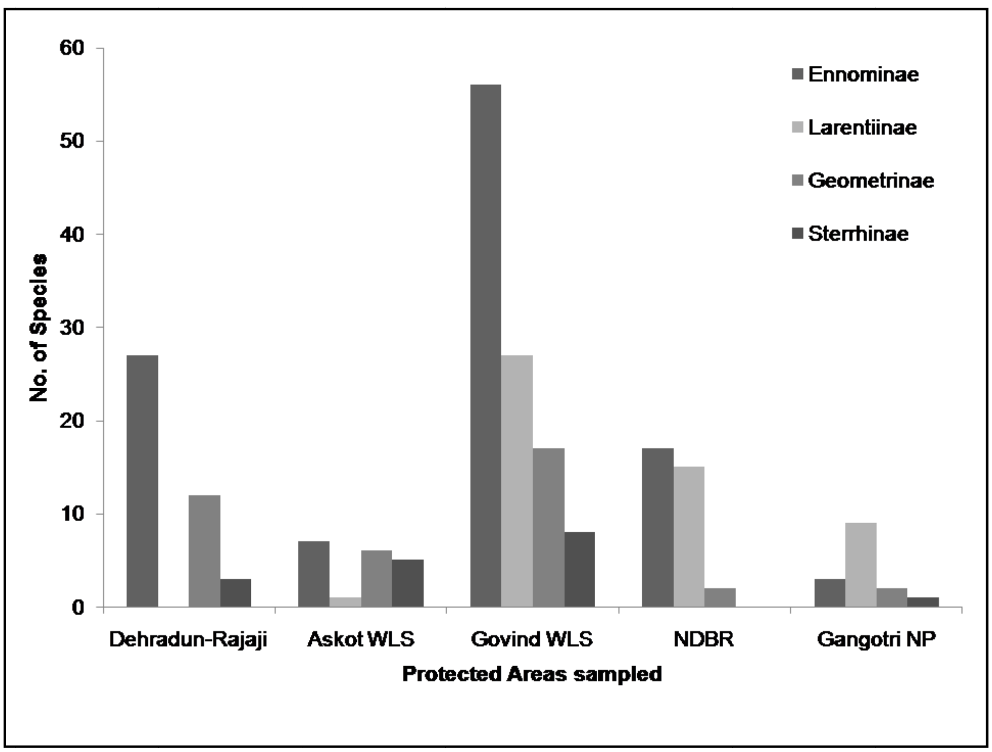


Figure 4: No. of species in each subfamily of Geometridae sampled across different Protected Areas in the Indian state Uttarakhand. The subfamily Ennominae was most numerous all through except in Gangotri NP. The subfamily Larentiinae had significant representation in high altitude protected areas and almost absent from lower altitude areas like Dehradun and Askot WLS

We categorized each species into four Biogeographic components based on their regional and global distribution from literature survey. Within Indian sub-region, 65% species were endemic to Himalayan region, while 16% species were also common in Gangetic plains. Around 19% species had common distribution throughout India (Figure 4a). Globally, 60% species were of Indo-Malayan origin, while significant portion (22%) was of Sino-Himalayan origin. A minor representation (9%) was also there of Eastern Palaearctic element while a similar proportion of species were also recorded which are globally distributed (Figure 4b). Species of subfamily Sterrhinae were mostly globally distributed.

We compared each species' maximum altitude record from past literature with highest altitude recorded in the current study and were able to document possible range expansion for at least 15 species. Among these species we recorded altitudinal range expansion of more than 1000m for 12 species: Abraxas irrorata (2000m to 3400m), Abraxas picaria (2000m to 3400m), Heterolocha phoenicotaeniata (2000m to 3200m), Odontopera heydena (1500m to 3200m), Odontopera lentiginosaria (600m to 3200m), Arichanna tenebraria (2000m to 3400m), Psyra debilis (2100m to 3400m), Eupithecia rajata (1500m to 2800m), Docirava aequilineata (Indian plains to 3400m), Docirava pudicata (Central India to 3200m); for 2 species, around 1000m expanse were recorded: Laciniodes plurilinearia (2400m to 3200m) and Xanthorhoe hampsoni (2200m to 3200m).

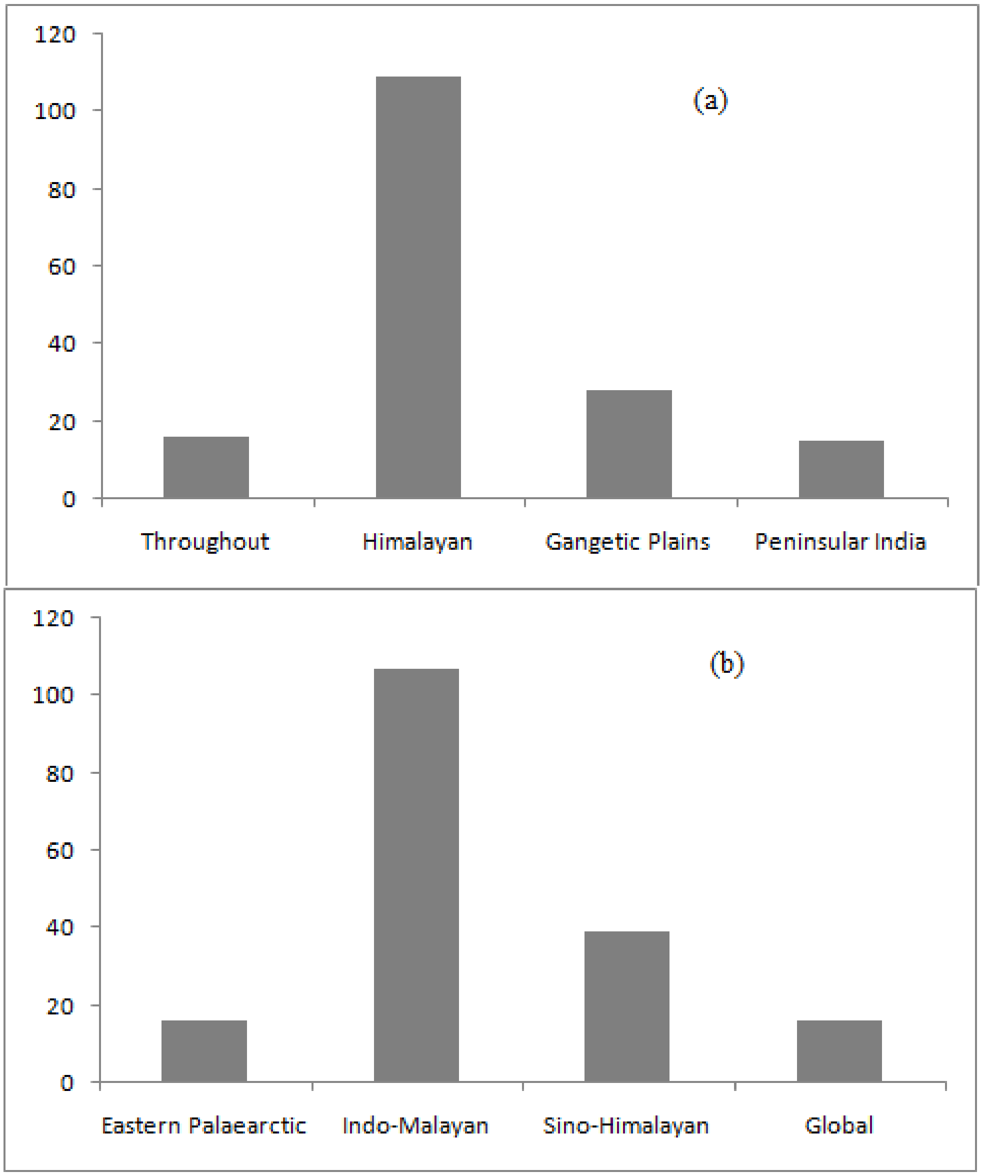


Figure 5: Biogeographic composition of sampled Geometridae assemblage: (a) Within Indian Subcontinent, Himalayan species dominated, the rest commonly distributed throughout. (b) The global pattern was dominated by Indo-Malayan species distributed along entire Himalayan breadth. There was significant proportion of Sino-Himalayan species as well as Eastern Palaearctic species

Characteristic moth species restricted to specific altitude or forest types were identified for each vegetation type using the Indicator Species Analysis (Dufrêne & Legendre, 1997) using program PC-ORD. This method combines measures of specificity and fidelity and provides an indicator value (IndVal) for each species, as a percentage with an associated test of significance, with high and significant percentages designating good indicator species. Three species were identified to be characteristic of low altitude Pine-broadleaved mix forest, *Semiothisa sufflata, Menophra subplagiata, Scopula pulchellata*; two species to Moist Temperate Deciduous forest: *Sirinopteryx rufivinctata, Odontopera kametaria*; single species each, were restricted to Western Mixed Coniferous forest and Kharsu Oak forest, *Pseudopanthera himaleyica* and *Odontopera lentiginosaria* respectively. The highest altitude forest, Subalpine forest was characterized by nine specialized species which were not recorded from any other forest types: *Arichana tenebraria, Photoscotosia amplicata, Opisthograptis tridentifera, Photoscotosia multilinea, Venusia crassisigna, Abraxas gunsana, Triphosa rubrodotata, Eustroma chalcoptera* and *Opisthograptis sulphurea* (Table 2).

Table 2: Indicator species of Geometridae family for different forest types sampled in Govind Wildlife Sanctuary from 2009-2012 (Abbrv: SPBM: Subtropical Pine Broadleaved Mix forest, MTD: Moist Temperate Deciduous Forest, WMC: Western Mix coniferous forest, WHUO F: Western Himalayan Upper Oak forest, SAF: Subalpine forest)

Forest Types	Species	Subfamily	Indicator Value	Sig (P)
SPBM	*Semiothisa sufflata*	Ennominae	81.6	0.001
SPBM	*Menophra subplagiata*	Ennominae	78.4	0.0008
SPBM	*Scopula pulchellata*	Sterrhinae	75.4	0.0013
MTD	*Sirinopteryx rufivinctata*	Ennominae	77.5	0.009
MTD	*Odontopera kametaria*	Ennominae	56.4	0.0048
WMC	*Pseudopanthera himaleyica*	Ennominae	56.9	0.0577
WHUOF	*Odontopera lentiginosaria*	Ennominae	81	0.0051
SAF	*Arichana tenebraria*	Ennominae	87.1	0.0004
SAF	*Photoscotosia amplicata*	Larentiinae	74.6	0.0009
SAF	*Opisthograptis tridentifera*	Ennominae	64.7	0.0033
SAF	*Photoscotosia multilinea*	Larentiinae	62.9	0.0024
SAF	*Venusia classisigna*	Larentiinae	62.9	0.0024
SAF	*Abraxas gunsana*	Ennominae	62.4	0.0032
SAF	*Triphosa rubrodotata*	Larentiinae	60.1	0.0166
SAF	*Eustroma chalcoptera*	Larentiinae	58.4	0.0069
SAF	*Opisthograptis sulphurea*	Ennominae	57.8	0.0099

Among five subfamilies of Geometridae sampled across different elevation and forest types, Ennominae was the dominant (92 species), followed by Larentiinae (37 species), Geometrinae (28 species), Sterrhinae (11 species) and Desmobathrinae (1 species). Altitudinal distribution of the four major subfamilies (Figure 3) showed that the subfamily Larentiinae was exceptionally distributed towards higher altitude while the other three were diverse in lower and middle elevation zones. Mean species distribution of the dominant subfamily Ennominae was recorded around 1400m while most of the species were recorded between 600m to 2300m and the species range extended up to 3400m. The mean species distribution of the subfamily Larentiinae was recorded around 2800m while most of the species were recorded between 2500m to 3300m and the species range extended from 1800m to 3600m. The mean species distribution of Geometrinae was around 700m while most of the species were recorded from 600m to 1300m, and the species range extended up to 2500m. For Sterrhinae, the mean species distribution was around 1400m, while most of the species were recorded from 700m to 1700m, and the species range extended up to 2900m (Figure 3).

10.1.4 Discussion

This study was an initial step towards better understanding of a long-neglected but diverse and charismatic herbivorous insect assemblage in Himalayan temperate altitudinal gradient. The diversity of this crucial group of nocturnal Lepidoptera has not been systematically inventoried in the Indian Himalaya except Walia (2005) and Smetacek (2008). Thus, the study recorded several species which were either first-time record from India, or from the Western Himalayan state of Uttarakhand. After intensive literature survey, we documented 36 species which were previously unrecorded from Uttarakhand. Among them 19 species were of subfamily Ennominae: *Anonychia violacea, Biston falcata, Psilalcis inceptaria, Medasina interruptaria, Medasina cervina, Erebomorpha fulguraria, Ourapteryx convergens, Arichanna tenebraria, Gnophos albidior, Hypomecis ratotaria, Loxaspilates hastigera, Odontopera heydena, Odontopera lentiginosaria, Plagodis inustaria, Psyra debilis, Opisthograptis sulphurea, Opisthograptis tridentifera, Sirinopteryx rufivinctata and Tanaoctenia haliaria;* 3 species of subfamily Geometrinae: *Chlorochaeta inductaria, Chlorochaeta pictipennis, Pingasa rubicunda;* and 13 species were of subfamily Larentiinae: *Photoscotosia multilinea, Photoscotosia metachryseis, Cidaria aurata, Electrophaes recta,* *Eustroma chalcoptera, Hydrelia bicolorata, Stamnodes pamphilata, Trichopterigia rufinotata, Triphosa rubrodotata, Perizoma albofasciata, Euphyia stellata, Xanthorhoe hampsoni and Heterothera dentifasciata*. One species *Rhodostrophia pelloniaria* of subfamily Sterrhinae was also the first record from Western Himalaya.

Latitudinal species richness gradients are studied in mountain ecosystems in a much smaller scale but are more ecologically informative (Sanders & Rahbek, 2012). In high altitude areas, the geographical distance between different habitat or environments is very less, resulting in steep ecological gradients and the influence of various factors on biodiversity can easily be teased apart (Axmacher et al. 2004). Brehm et al. (2003) studied elevational patterns of Geometrid moths in Andean rainforest and found a maximum diversity between 1040m and 2670m, revealing a distinctive pattern, whereas Schulze (2000) showed that high levels of diversity in geometrid moth communities existed over a broad elevational range in a tropical mountain rainforest in Mt. Kinabalu, Borneo. There was a gap in studies from Himalayan temperate altitudinal gradient leading to no robust or generalized pattern of species diversity across these mountain ecosystems. The present study covering a wide altitudinal and geographical stretch tried to achieve equal sampling effort all through the gradient. Initial analysis suggested multi-modal peaks in diversity around 1400m, 2600m, and 3200m.

Biotic interactions coupled with ecological and physiological characteristics of the species act as environmental filters (Webb et al. 2002; Graham et al. 2009) governing the species assemblages along the elevational and vegetational gradient. Not much is known about the climatic barriers influencing the moth assemblages, but the larval host plant availability must be substantial for the specialist species. But this constraint will not apply to specialists whose host plants are distributed across different elevations (Brehm et al. 2013). The host plant information compiled here for each species reflected that majority of the geometrid species are not even specialists as most belonging to the subfamily Ennominae are polyphagous. Polyphagy was more prominent for the species distributed in wider altitudinal range than restricted-range species.

