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Geometridae Stephens, 1829 from different altitudes in Western Himalayan Protected Areas of Uttarakhand, India (Lepidoptera: Geometridae)

A. K. Sanyal, P. Dey, V. P. Uniyal, K. Chandra & A. Raha

Abstract

The Geometridae Stephens, 1829 are considered as an excellent model group to study insect diversity patterns across elevational gradients globally. This paper documents 168 species of Geometridae belonging to 99 genera and 5 subfamilies from different Protected Areas in a Western Himalayan state, Uttarakhand in India. The list includes 36 species reported for the first time from Uttarakhand, which hitherto was poorly explored and reveals significant altitudinal range expansion for at least 15 species. We sampled different vegetation zones across an elevation gradient stretching from 600 m up to 3600 m, in Dehradun-Rajaji landscape, Nanda Devi National Park, Valley of Flowers National Park, Govind Wildlife Sanctuary, Gangotri National Park and Askot Wildlife Sanctuary. The subfamily Ennominae represented the maximum number of species, and the species of subfamily Larentiinae were found to be more restricted to higher elevation areas. Western Mixed Coniferous forest held the greatest number of species, whereas the Subalpine forest was characterized by the highest number of indicator species identified through Indicator Species Analysis. While Indo-Malayan species dominated the assemblage composition, the maximum number of Himalayan endemics suggested that these species are long adapted to the Himalayan climatic gradient and ongoing climate-mediated perturbation may hamper their future survival.
KEY WORDS: Lepidoptera, Geometridae, diversity, altitude, Western Himalaya, indicator species, Uttarakhand, India.

Geometridae Stephens, 1829 de diferentes altitudes de las áreas protegidas del Himalaya occidental de Uttarakhand, India (Lepidoptera: Geometridae)

Resumen

Los Geometridae Stephens, 1829 se consideran como un grupo modelo excelente para estudiar a nivel global, los patrones de diversidad de los insectos a lo largo de gradientes de elevación. Este trabajo documenta a 168 especies de Geometridae pertenecientes a 99 géneros y 5 subfamilias de diferentes áreas protegidas en el estado del Himalaya occidental, Uttarakhand, en India. La lista incluye 36 especies registradas por primera vez de Uttarakhand, que ha sido mal explorado hasta ahora y revela la expansión del alcance altitudinal de al menos 15 especies. Estudiamos muestras de distintas zonas de vegetación de elevación entre los 600 m y los 3.600 m, en el área de Dehradun-Rajaji, Parque Nacional de Nanda Devi, Parque Nacional del Valle de las Flores, Reserva Natural de Govind, Parque Nacional de Gangotri y Reserva Natural de Askot. La subfamilia Ennominae supone el mayor número de especies, pero se encontró que las especies de la subfamilia Larentiinae eran más restringidas a las áreas más elevadas. El bosque mixto de coníferas occidental reúne el mayor número de especies, mientras que el bosque subalpino se caracteriza por incluir el mayor número de especies indicadoras, identificadas por medio del análisis de especies indicadoras. Mientras que las especies indo-malayas dominan la composición del conjunto, el máximo número de endemismos del Himalaya, sugiere que estas especies están más adaptadas al gradiente climático del

Himalaya desde hace tiempo y las perturbaciones climáticas actualmente en curso, podrían dificultar su futura supervivencia.
PALABRAS CLAVE: Lepidoptera, Geometridae, diversidad, altitud, Oeste del Himalaya, indicador de especies, Uttarakhand, India.

Introduction

The distribution of species and higher taxa like families is known to change along environmental gradients globally (BREHM & FIEDLER, 2003). One such gradient is the altitudinal gradient which serves as a natural system for various experiments (BREHM & FIEDLER, 2003) in ecology providing a diverse array of habitat and micro-climatic regimes and associated steep changes in the biotic and abiotic factors in a small geographic area (HODKINSON, 2005). Thus, mountain ecosystems have turned out to be an ideal system to study the factors governing the diversity and distribution of organisms and to predict responses due to subtle climatic variation (ASHTON *et al.*, 2016). These ecosystems have now become critical areas for conservation need globally because of the high number of endemic and climate sensitive species (FOSTER, 2001) and can be used as tools to monitor climate change responses (BENISTON *et al.*, 1997).