The result from this study showed a similar pattern of distribution of subfamilies as in Ecuadorian Andes (Brehm & Fiedler, 2003) with Ennominae being the most abundant family at the lower altitudes and higher altitude places showing more abundance of the subfamily Larentiinae. Species found at lower elevations are intolerant to environmental stochasticity according to Rapoport's "rescue" hypothesis. Thus, species which occupy higher elevations have a larger range of tolerances and large elevational range (Brehm et al. 2007). Species that occupy high altitude areas must have the physiological characters to comply with the cooler temperatures and affiliation to the host plants that have colonised the upper areas (Brehm et al. 2013). The underlying factors are yet to be known, but it can be speculated that the Larentiinae moths are better suited to the cooler environments than the member of other subfamilies, especially Sterrhinae and Geometrinae (Brehm et al. 2013). The montane characteristics of Larentiinae was already explained by Holloway (1987), but the physiological properties that allow the moths of this subfamily to be unusually tolerant of unfavourable conditions remain unknown (Brehm & Fiedler, 2003). The primary predators of moths (bats and birds) also show a decline in species richness and abundance as we go up the elevation (Rahbeck, 1997). Larentiinae moths have a much weak body structure than the other sub-families making them weak flyers and thus might benefit in a predator–free environment (Brehm & Fiedler, 2003). However, the Geometridae moths are found to be less affected by temperature limitations than the other nocturnal moths (Beck et al. 2011). Thus, moderate host plant specificity coupled with adaptability to cooler temperatures describes the patterns in species distribution across the elevation (Brehm et al. 2013).

This study has covered an elevational range from 600m-3800m spread across different protected areas of Uttarakhand. Still there is a gap in moth samples between 1000m-1500m, which is mainly due to the absence of suitable natural sites in this range which are free from human disturbance. The sampling of entire elevational gradient would generate a more discernible pattern with relevant ecological explanations. The proportion of one taxon, when compared to other can be used for determining the species numbers (Colwell & Coddington, 1994), but it requires ample representation throughout the sampling effort. Determining the subfamily composition along environmental gradients allowed us to explore a significant pattern which complements the measures of species diversity (Brehm & Fiedler, 2003). It was found that preference of the subfamily Larentiinae for higher altitude sites holds true even in Himalayan context, and this pattern can be regarded as a universal phenomenon, irrespective of biogeographic positions. Concerning Lepidoptera, Himalaya represents a mixing ground of Palaearctic and Indo-Malayan communities which have caused a proliferation of species usually not found outside tropics. Biogeographically, the Himalayan range straddles a transition zone between the Palaearctic and Indo-Malayan realms. Species from both realms are found in the hotspot. High percentage of Himalayan endemics among sampled Geometridae species suggested that this assemblage is long adapted to Himalayan climatic gradient and human or climate-induced habitat alteration may threaten their future survival. For at least 15 species, a new altitudinal limit has been documented. In majority of the case, the previous records being more than hundred years old and the shift recorded more than 1000m, these species can be targeted for detailed life history and distribution study to confirm whether these range expansions are due to climate alteration or other stochastic factors. Climate induced shift in altitudinal range has already been recorded for moth assemblages in Finland (Parmesan, 2006) and Borneo (Chen et al. 2009).

The selection of suitable indicator species depends on several criteria. An effective indicator needs to be present in large numbers, be easily recognizable, as well as being sensitive to environmental variables (Scoble, 1995; Holloway, 1998). Moth groups that are sensitive to floristic change and which have low vagility (Ashton et al. 2011) fulfil these criteria and have been demonstrated to be good indicators across a variety of ecological investigations (Holloway, 1985; Scoble, 1995; Kitching et al. 2000; Beck et al. 2002). The analyses presented here suggested a set of 16 species of Indicators which may be useful as part of a multi-taxon predictor set for future monitoring of the impact of global warming on forest biodiversity. The existence of clear cut patterns of altitudinally delimited moth assemblages, with particular species having restricted altitudinal distributions, suggests that selected moth taxa will be useful in tracking any upward shifts in distribution and invasions of higher altitudes, a likely consequence of global warming. It also suggests that the highly distinctive upper elevation assemblage (the subalpine set of indicators) must be regarded as vulnerable and of conservation concern.

Although our data is still scattered and more intensive sampling can result in more addition to this species record of Geometridae, future research on this current database should benefit the conservation of entire moth assemblage and their habitats in Western Himalayan Biogeographic province.

Table 3: The complete species account of 169 Geometridae recorded in this study. The current valid name of species is provided after consultation of Lepindex (http://www.nhm.ac.uk/our-science/data/lepindex/). Host plant information is compiled from Host (http://www.nhm.ac.uk/our-science/data/hostplants/) and other relevant species-specific publications. Current altitudinal range from where the species is recorded is provided along with old altitudinal record of the species compiled from Smetacek (2008), Walia (2005) and original description of the species published mainly in Proceedings of Zoological Society, London in the years 1835-1897.

Subfamily	**Species**	**Author**	**Localities - PA**	**Altitude distribution (m)**	**Old altitudinal distribution (m)(Year of publication: Indian State)**	**Host plant (Global record)**
Ennominae	*Abraxas irrorata*	Moore,1867	Govind WLS	3200-3400	2000(1867:West Bengal)	No Record
Ennominae	*Abraxas peregrina*	Inoue,1995	Govind WLS	1200-1400	1600 (1995:Nepal)	No Record
Ennominae	*Abraxas picaria*	Moore,1867	Govind WLS, NDBR	2000-3000, 3000-3400	2000(1868:Uttarakhand)	No Record
Ennominae	*Abraxas sylvata*	Scopoli,1763	Govind WLS, Dehradun, NDBR	600-800, 2600-3400	450-2400(2008:Uttarakhand)	Betulaceae *(Betula sp., Corylus sp.),* Ulmaceae *(Ulmus sp.),* Rosaceae *(Prunus sp.),* Fagaceae *(Fagus sp.),* Rhamnaceae *(Frangula sp.)*
Ennominae	*Alcis variegata*	Moore,1888	Dehradun	600-800	2062(1867:West Bengal)/450-2200(2008:Uttarakhand)	Fagaceae (*Quercus* sp.), Rosaceae (*Rubus*, *Malus*), Pinaceae (*Pinus* sp.) as Genus host plant
Ennominae	*Alcis prosoica*	Wehrli, 1943	NDBR	2500-2700	No old altitude record	Fagaceae (*Quercus* sp.), Rosaceae (*Rubus*, *Malus*), Pinaceae (*Pinus* sp.) as Genus host plant
Ennominae	*Amblychia angeronaria*	Guenee,1858	Dehradun	600-800	450-1500(2008: Uttarakhand)	Lauraceae
Ennominae	*Anonychia lativitta*	Moore,1888	Govind WLS, NDBR	2600-3000	2000 (1888:West Bengal)	No Record
Ennominae	*Anonychia*	Moore, 1888	Gangotri NP,	1800-3200	2000 (1881:West Bengal)	No Record

	violacea		Govind WLS, NDBR			
Ennominae	*Anonychia exilis*	Yazaki, 1994	NDBR	2200-2400	No old altitude record	No Record
Ennominae	*Arichanna flavinigra*	Hampson,1907	NDBR	2200-2600, 3000-3200	No old altitude record	Ericaceae *(Rhododendron sp.)*
Ennominae	*Arichanna picaria*	Wileman,1910	NDBR	3000-3200	No old altitude record	Ericaceae *(Rhododendron sp.)*
Ennominae	*Arichanna tenebraria*	Moore,1867	Govind WLS, NDBR	2400-2600, 3000-3400	2000(1888:West Bengal)	Ericaceae *(Rhododendron sp.)*
Ennominae	*Biston (Buzura) suppressaria*	Guenee,1857	Askot WLS , Govind WLS, Dehradun	600-800,2200-2400	450-1500 (2008:Uttarakhand)	Apocynaceae *(Carissa carandas),* Lauraceae *(Cassia auriculata, Cassia fistula, Litsea monopetala),* Lythraceae *(Lagerstroemia indica),* Fabaceae *(Acacia catechu),* Euphorbiaceae *(Aleurites montana),* Fabaceae *(Bauhinia variegata),*Bombacaceae*(Bombax ceiba),*Theaceae*(Camellia sinensis),*Sapindaceae *(Dodonaea viscosa),* Myrtaceae *(Eugenia cumini)*
Ennominae	*Biston falcata*	Warren,1893	Govind WLS	2800-3200	No old altitude record	Polyphagous
Ennominae	*Buzura bengaliaria*	Guenée, 1858	Govind WLS	2000-2200	1500 (2008:Uttarakhand)	Theaceae *(Camellia sinensis)*
Ennominae	*Corymica arnearia*	Walker,1860	Dehradun	600-800	450-1500(2008:Uttarakhand)	Lauraceae (*Cinnamomum camphora* Oriental region)
Ennominae	*Corymica deducta*	Walker,1866	Dehradun	600-800	450-1500(2008:Uttarakhand)	Lauraceae *(Alseodaphne semecarpifolia)*
Ennominae	*Corymica specularia (oblongimacula)*	Warren,1896	Dehradun	600-800	450-1500(2008:Uttarakhand)	Lauraceae *(Lindera praecox* recorded from Japan)
Ennominae	*Dalima*	Walker,1860	Dehradun	600-800	450-1500(2008:Uttarakhand)	No Record

	patularia					
Ennominae	*Dasyboarmia subpilosa*	Warren,1894	Dehradun	600-800	450-1500(2008:Uttarakhand)	Apocynaceae
Ennominae	*Ectropis crepuscularia*	Duponchel,1829	Dehradun	600-800	No old altitude record	Pinaceae (*Tsuga sp.,Abies sp.,Pseudotsuga sp.,Larix sp., Picea sp.),*Cupressaceae (*Thuja sp.*), Rosaceae (*Rubus sp., Sorbus sp.*), Betulaceae (*Alnus sp.,Betula sp.*), Salicaceae (*Salix sp.*)
Ennominae	*Elphos pardicelata*	Walker,1862	Govind WLS	1600-2400	2400 (2008:Uttarakhand)	Lauraceae
Ennominae	*Erebomorpha fulguraria*	Walker,1860	Govind WLS	2400-2800	No old altitude record	Theaceae *(Camellia sinensis)*
Ennominae	*Fascellina chromataria*	Walker,1860	Dehradun	600-800	450-1500 (2008:Uttarakhand)	Lauraceae *(Alseodaphne semecarpifolia,Cinnamomum zeylanicum, Litsea monopetala, Persea gamblei, Phoebe lanceolata)*
Ennominae	*Fascellina plagiata*	Walker,1866	Askot WLS , Govind WLS, Dehradun	600-800, 1200-1400	450-2400 (2008:Uttarakhand)	Lauraceae *(Alseodaphne sp., Beilschmiedia sp., Cinnamommum sp.)*
Ennominae	*Gnophos albidior*	Hampson,1895	Govind WLS, NDBR	1600-1900, 2000-2200	1700 (1895:Nagaland)	No Record
Ennominae	*Heterocallia temeraria*	Swinhoe,1891	Govind WLS	1200-1400,1800-2000	1500(2008:Uttarakhand)	No Record
Ennominae	*Heterolocha patalata*	Felder,1874	NDBR	2000-2200	1500 (2008:Uttarakhand)	No Record
Ennominae	*Heterolocha phoenicotaeniata*	Kollar,1844	Govind WLS	1800-3200	2000 (1844:Uttarakhand)	Plumbaginaceae (*Plumbago auriculata*)
Ennominae	*Heterostegane sp.*		Askot WLS	600-800	No old altitude record	Leguminosae
Ennominae	*Heterostegane*	Walker,1863	Govind WLS,	600-800, 1400-	450-1500(2008:Uttarakhand)	Fabaceae *(Acacia sp., Mimosa sp.)*

	subtessellata		Dehradun	1600		
Ennominae	*Hirasa muscosaria*	Walker,1866	Govind WLS	1200-2800	No old altitude record	Fabaceae *(Quercus sp.)*
Ennominae	*Hyperythra lutea*	Stoll,1781	Govind WLS, Dehradun	2400-2600	600 (2008:Uttarakhand)	Rhamnaceae (*Gouania leptostachya*), (*Ziziphus oenoplia*)
Ennominae	*Hypomecis cineracea*	Moore,1888	Dehradun	600-800	450-600 (2008:Uttarakhand)	No Record
Ennominae	*Hypomecis ratotaria*	Swinhoe,1894	Govind WLS	1200-2400	No old altitude record	Betulaceae, Rosaceae, Fagaceae
Ennominae	*Hyposidra violescens*	Hampson,1895	Dehradun	600-800	450-1500 (2008:Uttarakhand)	Theaceae *(Camellia sinensis)*
Ennominae	*Krananda sp.*		Govind WLS, Askot WLS	600-800,1200-1400	No old altitude record	No Record
Ennominae	*Leptomiza calcearia*	Walker,1860	Dehradun	600-800	450-2400 (2008:Uttarakhand)	Rosaceae *(Rubus sp.)*
Ennominae	*Lomographa distans*	Warren,1894	NDBR	2000-2200	1200-2400 (2005: Himachal Pradesh)	Rosaceae (*Malus sp.*)
Ennominae	*Lomographa sp.1*		Govind WLS	1200-1400,2200-2400,2800-3000,3400-3600	No old altitude record	Leguminosae, Rosaceae
Ennominae	*Lomographa sp.2*		NDBR	2400-2600	No old altitude record	Leguminosae, Rosaceae
Ennominae	*Loxaspilates hastigera*	Butler,1889	Govind WLS, Dehradun, NDBR	600-800,1200-1400,3400-3600	3142 (1889:Himachal Pradesh)	No Record
Ennominae	*Loxaspilates obliquaria*	Moore,1897	NDBR	3400-3600	No old altitude record	No Record
Ennominae	*Luxiaria phyllosaria*	Walker,1860	Dehradun	600-800	450-600 (2008:Uttarakhand)	Melastomataceae
Ennominae	*Luxiaria sp.*		Govind WLS	1200-1400	No old altitude record	Melastomataceae
Ennominae	*Medasina*	Walker,1866	Govind WLS,	1400-3200	1500(2008:Uttarakhand)	Pinaceae *(Pinus*

	albidaria		Gangotri NP, NDBR			*wallichiana)*,Rosaceae *(Prunus sp., Rosa sp.)*
Ennominae	*Medasina cervina*	Warren, 1893	Govind WLS, NDBR	2000-3200	No old altitude record	No Record
Ennominae	*Medasina interruptaria*	Moore,1867	Govind WLS	2400-3000	No old altitude record	No Record
Ennominae	*Menophra bicornuta*	Inoue,1990	Govind WLS	1400-1600	2000 (1990)	Polyphagous
Ennominae	*Menophra subplagiata*	Walker,1860	Govind WLS, NDBR	1200-1600, 2200-2400	1500(2005:Himachal Pradesh)	Fagaceae (*Castanea crenata*, *Quercus serrata)*
Ennominae	*Odontopera heydena*	Swinhoe,1894	Govind WLS	2000-2200, 3000-3200	1500 (1894:Meghlaya)	Theaceae *(Camellia sinensis)*
Ennominae	*Odontopera kametaria*	Felder,1873	Govind WLS, NDBR	1800-2600	No old altitude record	Fabaceae *(Bauhinia variegata)*, Oleaceae *(Jasminium sp.)*
Ennominae	*Odontopera lentiginosaria*	Moore,1867	Govind WLS	2200-3200	670 (2005:Himachal Pradesh)	No Record
Ennominae	*Odontopera obliquaria*	Moore,1867	Govind WLS	3200-3400	No old altitude record	Theaceae *(Camellia sinensis)*
Ennominae	*Ophthalmitis herbidaria*	Guenee,1858	Govind WLS	1200-1400	450-1500 (2008:Uttarakhand)	Flacourtiaceae *(Caesaria elliptica)*
Ennominae	*Opthalmitis sp.*		Askot WLS	600-800	No old altitude record	No Record
Ennominae	*Opisthograptis sulphurea*	Butler, 1880	Govind WLS	2400-3600	2000 (1880:West Bengal)	Rosaceae, Betulaceae
Ennominae	*Opisthograptis tridentifera*	Moore, 1888	Govind WLS	1800-2000, 2800-3400	2000 (1888:Uttarakhand)	Rosaceae, Betulaceae
Ennominae	*Opisthograptis luteolata*	Linnaeus, 1758	NDBR	2000-2800	No old altitude record	Betulaceae (*Betula* sp.), Rosaceae (*Malus*, *Sorbus*, *Prunus*), Salicaceae (*Salix*)
Ennominae	*Ourapteryx clara*	Butler,1880	Dehradun	600-800	450-1500 (2008:Uttarakhand)	No Record
Ennominae	*Ourapteryx convergens*	Warren, 1897	Govind WLS	2400-2600	2200(1897:Himachal Pradesh)	No Record

Ennominae	*Ourapteryx ebuleata*	Guenee,1858	Govind WLS, Gangotri NP	1200-1400, 2400-2600, 3200-3400	1500-2400(2008:Uttarakhand)	Symplocaceae *(Symplocos sp.)*
Ennominae	*Ourapteryx sciticaudaria*	Walker,1862	Govind WLS	2400-2600	1500 (2008:Uttarakhand)	No Record
Ennominae	*Peratophyga hyalinata*	Kollar,1844	Govind WLS, Dehradun	600-800,1200-1400,1800-2000	2000,1500 (2005:Himachal Pradesh)/450-2400(2008:Uttarakhand)	Hypericaceae *(Hypericum sp.)*
Ennominae	*Percnia belluaria*	Guenee,1858	Govind WLS	1200-1400,2000-2200,3000-3200	No old altitude record	Lauraceae
Ennominae	*Petelia distracta*	Walker,1860	Dehradun	600-800	450-1500 (2008:Uttarakhand)	Rhamnaceae (*Gouania sp., Ziziphus sp., Hovenia sp.)*
Ennominae	*Phthonandria atrilineata*	Butler,1881	Govind WLS	1800-2000	850 (1990:West Bengal)/1500 (2008:Uttarakhand)	Moraceae *(Morus sp.)*
Ennominae	*Plagodis inusitaria*	Moore, 1867	Govind WLS	2800-3000	No old altitude record	Sapindaceae *(Acer sp.),* Betulaceae *(Betula sp.),* Salicaceae *(Salix sp.),*Pinaceae *(Picea sp.)*
Ennominae	*Plagodis reticulata*	Warren, 1893	Govind WLS	2400-3000	1500 (2008:Uttarakhand)	Sapindaceae *(Acer sp.),* Betulaceae *(Betula sp.),* Salicaceae *(Salix sp.),*Pinaceae *(Picea sp.)*
Ennominae	*Pseudomiza cruentaria*	Moore,1867	Govind WLS,NDBR	1200-1400,2000-2600	1500-2400(2008:Uttarakhand)	No Record
Ennominae	*Pseudopanthera himaleyica*	Kollar,1848	Govind WLS	1600-2600	2200 (2005:Uttarakhand),2000 (1844:Uttarakhand)	Labiatae
Ennominae	*Psilalcis inceptaria*	Walker,1866	Govind WLS	1400-3000	No old altitude record	Polyphagous
Ennominae	*Psyra angulifera*	Walker,1866	Govind WLS, NDBR	2000-3200	2400(2008:Uttarakhand)	Polyphagous
Ennominae	*Psyra debilis*	Warren,1888	Govind WLS ,NDBR	1600-2800, 3200-3400	2100(1889:Himachal Pradesh)	Polyphagous
Ennominae	*Psyra falcipennis*	Yazaki, 1994	Govind WLS	2200-2600	No old altitude record	Polyphagous, Rosaceae
Ennominae	*Psyra similaria*	Moore,1888	Govind WLS	2200-3000	2000(1868:Himachal Pradesh)	Polyphagous

Ennominae	*Psyra crypta*	Yazaki,1994	NDBR	2400-2800	No old altitude record	No Record
Ennominae	*Semiothisa eleonora*	Cramer,1780	Dehradun	600-800	450-1500 (2008:Uttarakhand)	No Record
Ennominae	*Semiothisa nora*	Walker, 1861	Askot WLS, Govind WLS	2200-2400	2000 (1861:West Bengal)	Cupressaceae *(Juniperus sp.)*
Ennominae	*Semiothisa sufflata*	Guenee,1858	Govind WLS	1200-1600	No old altitude record	Betulaceae *(Alnus sp.)*,Salicaceae *(Salix sp.)*
Ennominae	*Sirinopteryx rufivinctata*	Walker,1862	Govind WLS	1600-2200	2000(1863:West Bengal)	No Record
Ennominae	*Stenorumia ablunata*	Guenee,1858	NDBR	2000-2200	1500-2400 (2008:Uttarakhand)	Solanaceae *(Solanum tuberosum)*
Ennominae	*Stenorumia sp.*		Govind WLS	3000-3200	No old altitude record	Solanaceae
Ennominae	*Tanaoctenia haliaria*	Walker,1861	Govind WLS, NDBR	2200-2800	No old altitude record	Fagaceae
Ennominae	*Thinopteryx crocoptera*	Kollar, 1844	Govind WLS, Dehradun	1200-1400	2000 (1844:Uttarakhand)/450-1500 (2008:Uttarakhand)	Vitaceae (*Parthenocissus quinquefolia*), (*Vitis sp.*)
Ennominae	*Thinopteryx nebulosa*	Butler,1883	Dehradun	600-800	450-1500 (2008:Uttarakhand)	Vitaceae *(Vitis sp., Amelopsis sp.)*
Ennominae	*Xandrames latiferaria*	Walker,1860	Govind WLS	1400-1800	No old altitude record	Lauraceae *(Lindera praecox* Recorded from Japan)
Ennominae	*Zamarada symmetra*	Fletcher,1974	Dehradun	600-800	No old altitude record	No Record
Ennominae	*Zeheba aureatoides*	Holloway,1983	Askot WLS	600-800	2000 (1887:West Bengal)	No Record
Ennominae	*Zeheba sp.*		Govind WLS	1200-1400	-	No Record
Ennominae	*Ctenognophos sp.*		NDBR	2000-3600		No Record
Larentiinae	*Chartographa sp.*		Govind WLS	2200-2400	-	No Record
Larentiinae	*Chartographa trigoniplaga*	Hampson,1895	NDBR	2600-2800	No old altitude record	No Record

Larentiinae	*Cidaria aurata*	Moore, 1867	Govind WLS	1400-1600,2200-2400,3200-3400	No old altitude record	Rosaceae
Larentiinae	*Cidaria catenaria*	Moore,1971	NDBR	2400-2800	No old altitude record	No Record
Larentiinae	*Colostygia albigirata*	Kollar,1844	Govind WLS, Gangotri NP	1400-3600	2000(1844:Uttarakhand)	Rubiaceae *(Galium sp.* recorded from Europe)
Larentiinae	*Docirava aequilineata*	Walker, 1863	Govind WLS, Gangotri NP	2400-2600,3200-3400	No old altitude record	Rosaceae
Larentiinae	*Docirava pudicata*	Guenée, 1858	Govind WLS, NDBR	1800-2000,2400-2600,3000-3200	No old altitude record	Rosaceae, Labiatae
Larentiinae	*Dysstroma sp.*		Govind WLS, Gangotri NP	1400-1600,2000-2600,3000-3400	-	Betulaceae *(Alnus sp.),*Salicaceae *(Salix sp.),*Rosaceae *(Sorbus sp.,Rubus sp.)*
Larentiinae	*Ecliptopera postpallida*	Prout,1940	Govind WLS, Gangotri NP	1400-1600, 2200-2400,2800-3600	No old altitude record	Balsaminaceae *(Impatiens sp.)*
Larentiinae	*Electrophaes aliena*	Butler,1880	Askot WLS	600-800	1300(1940:Himachal Pradesh)/1500(2008:Uttarakhand)	No Record
Larentiinae	*Electrophaes recta*	Yazaki,1994	Govind WLS, NDBR	1600-2800,3200-3400	No old altitude record	Betulaceae, Rosaceae, Fagaceae
Larentiinae	*Electrophaes marginata*	Yazaki, 1994	NDBR	3000-3200	No old altitude record	Betulaceae, Rosaceae, Fagaceae
Larentiinae	*Euphyia coangulata*	Prout,1914	Govind WLS, NDBR	1600-3400	No old altitude record	Betulaceae *(Betula sp.),* Salicaceae *(Salix sp.),*Ulmaceae *(Ulmus sp.),* Caryophyllaceae *(Stellaria sp.),* Rosaceae *(Rubus sp.)*
Larentiinae	*Euphyia stellata*	Warren,1893	Govind WLS	2600-3600	No old altitude record	Betulaceae *(Betula sp.),* Salicaceae *(Salix sp.),*Ulmaceae *(Ulmus sp.)*
Larentiinae	*Euphyia subangulata*	Kollar,1844	NDBR	2400-2600	2000 (1844:Uttarakhand)	No Record
Larentiinae	*Eupithecia rajata*	Guenee,1858	Gangotri NP, NDBR	1400-1600,2400-2800	1500 (2008:Uttarakhand)	Pinaceae *(Abies sp.),* Betulaceae*(Alnus sp.)*
Larentiinae	*Eustroma chalcoptera*	Hampson, 1895	Govind WLS	2000-2200,3200-3600	3048 (1895:Sikkim)	Balsaminaceae *(Impatiens sp.)*

Larentiinae	*Heterothera dentifasciata*	Hampson, 1895	Govind WLS, NDBR	1400-2000	2100(1895:Himachal Pradesh)	Pinaceae *(Cedrus deodara)*
Larentiinae	*Hydrelia bicolorata*	Moore,1867	Govind WLS, NDBR	1800-2400	No old altitude record	Betulaceae *(Betula sp.),* Ulmaceae *(Ulmus sp.)*
Larentiinae	*Laciniodes plurilinearia*	Moore, 1867	Govind WLS	2000-2400, 3000-3200	2000(1868:West Bengal)/2400(2008:Uttarakhand)	Rubiaceae, Rosaceae, Oleaceae
Larentiinae	*Larentia nigralbata*	Warren,1888	NDBR	2400-2800	No old altitude record	No Record
Larentiinae	*Perizoma albofasciata*	Moore, 1888	Govind WLS, Gangotri NP, NDBR	1400-2600, 3000-3400	2000(1888:Uttarakhand)	No Record
Larentiinae	*Perizoma seriata*	Moore, 1888	Govind WLS, Gangotri NP, NDBR	1400-1600, 2200-3600,	2000(1888:Uttarakhand)	No Record
Larentiinae	*Photoscotosia amplicata*	Walker,1862	Govind WLS	2200-3600	No old altitude record	Rosaceae, Fagaceae
Larentiinae	*Photoscotosia metachryseis*	Hampson, 1896	Govind WLS, NDBR	2200-2400,2800-3200	No old altitude record	Rosaceae
Larentiinae	*Photoscotosia miniosata*	Walker, 1862	Govind WLS, Gangotri NP, NDBR	1600-3600	1500(2008:Uttarakhand)	Rosaceae *(Rubus sp., Rubus ellipticus)*
Larentiinae	*Photoscotosia multilinea*	Warren, 1893	Govind WLS	3000-3600	No old altitude record	Rosaceae
Larentiinae	*Rheumaptera melanoplagia*	Hampson,1902	NDBR	3000-3200	No old altitude record	Betulaceae *(Betula sp., Alnus sp.),* Salicaceae *(Salix sp.),*Berberidaceae *(Berberis sp.)*
Larentiinae	*Rheumaptera sp.*		Govind WLS	3400-3600	No old altitude record	Betulaceae *(Betula sp., Alnus sp.),* Salicaceae *(Salix sp.),*Berberidaceae *(Berberis sp.)*
Larentiinae	*Stamnodes pamphilata*	Felder, 1875	Govind WLS	2400-3400	No old altitude record	Rosaceae
Larentiinae	*Trichopterigia rufinotata*	Butler, 1889	Govind WLS	1200-1400	2740 (1889:Himachal Pradesh)	Fagaceae *(Quercus sp.)*

Larentiinae	*Triphosa rubrodotata*	Walker, 1862	Govind WLS, Gangotri NP	1400-1600,2400-3400	No old altitude record	Rosaceae *(Pyrus sp., Prunus sp.),Rhamnaceae (Rhamnus sp.)*
Larentiinae	*Venusia crassisigna*	Inoue,1987	Govind WLS, NDBR	2400-2600, 3000-3600	No old altitude record	Betulaceae *(Alnus sp., Betula sp.),* Salicaceae *(Salix sp.)*,Fagaceae *(Quercus sp.),* Rosaceae *(Malus sp., Sorbus sp.)*
Larentiinae	*Venusia roseicosta*	Yazaki,1994	Govind WLS	3000-3600	No old altitude record	Betulaceae *(Alnus sp., Betula sp.),* Salicaceae *(Salix sp.)*,Fagaceae *(Quercus sp.),* Rosaceae *(Malus sp., Sorbus sp.)*
Larentiinae	*Xanthorhoe hampsoni*	Prout, 1925	Govind WLS	3000-3200	No old altitude record	Polyphagous
Larentiinae	*Lobogonodes sp.*		NDBR	2300-2500	No old altitude record	No Record
Larentiinae	*Aplocera uniformata*	Urbahn,1971	NDBR	2200-2400	No old altitude record	Guttiferae (*Hypericum*) as Genus host plant
Sterrhinae	*Chrysocraspeda olearia*	Guenee,1857	Govind WLS, Dehradun	600-800, 2200-2400	No old altitude record	Myrtaceae *(Syzygium cumini)*
Sterrhinae	*Organopoda carnearia*	Walker,1861	Askot WLS	600-800	1500(2008:Uttarakhand)	No Record
Sterrhinae	*Problepsis albidior*	Warren,1899	Askot WLS, Govind WLS	600-800, 1600-1800	1300 (1899:Himachal Pradesh)	Oleaceae
Sterrhinae	*Problepsis vulgaris*	Butler,1889	Askot WLS, Govind WLS, Dehradun	600-800,1400-1600	733(1889:Himachal Pradesh)/450-1500(2008:Uttarakhand)	No Record
Sterrhinae	*Rhodometra sacraria*	Linnaeus,1767	Askot WLS, Govind WLS	600-800, 2800-3000	1500(2008)	Polygonaceae *(Polygonum sp., Rumex sp., Oxygonum sp.),* Rosaceae *(Malus sp.),* Anacardiaceae *(Rhus sp.)*
Sterrhinae	*Rhodostrophia pelloniaria*	Guenee,1858	Govind WLS, Gangotri NP	1400-1600, 2400-2800	1300(1935:Himachal Pradesh)	No Record
Sterrhinae	*Rhodostrophia olivacea*	Warren,1895	NDBR	2300-2500	2200 (1895: West Bengal)	No Record