Different species show different patterns in altitudinal stratification, where some species occupy very small altitudinal ranges and have a high turnover across altitudes, but there are species spread across a wide range of environmental conditions (ASHTON *et al.*, 2016). Many studies have found altitudinal stratification in insect assemblages like ants (BURWELL & NAKAMURA, 2011), moths (BREHM & FIEDLER, 2003; ASHTON *et al.*, 2011), beetles (ESCOBAR *et al.*, 2005), as well as birds (WILLIAMS *et al.*, 2010) and mammals (WILLIAMS, 1997). It is known from these studies that different groups respond distinctively to altitude (STORK & BRENDALL, 1990), with particular species staying restricted to high altitudes showing endemism (KESSLER, 2002; SZUMIK *et al.*, 2012) and high phylogenetic diversity (ZOU *et al.*, 2016), thus demanding increased conservation efforts of their habitats.

Moth assemblages react sensitively to environmental gradients and are distinctly stratified altitudinally in tropical and subtropical forests (ASHTON *et al.*, 2016). This kind of database certainly is lacking in the 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 at the junction of the Palaearctic and Oriental regions. 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 different families of nocturnal Lepidoptera along the altitude needs to be created, 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.

The Geometridae Stephens, 1829, generally known as Looper moths, are the second most speciose family of moths worldwide. They occur in every biogeographical region (SCOBLE *et al.*, 1995) and are a well-established model group for biodiversity studies in temperate and tropical regions. Their altitudinal distribution patterns have been studied extensively in tropical South America (BREHM *et al.*, 2003, 2007; HILT *et al.*, 2006), Africa (AXMACHER *et al.*, 2004), Australia (KITCHING *et al.*, 2000) and South-east Asia (HOLLOWAY, 1985; CHEY *et al.*, 1997; INTACHAT *et al.*, 1997; BECK *et al.*, 2002). They have been proposed and experimentally demonstrated as a good biological indicator in habitat assessment and monitoring program, as well as in climate change studies (CHEN *et al.*, 2009). Although the taxonomy of this family is well established for the temperate regions, the tropical areas need large-scale revisions. Around 23,000 species have been described to date worldwide (SCOBLE & HAUSMANN, 2007) with high synonymy at the species level which suggests much more revisionary work to be done. The study of patterns of species description reveals that much revision of the taxonomy is still required at the species level.

The present study aims to document Geometridae moths across different habitat types, along the 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 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.

Materials and methods

Study Area

The Uttarakhand state of India provides an epitome of the geological architecture of the entire Himalaya. The 88% hilly state has 62% of its geographical area under forest cover (CHAWLA *et al.*, 2008). 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 (600 m to 800 m) harbouring Moist Sal forest habitat. Subtropical hill forest habitats were sampled in Askot Wildlife Sanctuary (600 m to 1000 m). This landscape, located along the India-Nepal border is also significant as a junction between the Western and Central Himalaya, as floral elements from both these biogeographic zones converge here. Himalayan Moist

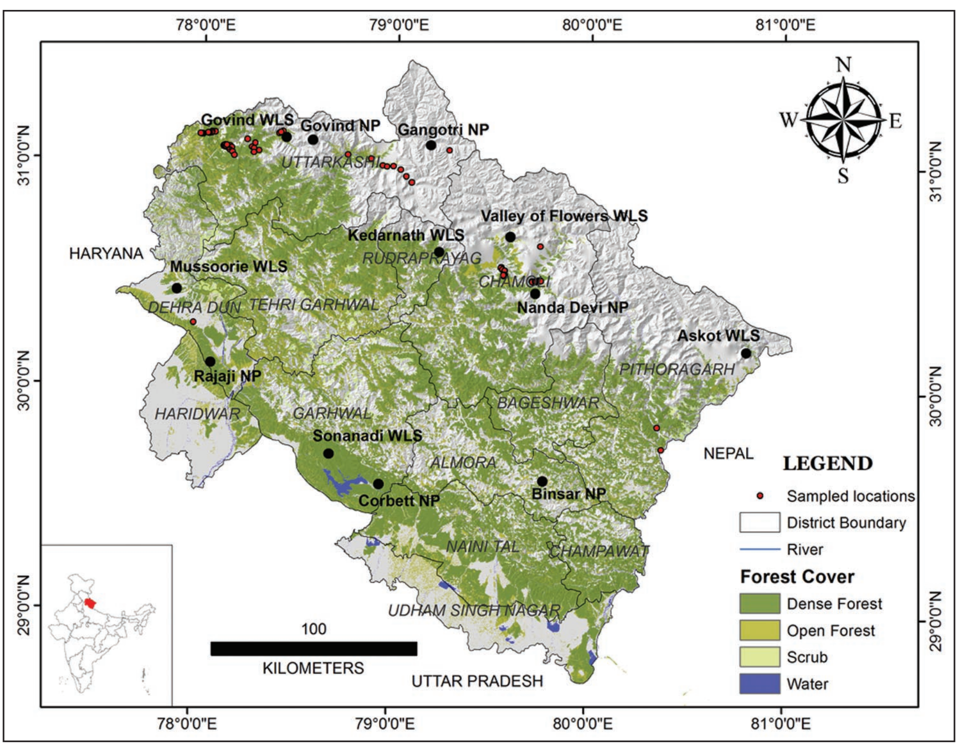

Fig. 1.– The distribution of the light-trapping sites for Geometridae across 5 Protected Areas in the Indian State of Uttarakhand.

Temperate habitat was sampled in Govind Wildlife Sanctuary ranging from an elevation of 1400 m to 3600 m 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 to the Trans-Himalayan condition of the 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. In total, 223 sampling nights (Table 1) were performed between 2008 and 2015 in 197 sites (all the sites sampled are shown in Figure 1) across 5 Protected Areas.

Sampling Geometrid Moths

Geometrid moths were sampled manually using a light trap running for 4 hours, in two sessions on consecutive nights, from 8 pm to 12 midnight and from 12 midnight to 4 am at a particular site, to ensure all the moths flying in a particular location or habitat in different quarters of the night could be recorded. Details of sampling sessions and sampling effort in various PAs are provided in Table 1. Light traps were set using a solar powered lantern and gas petromax equivalent to Mercury Vapour (MV) bulb. The combination of light sources was placed in front of a white 3 x 1.8 m cloth sheet hung between two vertical poles in such a way that it touched the surface and extended forward over the ground slightly. This was to ensure enough resting place for individual moths after they were attracted to light for live photography and collection. Some species were very active around a light trap and never settled on the white sheet. They were collected using an insect net. No sampling occurred within the period five days before to four days after the full moon, as light trapping is much less efficient during these periods (MCGEACHIE, 1989; YELA & HOLYOAK, 1997).

Table 1.– Details of the Light-trap sampling done for Geometridae moth in the different Protected Areas of Uttarakhand in the period 2008-20015 covering different seasons.

Protected Area	Sampling session	Sampling nights	Seasons sampled	Altitudinal range covered (m)
Dehradun-Rajaji Landscape	April-June, July-September, October-November, 2009-2014	32	Pre-Monsoon, Monsoon, Post-monsoon	600-800
Gangotri NP	October-November, 2008; October, 2012	18	Post-monsoon	2400-3600
Govind WLS	April-June, July-September, October-November, 2009-2012	84	Pre-Monsoon, Monsoon, Post-monsoon	1400-3600
Nanda Devi Biosphere Reserve	April-June, August-October, 2013-2015	65	Pre-monsoon, Post-monsoon	2000-3800
Askot WLS	May-June, September, 2013- 2014	24	Pre-monsoon, Post-monsoon	600-1000

Individual moths were collected in a wide-mouth glass jar filled with Benzene vapour evaporating from a cotton swab soaked in liquid Benzene and placed at the bottom of the glass jar. The specimens were first sorted into morphospecies and later identified with the help of the available literature and by comparison with the reference collections available at the Zoological Survey of India, Jabalpur and Kolkata. The identification was done following HAMPSON (1892, 1894, 1895 and 1896), HOLLOWAY (1993, 1996, 1997), BARLOW (1982), and HARUTA (2002). The nomenclature has been followed after SCOBLE & HAUSMANN (2007). The voucher specimens were submitted to the national repository at the Zoological Survey of India.

Results

Altogether 168 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 in Appendix 1.