Sterrhinae	*Scopula pulchellata*	Fabricius,1794	Askot WLS, Govind WLS	600-800, 1200-1600	No old altitude record	Plumbaginaceae *(Plumbago sp.* East Africa*)*
Sterrhinae	*Timandra griseata*	Petersen 1902	Govind WLS	1400-1600	No old altitude record	Polygonaceae *(Polygonum chinense)*
Sterrhinae	*Timandra ruptilinea*	Warren,1897	Govind WLS	1400-1600	No old altitude record	No Record
Sterrhinae	*Traminda mundissima*	Walker,1861	Dehradun	600-800	450-1500(2008:Uttarakhand)	No Record
Geometrinae	*Agathia carissima*	Butler,1878	Dehradun	600-800	No old altitude record	Asclepiadaceae *(Cynanchum wilfordii, Metaplexis japonica)* (Recorded from Japan)
Geometrinae	*Agathia hemithearia*	Guenee,1857	Govind WLS	1200-1600	1500(2008:Uttarakhand)	Apocynaceae *(Carissa sp., Holarrhena sp.,Nerium sp., Tabernaemontana sp.)*
Geometrinae	*Agathia hilarata*	Guenee,1858	Askot WLS	600-800	1500(2008:Uttarakhand)	Apocynaceae (*Trachelospermum carissa, T.jasminoides)*
Geometrinae	*Agathia lycaenaria*	Kollar,1844	Dehradun	600-800	2000(1848:Uttarakhand)/450-1500(2008:Uttarakhand)	Apocynaceae *(Nerium sp., Nerium oleander, Tabernaemontana heyneana, T.divaricata)*
Geometrinae	*Anisozyga gavissima*	Walker,1861	Dehradun, Govind WLS	600-800, 1400-1600	1500(2008:Uttarakhand)	No Record
Geometrinae	*Aporandria specularia*	Guenee,1857	Askot WLS , Govind WLS, Dehradun	600-800, 1200-1400	450-1500(2008:Uttarakhand)	No Record
Geometrinae	*Chlorissa aquamarina*	Hampson,1895	Dehradun	600-800	2100(1895:Uttarakhand)/450-2400(2008:Uttarakhand)	No Record
Geometrinae	*Chlorissa distinctaria*	Walker, 1866	Govind WLS, Gangotri NP	1200-1600	1500(2008:Uttarakhand)	No Record
Geometrinae	*Chlorissa gelida*	Butler,1889	Askot WLS, Govind WLS	600-800, 1200-1400,1800-2000	2100(1889:Uttarakhand)/1500(2008:Uttarakhand)	Apocynaceae
Geometrinae	*Chlorochaeta quadrinotata*	Butler,1889	Gangotri NP	2600-2800	2100(1889:Uttarakhand)	Apocynaceae *(Carissa sp.),* Fabaceae *(Acacia sp.)*

Geometrinae	*Chlorochaeta inductaria*	Guenee,1857	Govind WLS	1400-1600	No old altitude record	Fagaceae *(Quercus sp.)*,Rosaceae *(Malus sp.)*, Betulaceae *(Betula sp.)*,Juglandaceae *(Juglans sp.)*, Anacardiaceae *(Rhus sp.)*
Geometrinae	*Chloromachia divapala*	Walker,1861	Askot WLS, Dehradun	600-800	450-1500(2008:Uttarakhand)	No Record
Geometrinae	*Chlororithra fea*	Butler,1890	Askot WLS	600-800	2100(1889:Himachal Pradesh)	No Record
Geometrinae	*Cholorochaeta pictipennis*	Butler,1880	Govind WLS	2400-2600	2000 (1888:West Bengal)	No Record
Geometrinae	*Comostola subtiliaria*	Bremer, 1864	Govind WLS	1200-2000	1500(2008:Uttarakhand)	Fagaceae *(Quercus sp.)*, Myrtaceae *(Syzigium sp.)*
Geometrinae	*Dysphania militaris*	Linnaeus,1758	Dehradun	600-800	450-1500(2008:Uttarakhand)	Theaceae *(Eurya sp.)*, Rosaceae *(Malus sp.)*, Adoxaceae *(Viburnum sp.)*
Geometrinae	*Hemithea tritonaria*	Walker, 1863	Govind WLS	1400-1600	1500(2008:Uttarakhand)	Rhizophoraceae (*Carallia sp.* recorded from Oriental region), *Carallia brachiata, (Kandelia candel* recorded from Hongkong)
Geometrinae	*Herochroma cristata*	Warren,1894	Govind WLS, Dehradun	600-800, 2000-2400	450-2400(2008:Uttarakhand)	Fabaceae *(Acacia sp.)*
Geometrinae	*Herochroma orientalis*	Holloway,1982	Dehradun	600-800	No old altitude record	Araliaceae (*Araliaceae Schefflera* recorded from Hongkong)
Geometrinae	*Mixochlora vittata*	Moore, 1867	Govind WLS, NDBR	2400-2600,3200-3400	1500(2008:Uttarakhand)	Araliaceae (*Araliaceae Schefflera* recorded from Hongkong)
Geometrinae	*Ornithospila avicularia*	Guenée, 1857	Govind WLS, Dehradun	600-800,2200-2400	450-2400(2008:Uttarakhand)	Fabaceae (*Quercus sp.* specially *Quercus incana*)
Geometrinae	*Pingasa alba*	Swinhoe, 1891	Govind WLS	1200-1400	1500(2008:Uttarakhand)	No Record
Geometrinae	*Pingasa lariaria*	Walker,1860	Dehradun	600-800	No old altitude record	Fabaceae *(Dalbergia sp.)*,Lauraceae *(Litsea sp.)*,Malvaceae *(Sterculia sp.)*
Geometrinae	*Pingasa rubicunda*	Warren, 1894	Govind WLS	1200-1400	No old altitude record	No Record

Geometrinae	*Pingasa ruginaria*	Guenée, 1857	Govind WLS	1200-1800	No old altitude record	Dipterocarpaceae *(Shorea* recorded from Malaysia)
Geometrinae	*Tanaorhinus reciprocata*	Walker, 1861	Govind WLS	1200-1400	450-2400(2008:Uttarakhand)	Fabaceae *(Dalbergia monetaria, Xylia xylocarpa),* Lauraceae *(Litsea elongata),* Malvaceae *(Sterculia villosa),* Rubiaceae *(Wendlandia notoniana)*
Geometrinae	*Thalassodes veraria*	Guenee,1857	Askot WLS, Govind WLS, Dehradun, NDBR	600-800,2200-3200	450-2400(2008:Uttarakhand)	Fagaceae *(Quercus* recorded from Japan), *Quercus cerris, Q.serrata)*
Geometrinae	*Hypochrosis abstractaria*					
Desmobathrinae	*Eumelea rosalia*	Stoll,1781	Govind WLS , Dehradun	600-800, 1400-1600	450-1500(2008:Uttarakhand)	Fabaceae *(Xylia sp.)*

10.1.5 Plates of Geometridae family species (Plate I)

Abraxas irrorata

Abraxas peregrina

Abraxas picaria

Abraxas sylvata

Alcis variegata

Alcis prosoica

Amblychia angeronaria

Anonychia lativitta

Anonychia violacea

Anonychia exilis

Arichanna flavinigra

Arichanna picaria

Plates II

Arichanna tenebraria

Biston suppressaria

Biston falcata

Buzura bengaliaria

Corymica arnearia

Corymica deducta

Corymica specularia

Dalima patularia

Dasyboarmia subpilosa

Ectropis crepuscularia

Elphos pardicelata

Erebomorpha fulguraria

Plates III

Fascellina chromataria

Fascellina plagiata

Gnophos albidior

Heterocallia temeraria

Heterolocha patalata

Heterolocha phoenicotaeniata

.Heterostegane subtessellata

Hirasa muscosaria

Hyperythra lutea

Hypomecis cineracea

Hypomecis ratotaria

Hyposidra violescens

Plates IV

.*Krananda sp*

Leptomiza calcearia

Lomographa distans

Lomographa sp.1

Lomographa sp.2

Loxaspilates hastigera

Loxaspilates obliquaria

Luxiaria phyllosaria

.*Luxiaria sp*

Medasina albidaria

Medasina cervina

Medasina interruptaria

Plates V

Menophra bicornuta

Menophra subplagiata

Odontopera heydena

Odontopera kametaria

Odontopera lentiginosaria

Odontopera obliquaria

Ophthalmitis herbidaria

.Opthalmitis sp

Opisthograptis sulphurea

Opisthograptis tridentifera

Opisthograptis luteolata

Ourapteryx clara

Plates VI

Ourapteryx convergens

Ourapteryx ebuleata

Ourapteryx sciticaudaria

Peratophyga hyalinata

Percnia belluaria

Petelia distracta

Phthonandria atrilineata

Plagodis inusitaria

Plagodis reticulata

Pseudomiza cruentaria

Pseudopanthera himaleyica

Psilalcis inceptaria

Plates VII

Psyra angulifera

Psyra debilis

Psyra falcipennis

Psyra similaria

Psyra crypta

Semiothisa eleonora

Semiothisa nora

Semiothisa sufflata

Sirinopteryx rufivinctata

Stenorumia ablunata

.Stenorumia sp

Tanaoctenia haliaria

Plates VIII

Thinopteryx crocoptera

Thinopteryx nebulosa

Xandrames latiferaria

Zamarada symmetra

Zeheba aureatoides

.Zeheba sp

.Ctenognophos sp

.Chartographa sp

Chartographa trigoniplaga

Cidaria aurata

Cidaria catenaria

Colostygia albigirata

Plates IX

Docirava aequilineata

Docirava pudicata

.Dysstroma sp

Ecliptopera postpallida

Electrophaes aliena

Electrophaes recta

Electrophaes marginata

Euphyia coangulata

Euphyia stellata

Euphyia subangulata

Eupithecia rajata

Eustroma chalcoptera

Plates X

Heterothera dentifasciata

Hydrelia bicolorata

Laciniodes plurilinearia

Larentia nigralbata

Perizoma albofasciata

Perizoma seriata

Photoscotosia amplicata

Photoscotosia metachryseis

Photoscotosia miniosata

Photoscotosia multilinea

Rheumaptera melanoplagia

.Rheumaptera sp

Plates XI

Stamnodes pamphilata

Trichopterigia rufinotata

Triphosa rubrodotata

Venusia crassisigna

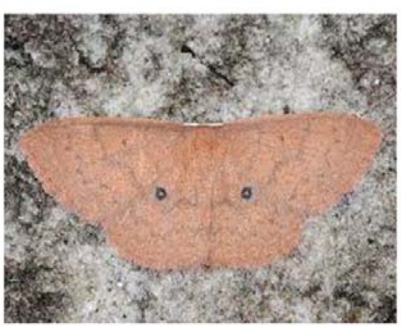
Venusia roseicosta

Xanthorhoe hampsoni

.Lobogonodes sp

Aplocera uniformata

Chrysocraspeda olearia



Organopoda carnearia

Problepsis albidior

Problepsis vulgaris

Plates XII

Rhodometra sacraria

Rhodostrophia pelloniaria

Rhodostrophia olivacea

Scopula pulchellata

Timandra griseata

Docirava fulgurata

Traminda mundissima

Agathia carissima

Agathia hemithearia

Hemithea sp.

Agathia lycaenaria

Anisozyga gavissima

Plates XIII

Aporandria specularia

Chlorissa aquamarina

Chlorissa distinctaria

Chlorissa gelida

Chlorochaeta quadrinotata

Chlorochaeta inductaria

Chloromachia divapala

Chlororithra fea

Cholorochaeta pictipennis

Comostola subtiliaria

Dysphania militaris

Hemithea tritonaria

Plates XIV

Herochroma cristata

Herochroma orientalis

Mixochlora vittata

Ornithospila avicularia

Pingasa alba

Pingasa lariaria

Pingasa rubicunda

Pingasa ruginaria

Tanaorhinus reciprocata

Thalassodes veraria

Hypochrosis abstractaria

Eumelea rosalia

10.2 PATTERNS OF DISTRIBUTION OF MOTH ASSEMBLAGES ALONG ALTITUDINAL AND VEGETATIONAL GRADIENT

10.2.1 Introduction:

Knowledge of spatial diversity patterns is a key prerequisite for the development of effective strategies in biodiversity conservation (Cabeza et al. 2004, Gaston 2000, Lamoreux et al. 2006). While such knowledge is already widely available for many vertebrate and plant taxa, it is less so in case of invertebrates, especially insects. On current knowledge, insects are by far the most species-rich group, with their estimated share in global macro-biodiversity exceeding 50%, but huge knowledge gaps currently prevail in relation to their diversity and distribution. Not least due to their enormous species richness, insects perform a multitude of fundamental roles in ecosystems. It seems logical to conclude that the great knowledge gaps relating to insect diversity, their distribution patterns and the factors causing these patterns need to be addressed to enable the effective conservation of the global species pool and ecosystem functioning (Leather & Quicke, 2010). Lepidoptera are among the most speciose and taxonomically tractable groups of insects and have important functional roles in forests as selective herbivores, pollinators, detritivores, and food resource for organisms at higher trophic levels. Furthermore, the Lepidoptera show promise as indicators of forest health (Kitching et al. 2000) and as surrogates for the diversity of other insect groups such as the Hymenoptera (Kerr et al. 2000). Thus, the Lepidoptera comprise a critical fauna for answering questions concerning spatial scale and biodiversity in forests. Another interesting aspect to study the spatial pattern of highly diverse insect assemblage is along altitudinal gradient in a mountain habitat. Mountains offer a unique scenario to unravel the influence of environment on the spatial variation in the taxonomic composition of insect species assemblages. They represent a kind of ‘natural experiment’ whereby to examine the extent to which substantial changes in environment may be associated with evolutionary adaptation of organisms and biodiversity maintenance over relatively short spatial distances (Lomolino 2001, Ko¨rner, 2007). Main altitudinal climatic trends usually co-vary with other factors at local and regional scale, such as variation in vegetation, regional climatic trends (e.g. seasonality and precipitation), land surface orientation and soil characteristics (Ko¨rner 2007). Nonetheless, although it is well documented that insect species composition varies along altitudinal gradients (e.g. dung beetles in South Africa: Davis et al. 1999; geometrid moths in Ecuador: Brehm & Fiedler 2003; dung beetles in the Alps: Errouissi et al. 2004; ground spiders in Greece: Chatzaki et al. 2005; beetles in Spain: Gonza´lez- Megıas et al.

2008), the extent to which local and regional factors influence the spatial variation in species composition is still inconclusive. In the current study in the Western Himalayan altitudinal gradient in Uttarakhand, the diversity of a "megadiverse" group of herbivorous insects, nocturnal Lepidoptera was investigated. This chapter focuses on patterns of intra-habitat diversity (alpha-diversity) along an altitudinal gradient. The extensive coniferous, broadleaf and mixed forests and alpine grassland patches, with intermediate subalpine forests of this vast landscape is one of the last resort for many naturally occurring insect assemblages.

Samples taken from tropical arthropod communities are always a methodological challenge for diversity measures. They are almost always incomplete and the numbers of specimens available for analyses often vary considerably between sites (e.g. Schulze & Fiedler, 2002). Moreover, tropical arthropod communities are characterized by a high proportion of rare species that cannot be excluded as artefact or a group of marginal importance (Price et al. 1995, Novotný & Basset, 2000). So, suitable diversity measures should be able to discriminate between samples of different diversity and be independent of sample size in order to avoid misleading bias in the results. Here we present a description of diversity and species composition within a Himalayan altitudinal gradient in different protected areas. Analyses were carried out at the level of altitude as well as at the level of different habitats found throughout the gradient. The objective was to describe the diversity and characteristics of species assemblages found in different habitat types. Using this information, the communities of moth assemblages in different vegetation types was compared and the possible effect of habitat characteristics on species occurrence and observed pattern was explained.

10.2.2 Analysis

Moths captured by light trapping at a single site for 2-3 nights were pooled for quantitative analysis. 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. (iii) 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. (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). The similarity across sites was depicted as Bray-Curtis similarities (Krebs, 1989), using species composition. Cluster plots were constructed based upon similarity values of species composition across habitat types in program PAST (Hammer et al. 2007).

10.2.3 Results

Patterns in NDBR

Species of Geometridae family were found to be most abundant in both Joshimath (0.71) and Lata (1.15) gradient across all the sampling plots. The second most prominent family is Noctuidae with high abundance in Lata (0.65) but low abundance in Joshimath (0.16) (Fig. 1).

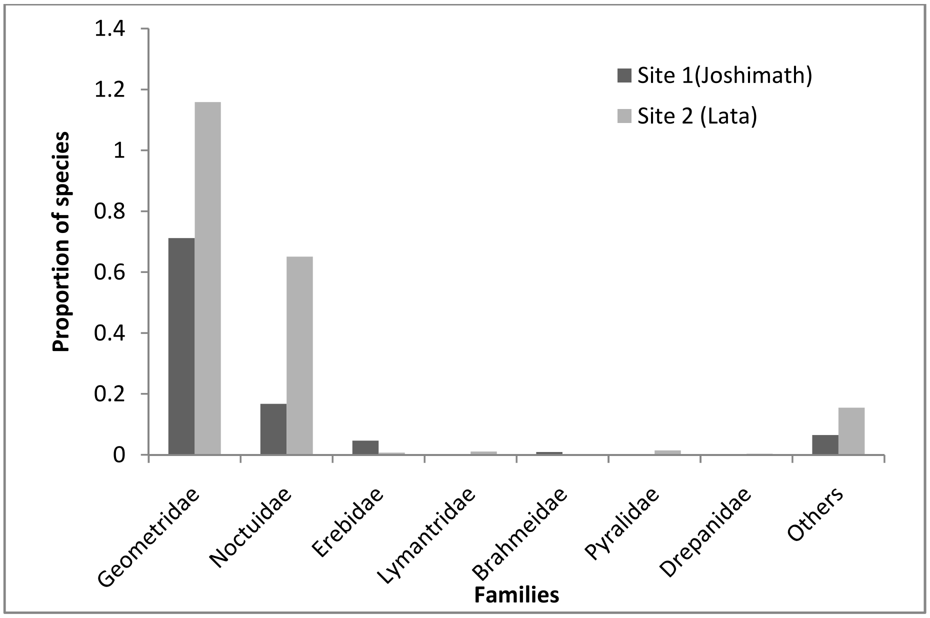


Figure 1: Family composition of moth in two altitudinal gradient, viz. Joshimath and Lata in NDBR

The temperate forest type showed the maximum species richness in both Joshimath (243) and Lata (150) gradient. The extent of temperate forest type was the most within our sampling altitude range (2000-3800m) and is more heterogenous in vegetation structure with mixed coniferous tree species diversity (Pine-Fir) in the lowest reaches and oak and deodar species in the mid-altitudes. The highest elevation band in Joshimath gradient was 3200m, so there was no sampling in the alpine scrubland forest type in this gradient (Fig. 2).

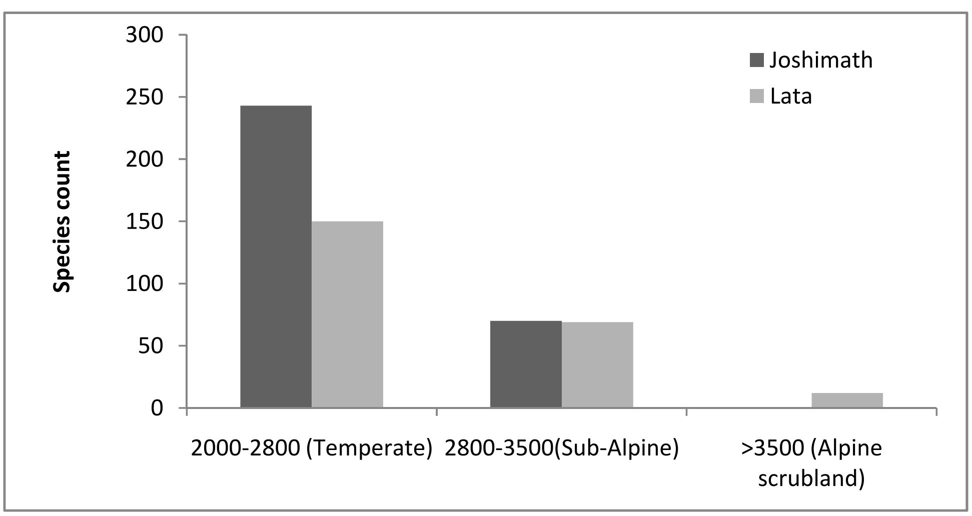


Figure 2: Species richness in different forest types in joshimath and Lata gradient in NDBR

Fisher's alpha was computed to look into the alpha diversity across the sampling plots negating the effect of sampling size. The alpha diversity showed a mid-elevation peak in the Joshimath gradient whereas the alpha diversity declined gradually with the increase in the elevation in Lata. This differential response of species richness to elevation among two gradients is interesting from the point of view of understanding the driving factors of community structure of moth assemblages in a broader sense (Fig.3).

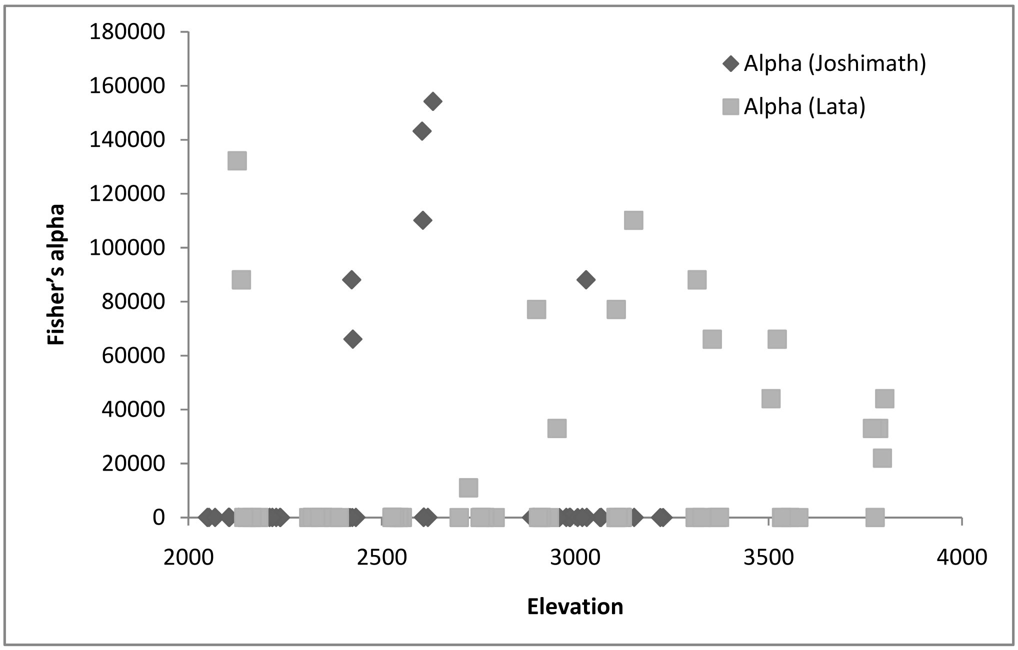


Figure 3: Fisher's Alpha along increasing altitude in two different gradients in NDBR

Species Richness of moths across sampling plots was plotted against elevation. The species richness also showed a peak in the mid-altitudes and sharp decline with increasing altitude in

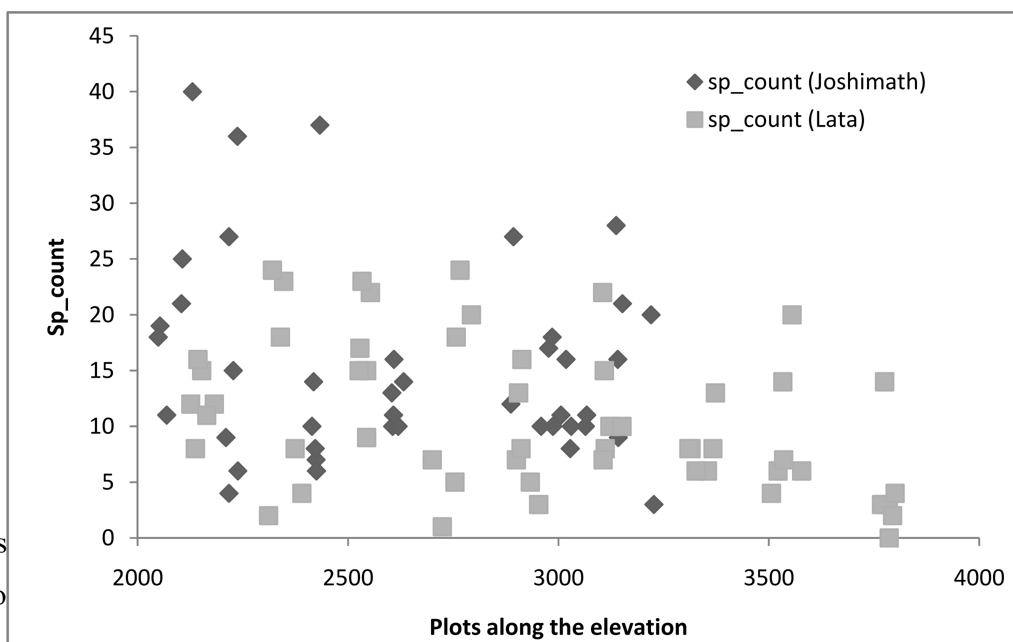


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Figure 4: Species richness across two different altitude gradients in NDBR

species richness and elevation relation is similar to the Alpha diversity and elevation relation (Fig. 4).

Dendrogram (Fig. 5a & b) shows clustering of sites with similar species composition based on Bray-curtis dissimilarity index. The plots were then categorised into forest types: broadleaf conifer, western mix coniferous (both these are sub-types of the Temperate forest type), sub-alpine and alpine).

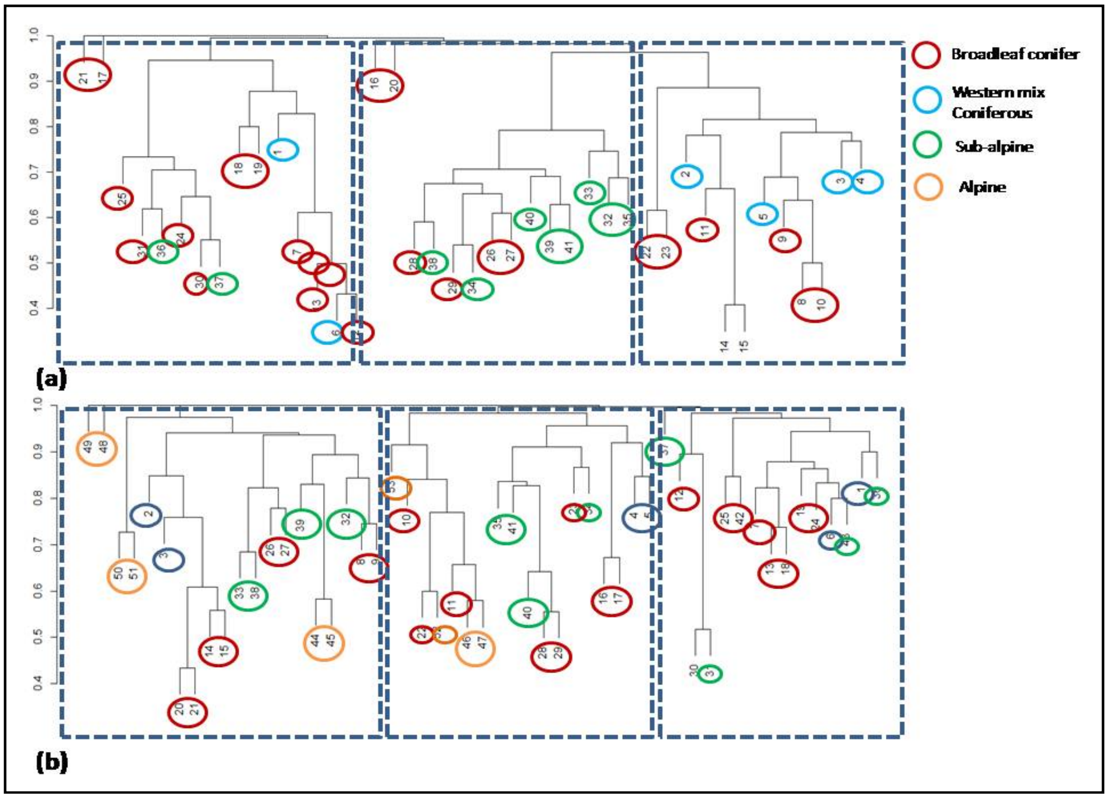
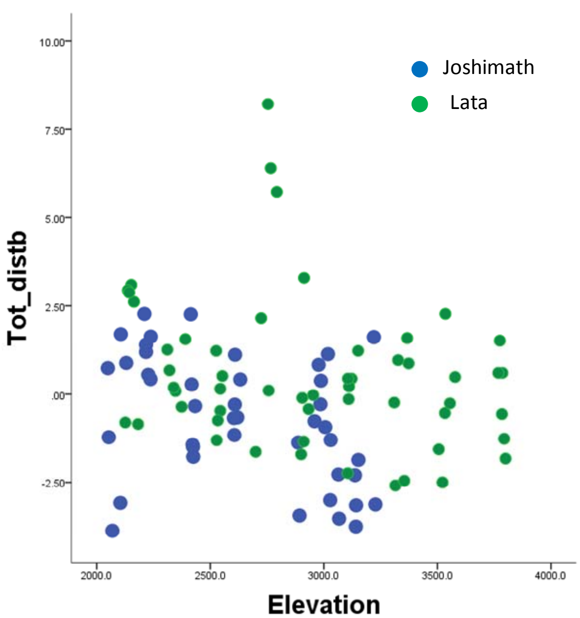


Figure 5: Site-clustering of sampling sites based on Bray-Curtis dissimilarity index

In Joshimath gradient (5a) all the plots are clustered in three prominent clusters on the basis of their species composition similarity. Cluster 1 show that most of plots in the broadleaf conifer forest type have similar species composition. Cluster 2 shows most of the plots in the sub-alpine have similar species composition and Cluster 3 shows western mix coniferous forest type plots have similar species composition. In Lata gradient (5b) none of the clusters show the effect of any particular forest type governing the similarity in species composition. These results further reinforce the fact that vegetation structure is coupled with other factors govern the moth species assemblage.