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 was mainly the mid-elevation area stretching from 2200 m to 2800 m altitude zone. Among other species-rich areas were Pine (*Pinus roxburghii*) Mix forests (46 species) extending from 1400 m to 1800 m and Subalpine forest (43 species) between 3200 m to 3600 m. 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 3600 m beyond tree-line yielded 20 species (Figure 2).

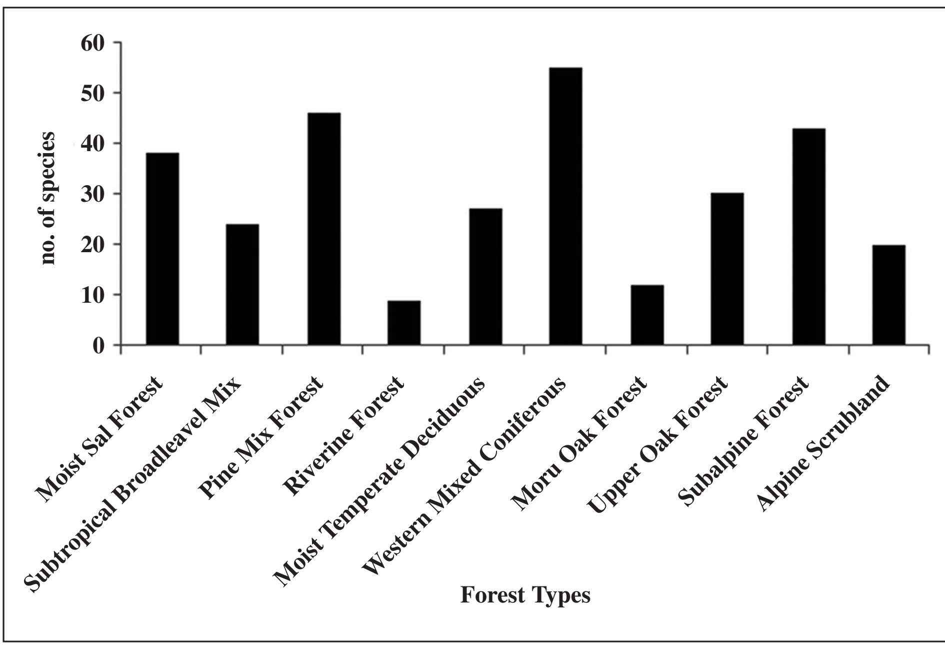

Fig. 2.– The number of species recorded in the different types of forest sampled across all the sampling areas. Western Mixed Coniferous forest was the most species-rich habitat followed by Pine Mix forest, Subalpine forest and Moist Sal forest.

Among five subfamilies of Geometridae sampled across different elevation and forest types, Ennominae were 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 1400 m while most of the species were recorded between 600 m to 2300 m and the species range extended up to 3400 m. The mean species distribution of the subfamily Larentiinae was recorded around 2800 m while most of the species were recorded between 2500 m to 3300 m and the species range extended from 1800 m to 3600 m. The mean species distribution of Geometrinae was around 700 m while most of the species were recorded from 600 m to 1300 m, and the species range extended up to 2500 m. For Sterrhinae, the mean species distribution was around 1400 m, while most of the species were recorded from 700 m to 1700 m, and the species range extended up to 2900 m (Figure 3).