A total disturbance variable was computed taking in the disturbance variables (The variables which were directly related to the elevation were summed up and the variable which was inversely related with elevation was subtracted).The total disturbance of each sampling plot were plotted against elevation. The disturbance peaked at mid-elevation at the Lata gradient. Joshimath gradient shows high disturbance throughout low and mid altitudes and sudden decline at the higher latitudes. The trend is justified by the fact that the Lata village is situated at an elevation of 2300m in the Lata gradient and there is a lot of resource extraction and grazing pressure around the mid-altitudes. In Joshimath gradient there are two settlements, Joshimath around 2000m and Sunil-Auli around 2400-3000m so there is high disturbance throughout the mid-altitude zone.



Total disturbance=Pellet density+Felling density+Lopping density - dist.to settlement

Figure 6: Principal Component Analysis showed the response of species richness with elevaton and Total disturbance

Patterns in Gangotri Landscape Area (GLA)

The diversity was maximum in lower altitude zone and decreased gradually in three subsequent zones (Fig 7a). Fisher's alpha was highest, 85.37±3.31 in 1400m-1900m, and lowest 48.02±1.75 in 2900-3400m. Simpson's Index was 112.14±4.56, 93.27±3.84, 76.04±4.73, 65.89±2.74 in 1400-1900m, 1900-2400m, 2400-2900m and 2900-3400m respectively. As nonparametric estimator of asymptotic species richness, Chao1 was used which is based on the frequencies of rare species in the sample. Observed and estimated species richness using Chao1 did not vary much, signifying that sampling was almost complete at local scale. Observed species richness and estimated species richness (Fig. 7b) was 271, 293.54±9.37 for 1400m-1900m, 193, 196.76±3.07 for 1900m-2400m, 203, 217.8±8.26 for 2400m-2900m and 203, 211.09±5.17 for 2900m-3500m. The percent completeness, represented as ratio between observed species richness and estimated species richness was 92%, 98%, 93%, and 96% respectively for the four altitudinal zones studied.

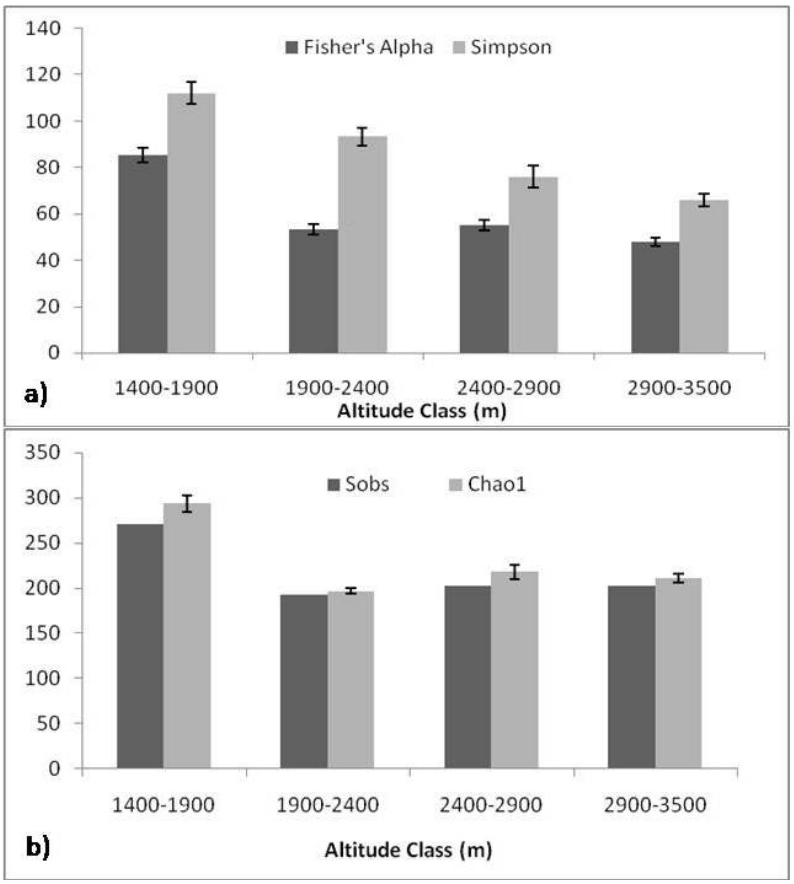


Figure 7: (a) Diversity indices of moth assemblage in different altitude classes in GLA; (b) Number of observed species (Sobs) and estimated species richness (Chao1) of moth assemblage in different altitude classes in GLA

Alpha diversity (Fisher's alpha) and Simpson's index were highest (Fig 8a) in Subtropical Pine Broadleaved Mix forest (80.89±3.56, 105.18±7.56) and Western Mix Coniferous forest (82.66±2.84, 108.23±2.4) and lowest in Subalpine forest (47.47±1.9, 62.36±2.94). Almost similar diversity patterns were recorded in Moist Temperate Deciduous forest (48.21±2.51, 71.43±5.74) and Western Himalayan Upper Oak forest (56.69±2.24, 70.97±3.38). At habitat level also, relatively, sampling success was achieved with no major difference in observed species richness and estimated species richness using Chao 1. Observed and estimated species richness was highest (Fig. 8b) in Western Mixed Coniferous forest (294, 306.99±6.11) and lowest in Moist Temperate Deciduous forest (152, 156.26±3.24). The values for observed and estimated species richness for other vegetation classes were like 237, 264.84±11.56 for Subtropical Pine Broadleaved mix forest, 210, 226.13±8.29 for Western Himalayan Upper Oak forest and 187, 193.86±4.67 for Subalpine forest.

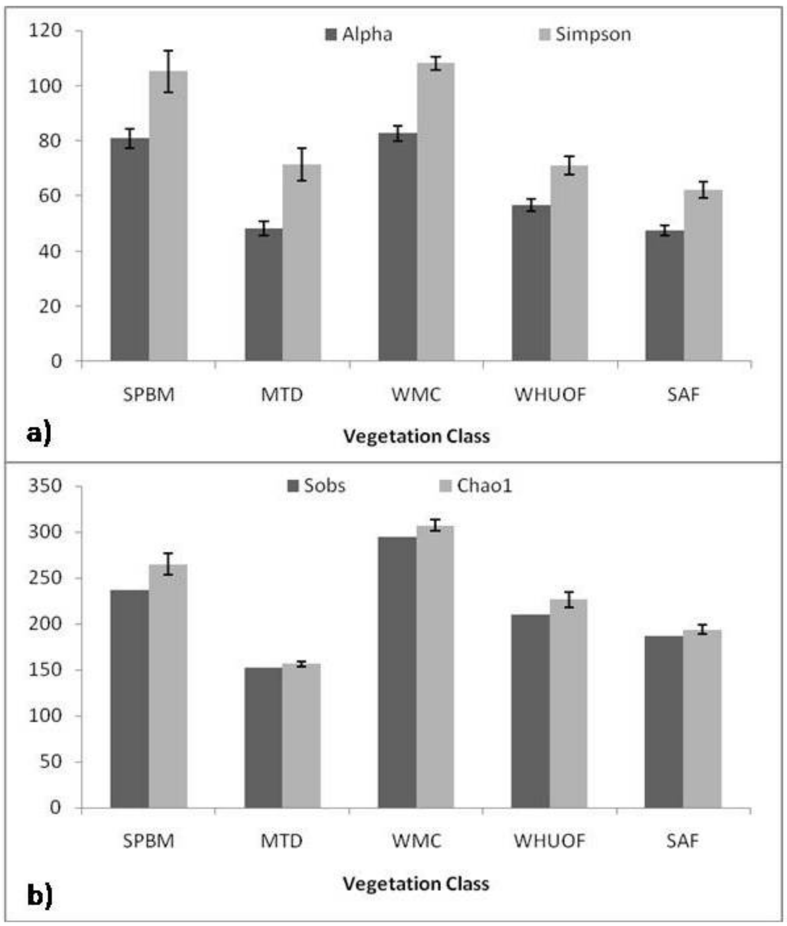


Figure 8: a) Diversity indices of moth assemblage in different vegetation classes in GLA; b) Number of observed species (Sobs) and estimated species richness (Chao1) of moth assemblage in different vegetation classes in GLA

Comparing among different sites revealed that on average, species composition was much more similar within the same habitat type than among different habitat types. NMDS plot generated from relative abundances of different moth species in each habitat type showed that sampling sites from each habitat type clustered together, though the resolution of clustering was not accurately fine (Fig. 9). Sampling sites of Pine Broadleaved mixed forest has little overlap with Montane Temperate Deciduous forest sites, whereas Western Mixed Coniferous forest sites formed the most separated cluster from the rest of the habitat types. Whereas Western Himalayan Upper oak forest sites clustered among Coniferous forest sites, the subalpine forest sites made a separate cluster of their own. Overall the moth species assemblage was successful enough to tell apart one habitat type from other and their positioning reflected a gradual transition from lowest altitude habitat to higher ones with little overlapping with habitat types at next altitude level.

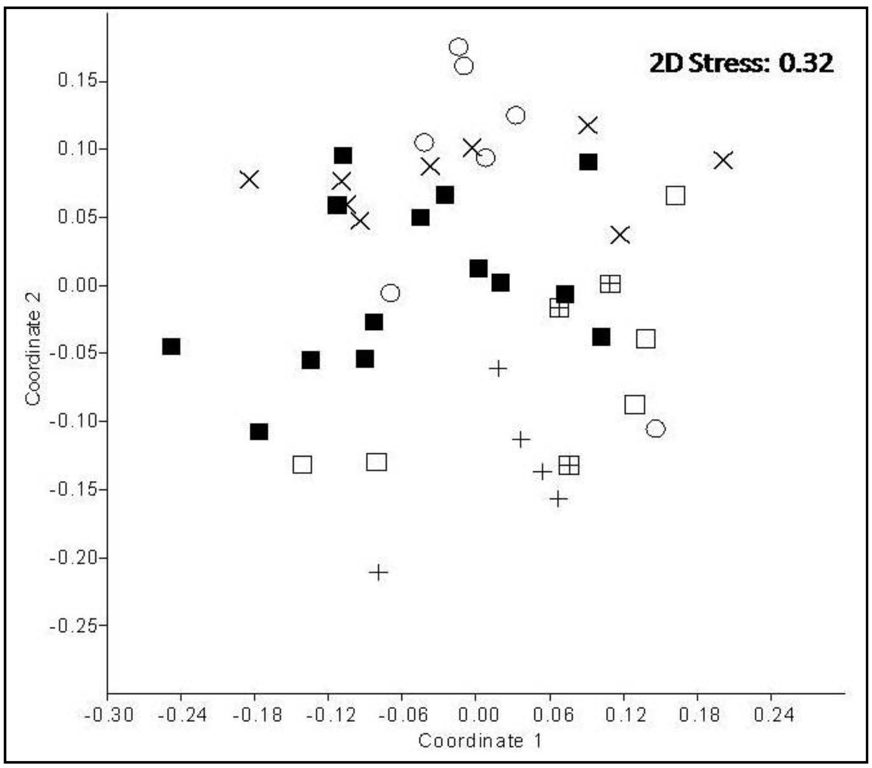


Figure 9: MDS ordination plots of sampling sites in GLA, generated by species composition sorted according to habitat types (Plus: Subtropical Pine Broadleaf Mix, Open Square: Moist Temperate deciduous, Filled Square: Western Mix Coniferous, Cross: Western Himalayan Upper Oak Forest, Open Circle: Subalpine Forest)

10.2.4 Discussion

The scale at which to look into the diversity pattern of a hyperdiverse taxa like moth is very important to decide, more so in a Himalayan landscape which is not only poorly studied previously, but also difficult to sample from the logistic point of view due to a wide altitudinal range as well as inaccessibility issues. There is also long-standing debate in choosing for appropriate alpha diversity measure for taxa like moth, assemblage structure of which is always dominated by rare species which renders the dataset to look ever-inadequate. In this backdrop, the aim of the current chapter was to look for suitable scale to sample as well as choosing for proper alpha diversity measures which will not only be sample-size independent, but also robust enough to discriminate between different levels of sampling units.

The moth diversity captured was not similar in the different altitude and vegetation zones, although the altitude zonation was little unrealistic and not flawless, mirroring the underlying changes in vegetation composition. Overall, the assemblages varied among zones and revealed a pattern of assemblage response in relation to altitude and the related microclimatic regime. In NDBR, plots have similar composition in similar forest types in the more disturbed gradient, like in Joshimath. Species richness and alpha-diversity shows mid-elevation peak in Joshimath gradient where there is a high-disturbance also. The interesting differential response to variables in two gradients studied more or less reflected effect of anthropogenic disturbances on assemblage composition.

In Gangotri Landscape Area, the Subtropical Pine Broadleaved mix forest, comprising excellent stands of Chir Pine and mix diversity of associated broadleaved habitats showed second highest alpha diversity and Simpson's, second highest numbers of species observed (Sobs) and estimated species richness. The reason may be that the Pine forests are open kind of forest with high but open canopy and relatively less dense understory vegetation rendering light trapping little unsuccessful and to capture an assemblage with cross-attracted species from adjacent habitats like Riverine and Moist Temperate Deciduous forests. Moist Temperate Deciduous habitats stretching from 1800m to 2200m, also including the riverine habitats were least diverse among all the major habitat types with lowest Fisher's Alpha, lowest number of species observed and estimated species richness. Though sampling was complete with lowest number of singletons, the low number of species and individuals captured signifying a comparatively less diverse assemblage. The Western Mixed Coniferous forests stretching from 2200m to 2600m were the hub of most diverse assemblage with highest values of Alpha diversity and Simpson's index, highest numbers of species and individuals collected. These were the most extensive and intact habitats in the study area and characteristics of typical Western Himalayan vegetation community. Above these, were the Western Himalayan Upper Oak forests, mainly dominated by Kharsu Oak forest between 2800m and 3200m which harbors a diverse and unique moth assemblage with second lowest alpha diversity and Simpson's index, third highest observed and estimated species richness. The subalpine forests constituting Western Himalayan Birch-Fir forest, Birch-Rhododendron scrub forest and Deciduous Alpine scrublands were one of the least diverse habitats in terms of Alpha diversity and Simpson's index, second lowest observed and estimated species richness. The individuals recorded were high signifying a characteristic assemblage adapted and very successful to harsh climatic conditions associated with this highest altitude vegetation community.

In conclusion, despite gradual and small distances between various habitat types studied, each one had significant resources to support its own characteristic moth assemblage. Overall, local diversity among moth communities were high all through the gradient signifying enough resource availability at every altitude and vegetation zones studied. The high diversity documented for the first time of a major herbivorous insect community in this typical Western Himalayan altitudinal gradient can be instrumental enough to ascertain its conservation significance. The results confirm that unless sampled extensively over a large temporal scale, the recorded species number is an unreliable measure of diversity because of its dependence on the number of specimens collected. Use of a set of sample size independent diversity measures like Fisher's alpha, Chao I and Jackknife should complement each other in different aspects of diversity as well as mathematical assumptions underlying their usage. Concordant diversity picture yielded by all these different measures should also minimize the possible risk of misinterpretations. The results provided in this chapter emphasizes need for a better understanding of the natural histories of Himalayan moth fauna, as well as the enormous importance of Himalayan coniferous and subalpine forests in conservation issues.

11. Syntheses and Conclusion

11.1 General conclusion

Conserving mountain biodiversity poses particular challenges with high species turnover. Adding to that, conserving mountains within a biodiversity hotspot, where there is high rate of human encroachment and urbanization going on, makes it even more challenging (Pryke & Samways, 2010). In such cases, it is important to take up multi-taxa approach in conservation as important areas or responses may be overlooked (Kotze and Samways 1999b; Lovell et al. 2007; Tropek et al. 2008). Community level conservation approaches for non-charismatic taxa has been advocated by many (Pearson & Cassola, 1992; Pimm & Gittleman, 1992; Scott et al. 1993; Meffe & Carroll, 1997; Oliver et al. 1998) and moths certainly fall in this category. Basic species distribution data can provide the information on how to manage a taxon's diversity based on the scale of sampling and can also throw light on the natural history traits associated with habitat generalization or specializations. Habitat specificity can narrow down species which are vulnerable to habitat loss and can be targeted for long term monitoring and conserving their habitat.

The information available is limited on the distribution and decline in general. Moths tend to "bridge the gap" in practical conservation considerations, as it focuses constructively on single target species to assemblage diversity and its patterns related to land-use and disturbance (New, 2004).In the time of need for resources and time for the conservation of biodiversity, rapid methods of assessing biogeographic details are gaining momentum. The use of indicators of overall species richness is one method which assumes that the species richness of well-known and lesser known groups is correlated (Hughes et al. 2000). Monitoring the invertebrates has become a priority worldwide because of their ecosystem services (Dobson, 2005; Rohr et al. 2007)

From our results, taxon proportions change with environmental gradient, but these results can be extrapolated only if the impacts of environmental gradients in each case is assessed for a particular area. As if the local changes in species composition are not taken into consideration then extrapolation might lead incorrect interpretation of patterns. To understand biodiversity patterns, different scales of studies are essential. Geometridae family with such abundance and taxonomic coverage can be targeted as models for undertaking such studies. Species which are proposed from various studies for conservation management with an element of ‘crisis management’, are not always based on sound knowledge about their biology (New, 2004). Individual species-targeted management is a complicated process and must be suited to the needs of the area under consideration. It can be said that mths have the potential to generate a informed mutual understanding between management authorities and conservation biologists, both aiming for ecological sustainability, but with a different approach (New, 2004).

The restriction of certain species at the higher elevations definitely indicates the need for conserving their habitat. While the higher elevations are well conserved often, the lower reaches are poorly protected (Sergio & Pedrini, 2007)

The study will enrich knowledge about the moth biodiversity in a unique landscape pattern of Western Himalaya, the meeting point of Oriental and Palaearctic faunal elements. An initial database of the family Geometridae and checklist will be produced based on the ground level sampling. The influence of climatic, topographic and anthropogenic effect on Geometrid moth assemblages will be understood. It will be possible to identify groups of indicator species with correspondence to intact or disturbed patches in given landscape. This will have a conservation implication by depicting the habitat condition of the landscape which is very important repository for unique Himalayan flora and fauna. The findings from this study would be of local significance and generally applicable to mountain ecosystem management.

11.2 Way forward: need for integrative taxonomy

The present study has revealed our lack of knowledge about the invertebrate fauna in such a biodiversity rich mountain. More assessment and studies are required for such ecosystems where there is high beta diversity to understand and generate more ecologically robust patterns. The remnant patches which have a direct connection with the natural vegetation would have more conservation value which is worth studying and further exploration.

For many inventories of hyperdiverse taxa, the lack of taxonomic expertise, or concentration of expertise to only a few individuals, inhibits morphological assessment of large numbers of specimens. Thus, an ambitious arthropod inventory can quickly overwhelm taxonomists with too many specimens, and thus are often unable to provide fine scale data for conservation for many groups.

Inventories are essential for documenting global diversity and generating necessary material for taxonomic study. However, for inventories to be relevant in the short term, the inventory process must reduce the bottlenecks in returning relevant data for conservation.

A sequence-based approach to the analysis of diversity, backed by a database of single gene barcodes, allows the exploration of diversity to scale to a rate that is not currently feasible using morphology alone. The DNA barcode provides a surrogate method for identifying units of diversity—a surrogate that will later serve as an additional character set for taxonomic assessment. If taxonomy is to provide a necessary tool to ecology and conservation science in hotspots it must be done at a much faster rate than in the past—especially with small, hyperdiverse or as yet undescribed fauna.

A major goal of systematic biology is to discover and describe species. Species delimitation, the process of determining species boundaries and discovering new species (Wiens, 2007), has resurged in systematic research because of accelerated threats to biodiversity from anthropogenic activities. Historically, phenetic methods based on morphological similarity delimited species. As technology advanced through the 20th century, phylogenetic methods based on genomic data augmented phenetic approaches to species delimitation. DNA barcoding has become an international initiative which has combined phenetic and genomic tools to identify species diversity in a standardized fashion. DNA barcoding uses the sequence variation in a short, standardized gene region to identify organisms to species (Hebert et al. 2003). In animal life, the DNA barcode is a 658 bp region of cytochrome c oxidase I (COI), a mitochondrial protein coding gene (Hebert et al. 2003). Traditionally, distance based methods that create and compare similarity matrices are used to calculate intra and inter-specific sequence divergences.

Higher inter-specific divergence than intra-specific divergence between DNA barcode lineages create a "barcode gap" used for species delimitation. Sequence divergence thresholds have also been applied, for instance a 2% threshold of DNA barcode divergences has been used to evaluate species boundaries that have been defined morphologically (Hebert et al. 2003b). In most DNA barcode studies that apply thresholds, species that show higher than 1.5-2% sequence divergence are "flagged" as potentially cryptic species. This type of analysis can flag cryptic species but additional evidence is required to support the hypothesis that this intra-specific variation represents provisional cryptic species.

11.3 Application Potential:

11.3.1 Immediate:

The sole goal of the project was to prepare the tentative inventory of moth fauna for the protected area of Uttarakhand which can be used as baseline information for further long term monitoring program.

11.3.2 Long Term:

Geometridae family with such high abundance are potent indicator species and can be studied for long-term as indicative of environmental changes. The study anticipates to establish moth assemblage as a surrogate for entire insect community and use them as indicator taxa in rapid habitat-quality assessment program for conservation management in Nanda Devi Biosphere Reserve. The outcome of the study divides the species diversity into different groups by characterization of habitat as indicator species as: habitat generalist that occurred numerously in all habitat types; forest generalist, that occurred exclusively in the forested habitat or most abundant in the forest habitats (forest interior and forest edge) and forest specialist species. This study will indicate a considerable potential for the forest edges and area of disturbance and site location. Landscape management schemes can attempt to maintain and encourage by management practice to design the particular case for the conservation of protected area management.

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13. APPENDIX 2: Species inventory (except the family Geometridae) from different Protected Areas (PA) of Uttarakhand. Abbrv: GL: Gangotri Landscape, AWS: Askot Wildlife Sanctuary, DRL: Dehradun-Rajaji Landscape, NDBR: Nanda Devi Biosphere Reserve

Superfamily	**Family**	**Subfamily**	**Genus**	**Species**	**PA recorded from**
TINEOIDEA	Tineidae	Hieroxestinae	*Opogona*	*flavofasciata*	GL
			Opogona	*theobroma*	GL
			Opogona	*sp.*	AWS
	Pterophoridae	Pterophorinae	*Buckleria*	*paludum*	GL
		Deuterocopinae	*Deuterocopus*	*socotranus*	GL
		Unassigned	*Diacrotricha*	*fasciola*	GL
TORTRICOIDEA	Tortricidae	Totricinae	*Clepsis*	*sp.*	GL
		Unassigned	*Homana*	*sp.*	GL
		Unassigned	*Dynatocephala*	*omophaea*	GL
		Unassigned	*Totricia*	*sp.*	AWS
PYRALOIDEA	Pyralidae	Epipaschiinae	*Macalla*	*sp.*	GL
			Lista	*haraldusalis*	GL
		Phycitinae	*Epicrocis*	*hilarella*	GL
		Pyralinae	*Diloxia*	*fimbriata*	NDBR, GL
			Endotricha	*olivacealis*	GL
			Endotricha	*sp.*	NDBR
			Orybina	*flaviplaga*	GL
			Sacada	*discinota*	GL
			Orthopygia	*igniflualis*	GL
	Crambidae	Musotiminae	*Cymoriza*	*ustalis*	GL
			Musotima	*suffusalis*	DRL
		Nymphulinae	*Eoophyla*	*peribocalis*	NDBR, GL
		Pyraustinae	*Herpetogramm a*	*luctuosalis*	GL
			Hyaloplaga	*pulchralis*	GL
			Pagyda	*quadrilineata*	AWS
			Pyrausta	*signatalis*	DRL
		Spilomelinae	*Pygospila*	*tyres*	DRL
			Agathodes	*ostentalis*	AWS
			Agrotera	*scissalis*	AWS
			Botyodes	*asialis*	AWS,DRL
			Bradina	*diagonalis*	AWS
			Cirrhochrista	*brizoalis*	AWS, GL,DRL
			Cotachena	*histricalis*	GL
			Cotachena	*pubescens*	DRL
			Cotachena	*alysoni*	AWS
			Dichocrocis	*definita*	GL
			Dichocrocis	*punctiferalis*	GL,DRL
			Dichocrocis	*nigrilinealis*	AWS
			Dichocrocis	*pluto*	AWS

			Dysallacta	*negatalis*	GL
			Endocrossis	*flavibasalis*	GL
			Glyphodes	*crithealis*	GL,DRL
			Glyphodes	*bivitralis*	GL
			Glyphodes	*sp.*	NDBR
			Glyphodes	*bicolor*	
			Glyphodes	*actorionalis*	AWS
			Goniorhynchus	*signatalis*	NDBR, GL
			Lamprosema	*commixta*	GL
			Lamprosema	*sp.*	NDBR
			Maruca	*vitrata*	AWS,DRL
			Nausinoe	*geometralis*	AWS,DRL
			Nausinoe	*perspectata*	DRL
			Nomophila	*noctuella*	GL
			Omiodes	*noctescens*	GL
			Pleuroptya	*balteata*	GL
			Pleuroptya	*quadrimaculalis*	GL
			Pleuroptya	*ruralis*	GL,DRL
			Pleuroptya	*sp.*	NDBR
			Polygrammodes	*sabelialis*	GL
			Sameodes	*cancellalis*	GL,DRL
			Spoladea	*recurvalis*	NDBR, AWS, GL,DRL
			Stegothyris	*diagonalis*	AWS
			Syllepte	*verecunda*	NDBR, GL
			Syngamia	*falsidicalis*	GL
			Terastia	*egialealis*	AWS, GL,DRL
			Palpita	*asiaticalis*	DRL
		Scopariinae	*Heliothela*	*ophideresana*	AWS
		Crambinae	*Euchromius*	*ocellea*	GL
			Ancylolomia	*sp.*	GL
	Thyrididae		*Banisia*	*owadai*	AWS
			Striglina	*scitaria*	DRL
ZYGAENOIDEA	Zygaenidae		*Chalcosia*	*suffusa*	GL
			Gynautocera	*philomera*	AWS, DRL
			Gynautocera	*papilionaria*	DRL
			Neochalcosia	*remota*	AWS
			Goniorhynchus	*sp.*	AWS
COSSOIDEA	Cossidae		*Xyleutes*	*strix*	AWS, GL,DRL
			Zeuzera	*coffeae*	DRL
			Zeuzera	*multistrigata*	GL
	Limacodidae	Unassigned	*Altha*	*subnotata*	GL
			Chalcoscelides	*castaneipars*	GL

			Phocoderma	*velutina*	AWS, GL
		Limacodinae	*Scopelodes*	*unicolor*	GL
			Phocoderma	*velutina*	DRL
			Miresa	*albipuncta*	GL
URANIOIDEA	Uraniidae	Microninae	*Micronia*	*aculeata*	GL
		Epipleminae	*Orudiza*	*protheclaria*	GL, DRL
			Epiplema	*bicaudata*	NDBR, GL
DREPANOIDEA	Drepanidae	Drepaninae	*Agnidra*	*discispilaria*	GL
			Auzata	*semipavonari a*	GL
			Drepana	*pallida*	GL
			Teldenia	*vestigiata*	GL,DRL
			Macrocilix	*mysticata*	GL
			Nordstromia	*duplicata*	GL
			Tridrepana	*flava*	AWS,DRL
		Thyatirinae	*Tethea*	*oberthueri*	GL
			Gaurena	*dierli*	GL
			Habrosyne	*conscripta*	GL
			Oreta	*pavaca*	GL
			Thyatira	*batis*	GL
		Cyclidiinae	*Cyclidia*	*substigmaria*	AWS, GL,DRL
BOMBYCOIDEA	Bombycidae	Unassigned	*Triuncina*	*religiosae*	GL
		Primostictinae	*Mustilia*	*sphingiformis*	GL
		Unassigned	*Ocinara*	*albicollis*	DRL
			Ocinaria	*sp.*	AWS
	Lasiocampidae	Lasiocampinae	*Trabala*	*vishnou*	AWS, GL, DRL
			Gastropacha	*pardale*	GL
			Euthrix	*laeta*	GL
			Malacosoma	*indica*	GL
			Metanastria	*hyrtaca*	DRL
			Paralebeda	*plagifera*	GL
	Brahmaeidae		*Brahmaea*	*wallichii*	NDBR, GL
	Saturniidae	Saturniinae	*Antheraea*	*assamensis*	AWS, GL
			Antheraea	*frithi*	DRL
			Antheraea	*paphia*	GL
			Actias	*maenas*	AWS
			Caligula	*thibeta*	GL
			Loepa	*katinka*	AWS, GL
			Samia	*cynthia*	DRL
	Eupterotidae	Eupterotinae	*Eupterote*	*Sp. (Complex)*	GL
			Eupterote	*geminata*	AWS,DRL
			Eupterote	*undata*	DRL
			Eupterote	*fabia*	AWS,DRL
		Unassigned	*Ganisa*	*plana*	AWS,DRL

			Ganisa	*postica*	DRL
			Apona	*caschmirensis*	GL
SPHINGOIDEA	Sphingidae	Macroglossinae	*Elibia*	*dolichus*	AWS
			Acosmeryx	*anceus*	AWS, GL, DRL
			Acosmeryx	*sericeus*	DRL
			Daphnis	*nerii*	GL, DRL
			Hippotion	*boerhaviae*	GL
			Hippotion	*boerhaviae*	GL
			Hippotion	*rosetta*	GL
			Hippotion	*rosetta*	GL
			Hippotion	*echeclus*	AWS, DRL
			Macroglossum	*bombylans*	GL
			Macroglossum	*bombylans*	GL
			Rhopalopsyche	*nycteris*	GL
			Theretra	*alecto*	GL
			Theretra	*nessus*	GL, DRL
			Theretra	*oldenlandiae*	GL, DRL
			Theretra	*clotho*	AWS, DRL
			Nephele	*comma*	GL
			Nephele	*hespera*	DRL
			Deilephila	*elpenor*	AWS
			Pergesa	*acteus*	AWS, DRL
			Cephonodes	*hylas*	DRL
			Elibia	*dolichus*	DRL
			Hyles	*livornica*	DRL
			Rhagastis	*acuta*	DRL
		Smerinthinae	*Ambulyx*	*sp.*	GL
			Ambulyx	*belli*	DRL
			Ambulyx	*liturata*	DRL
			Amplypterus	*panopus*	GL
			Clanis	*stenosema*	AWS, GL
		Sphinginae	*Leucophlebia*	*lineata*	GL, DRL
			Marumba	*sperchius*	GL
			Marumba	*sp*	AWS
			Marumba	*dyras*	DRL
			Psilogramma	*increta*	GL
			Psilogramma	*menephron*	AWS, DRL
			Agrius	*convolvuli*	AWS, GL, DRL
			Acherontia	*styx*	AWS, DRL
			Acherontia	*lachesis*	DRL
NOCTUOIDEA	Notodontidae	Platychasmatinae	*Cyphanta*	*xanthochlora*	GL
		Thaumetopoeinae	*Gazalina*	*apsara*	GL
			Oligoclona	*chrysolopha*	NDBR, GL

		Phalerinae	*Phalera*	*grotei*	GL
			Phalera	*sangana*	GL
			Phalera	*raya*	AWS, DRL
		Dudusiinae	*Tarsolepis*	*remicauda*	GL
		Heterocampinae	*Stauropus*	*sp*	AWS
		Unassigned	*Allodonta*	*sikkima*	GL
			Bireta	*longivitta*	GL
			Formofentonia	*orbifer*	GL
			Ginshachia	*gemmifera*	GL
			Ginshachia	*sp.*	NDBR
			Homocentridia	*concentrica*	GL
			Neodrymonia	*sp.*	GL
			Neopheosia	*fasciata*	GL
			Ptilodon	*saturata*	GL
			Semidonta	*biloba*	GL
			Rachia	*plumosa*	GL
			Damata	*longipennis*	AWS, GL
			Chadisra	*bipars*	DRL
			Benbowia	*virescens*	DRL
			Hemiceras	*satelles*	DRL
			Neocerura	*liturata*	DRL
	Erebidae	Arctiinae	*Spilosoma*	*sp.*	NDBR
			Spilosoma	*obliqua*	NDBR, AWS,GL,DRL
			Spilosoma	*unifascia*	NDBR, GL
			Spilosoma	*erythrozona*	NDBR, GL
			Spilosoma	*melli*	GL
			Spilosoma	*casigneta*	GL
			Spilosoma	*strigatula*	GL
			Spilosoma	*punctaria*	GL
			Spilosoma	*melanostigma*	GL
			Spilosoma	*leopardina*	GL
			Cyana	*sp.*	NDBR
			Estigmene	*quadriramosa*	NDBR, GL
			Callimorpha	*principalis*	NDBR
			Nannoarctia	*obliquifascia*	AWS
			Nyctemera	*adversata*	AWS,DRL
			Cyana	*sp.*	AWS
			Ceryx	*sp.*	AWS
			Spilosoma	*multiguttata*	AWS
			Creatonotus	*transiens*	AWS,DRL
			Creatonotos	*gangis*	DRL
			Utethesia	*lotrix*	AWS, GL,DRL
			Olepa	*ricini*	AWS

			Vamuna	*remelana*	AWS,GL, DRL
			Asura	*calamaria*	AWS
			Miltochrista	*nubifascia*	AWS
			Miltochrista	*cuneonotata*	GL
			Amsacta	*lactinea*	GL
			Areas	*galactina*	GL,DRL
			Areas	*imperialis*	GL
			Argina	*astrea*	GL,DRL
			Asura	*calamaria*	GL
			Chrysorabdia	*bivitta*	GL
			Chrysorabdia	*viridata*	GL
			Creatonotos	*gangis*	GL
			Creatonotos	*transiens*	GL
			Agylla	*beema*	GL
			Agylla	*prasena*	GL
			Eilema	*caniola*	GL
			Eilema	*antica*	NDBR, GL
			Macrobrochis	*gigas*	DRL
			Macrobrochis	*pallens*	GL
			Panaxia	*principalis*	GL
			Panaxia	*similis*	GL
			Sidyma	*albifinis*	GL
			Chionaema	*coccinea*	GL,DRL
			Chionaema	*peregrina*	GL
			Chionaema	*bellissima*	DRL
			Chionaema	*puella*	DRL
			Chionaema	*signa*	GL
			Olepa	*ricini*	DRL
			Amsacta	*lactinea*	DRL
		Catocalinae	*Trigonodes*	*hyppasia*	NDBR, GL
			Grammodes	*geometrica*	NDBR, DRL
			Fodina	*stola*	NDBR, DRL
			Catocala	*armandi*	GL
			Anomis	*mesogona*	NDBR
			Hypena	*indicatalis*	NDBR
			Arcte	*polygrapha*	NDBR
			Arcte	*coerula*	GL
			Anomis	*mesogona*	GL
			Bastilla	*acuta*	GL, DRL
			Bastilla	*crameri*	NDBR, AWS, DRL
			Bastilla	*joviana*	DRL
			Bastilla	*praetermissa*	DRL
			Dysgonia	*algira*	GL
			Hypopyra	*vespertilio*	GL, DRL

			Ophiusa	*tirhaca*	GL, DRL
			Ophiusa	*triphaenoides*	DRL
			Remigia	*discios*	GL, DRL
			Remigia	*undata*	DRL
			Spirama	*retorta*	GL, DRL
			Lagoptera	*juno*	GL, DRL
			Trigonodes	*hyppasia*	GL, DRL
			Bamra	*lepida*	GL
			Cymatophorop sis	*sinuata*	GL
			Ericeia	*pertendens*	GL
			Lacera	*procellosa*	GL
			Erebus	*ephesperis*	AWS, DRL
			Erebus	*caprimulgus*	DRL
			Erebus	*hieroglyphica*	DRL
			Oraesia	*emarginata*	GL, AWS
			Oraesia	*rectistria*	DRL
			Anisoneura	*aluco*	DRL
			Episparis	*liturata*	DRL
			Homaea	*clathrum*	DRL
			Eudocima	*homaena*	DRL
			Hypocala	*rostrata*	DRL
			Ischyja	*manlia*	DRL
			Macaldenia	*palumba*	DRL
			Pleurona	*falcata*	DRL
			Thyas	*coronata*	DRL
		Calpinae	*Othreis*	*fullonia*	GL
			Calyptra	*ophideroides*	AWS
			Calesia	*haemorrhoa*	AWS
			Calesia	*dasyptera*	NDBR
			Eudocima	*phalonia*	AWS
			Hamodes	*propitia*	AWS, DRL
			Dierna	*strigata*	DRL
			Psimada	*quadripennis*	DRL
		Lymantriinae	*Arctornis*	*comma*	GL, DRL
			Olene	*inclusa*	DRL
			Artaxa	*vitellina*	GL
			Laelia	*exclamationis*	GL
			Dasychira	*cerebosa*	GL
			Lymantria	*concolor*	NDBR, GL, DRL
			Lymantria	*semicincta*	DRL
			Lymantria	*mathura*	AWS, GL, DRL
			Lymantria	*sp.1*	AWS
			Lymantria	*sp.2*	AWS

			Lymantria	*singapura*	AWS
			Lymantria	*albolunulata*	DRL
			Lymantria	*marginata*	DRL
			Toxoproctis	*sp.*	AWS
			Stigmatophora	*sp.*	AWS
			Euproctis	*scintillans*	AWS, DRL, GL
			Euproctis	*plagiata*	DRL
			Euproctis	*vitellina*	NDBR, GL
			Himala	*argentea*	GL
			Leucoma	*clara*	GL, DRL
	Euteliidae		*Eutelia*	*adulatrix*	GL, DRL
	Nolidae	Chloephorinae	*Xanthodes*	*intersepta*	AWS
			Xanthodes	*transversa*	GL
			Gabala	*argentata*	GL
			Gabala	*roseoretis*	AWS
			Risoba	*prominens*	GL
			Pseudoips	*prasinanus*	AWS
	Noctuidae	Plusiinae	*Autographa*	*nigrisigna*	GL
			Autographa	*purpureofusa*	NDBR, GL
			Chrysodeixis	*acuta*	GL
			Erythroplusia	*pyropia*	GL
			Plusiopalpa	*sp.*	GL
			Thysanoplusia	*orichalcea*	NDBR, GL, DRL
			Euxoa	*hypochlora*	NDBR
			Chrysodeixis	*sp.*	NDBR
			Agrapha	*albostriata*	AWS
		Acontiinae	*Pseudeustrotia*	*dimera*	GL
			Ozarba	*punctigera*	AWS
			Oruza	*divisa*	DRL
		Acronictinae	*Auchmis*	*indica*	GL
			Auchmis	*inextricata*	DRL
			Diphtherocome	*fasciata*	GL
			Diphtherocome	*pallida*	NDBR, GL
			Nacna	*malachite*	GL
			Acronicta	*indica*	AWS
		Cuculliinae	*Cucullia*	*pullata*	NDBR, GL
			Valeriodes	*heterocampa*	GL
			Dasypolia	*atrox*	NDBR
			Bryopolia	*centralasiae*	NDBR
		Aganainae	*Asota*	*producta*	AWS
			Asota	*ficus*	AWS
			Asota	*caricae*	DRL
		Amphipyrinae	*Amphipyra*	*monolitha*	GL
			Amphipyra	*cupreipennis*	GL

		Agaristinae	*Mimeusemia*	*peshwa*	GL
			Episteme	*lectrix*	GL, DRL
			Aegocera	*bimacula*	AWS, GL
			Sarbanissa	*albifascia*	DRL
		Heliothinae	*Helicoverpa*	*armigera*	NDBR, GL, DRL
			Aspila	*peltigera*	GL
			Pyrrhia	*umbra*	GL, DRL
		Hadeninae	*Anapoma*	*albicosta*	GL
			Apamea	*aquila*	GL
			Callopistria	*sp.*	NDBR
			Callopistria	*albolineola*	GL
			Callopistria	*placodoides*	GL
			Callopistria	*repleta*	GL
			Callopistria	*rivularis*	GL, DRL
			Euplexia	*plumbeola*	GL
			Euplexia	*semifascia*	GL
			Euplexia	*tibetensis*	GL
			Ebertidia	*haderonides*	GL
			Haderonia	*culta*	GL
			Heliophobus	*texturata*	GL
			Leucania	*compta*	GL
			Lophotyna	*albosignata*	GL
			Phlogophora	*subpurpurea*	GL
			Polia	*scotochlora*	GL
			Prospalta	*leucospila*	GL
			Spodoptera	*littoralis*	NDBR, AWS, GL, DRL
			Aletia	*sp.*	NDBR
			Mythimna	*sp.*	NDBR
			Chasmina	*candida*	AWS, DRL
			Callyna	*jugaria*	DRL
			Callyna	*monoleuca*	DRL
			Mythimna	*consanguis*	DRL
			Tiracola	*plagiata*	DRL
		Glottulinae	*Polytela*	*gloriosae*	AWS
		unassigned	*Anaplectoides*	*perviridis*	AWS, GL
			Axylia	*renalis*	GL
			Pencillaia	*sp.*	AWS

14. S&T benefits accrued:

(i) List of research publications arising out of the project

Papers published/accepted/communicated:

Pritha Dey, V. P. Uniyal and Abesh K. Sanyal. Moth assemblages (Lepidoptera: Heterocera) as a potential conservation tool for biodiversity monitoring – study in Western Himalayan Protected Areas. 2015. Indian Forester 141(9), 985-992

Pritha Dey and V.P. Uniyal. A prefatory estimation of diversity and distribution of moths in Nanda Devi Biosphere Reserve, Western Himalaya, India. (Accepted in National Academy of Science Letters)In press.

Pritha Dey, Abesh Kumar Sanyal, V.P. Uniyal and Kailash Chandra. Geometridae moths along altitude: Pattern from Western Himalayan Protected Areas in Uttarakhand, India (Communicated to Journal of Asia-Pacific Entomology)

Popular Articles:

Pritha Dey (Popular Article). A "moth"ful of wonders! 2015. Saevus Wildlife Magazine 4(6), 84-89

Pritha Dey and V.P. Uniyal. Mothing in the Himalaya: No mountain too high. 2016.Antenna , Bulletin of Royal Entomological Society 40(1), 4-8.

Pritha Dey and V.P.Uniyal. Moths and the Mountains. Parthenos (in press)

Conference Proceedings:

Patterns in diversity of moth assemblages in Nanda Devi Biosphere Reserve, Western Himalaya- Pritha Dey, V. P. Uniyal (**9th Uttarakhand State Science & Technology Congress, 2015)**

Moth assemblages in Nanda Devi biosphere Reserve, Western Himalaya -Understanding the trend in diversity and their role as a conservation tool- Pritha Dey **(Student Conference on Conservation Science, University of Cambridge, 2015)**

Ecological Indicators for monitoring biodiversity in Nanda Devi Biosphere Reserve-World Heritage Site, Western Himalaya: Climate Change Perspective.V.P.Uniyal, Shazia Quasin, Pritha Dey **(Perth iii: Mountains of Our Future Earth, 2015)**

(ii) Manpower trained in the project

(a) Research Scientists or Research Associates

(b) No.of Ph.D registered: **One**

Thesis Title is **Diversity assessment and Molecular characterization of Geometridae moths in Nanda Devi Biopshere Reserve, Uttarakhand, India** at Saurashtra University under the supervision of Dr.V.P.Uniyal, Wildlife Institute of India

(c) Other technical personnel trained: Four

(iii) Patents Filed: NIL

15. FINANCIAL POSTION:

S.No.	**Financial Position/Budget head**	**Funds sanctioned**	**Expenditure**	**% of total cost**
1	Salaries/Manpower costs Consumables Travel Contingencies	12,97,200	12,97,200	100
2	Overhead Expenses	2,59,200	2,59,200	100
	Total	15,56,200	15,56,200	100

16. PROCUREMENT AND USAGE OF EQUIPMENT:

Major Equipment (Model and Make)					
S No	**Sanctioned List**	**Procured (Yes/ No) Model & make**	**Cost (Rs in lakhs)**	**Working (Yes/ No)**	**Utilisation Rate (%)**
-	-	NIL	-	-	-

-- (Principal Investigator)