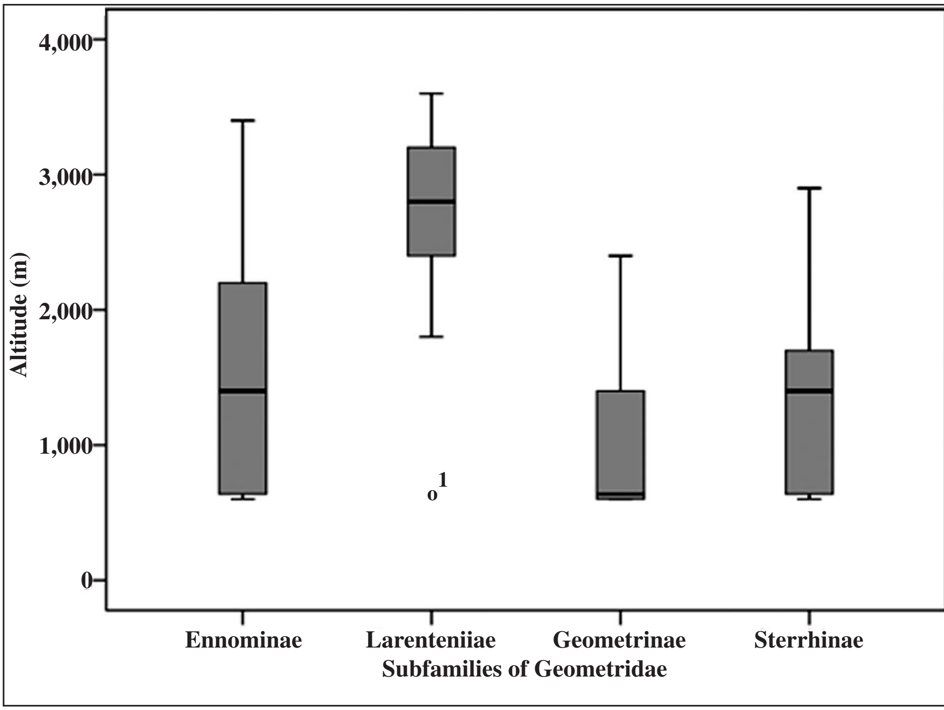

Fig. 3.– The altitudinal distribution of four major subfamilies of the family Geometridae collected across all sampling sites. While the subfamily Ennominae was widely distributed, species of subfamily Larentiinae had clear preference for higher altitudes.

The subfamily composition of the Geometridae also changes according to various PAs covered, depending on their elevational position (Figure 4). While there was a dominance of subfamily Ennominae in all the PAs, except Gangotri NP, which being truly a high-altitude PA ranging above 3000 m, 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). Specimens of Tribe Eupitheciini and Perizomini were mostly excluded from the analysis since their identification up to species level could not be confirmed except one species of *Eupithecia* and two

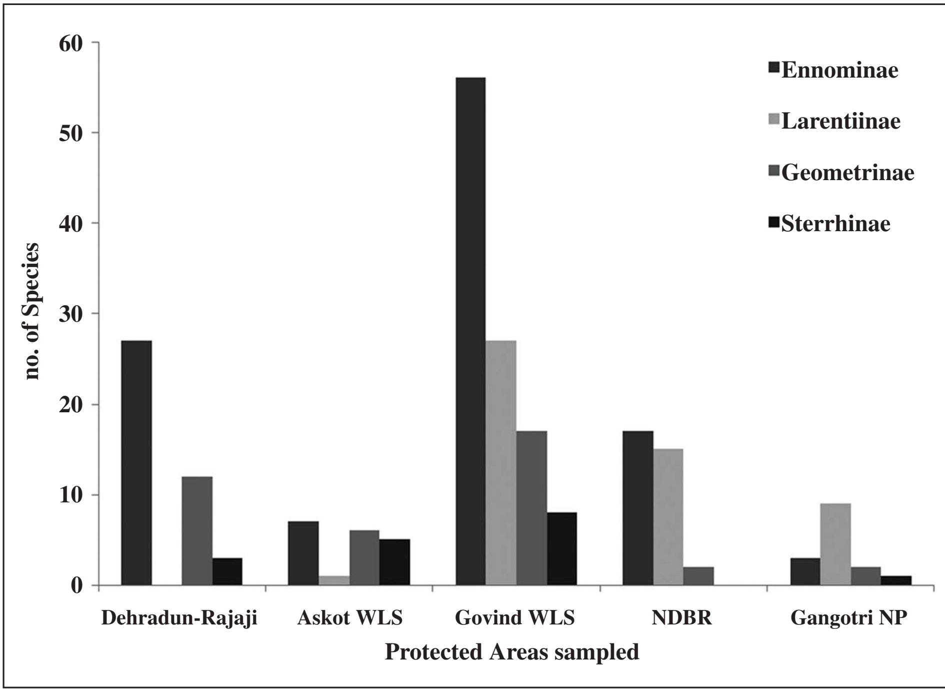

Fig. 4.– No. of species in each subfamily of Geometridae sampled across different Protected Areas in the Indian state Uttarakhand. The subfamily Ennominae was most numerous all through except in Gangotri NP. The subfamily Larentiinae had significant representation in high altitude protected areas and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

species of *Perizoma*. Among Geometrinae, 43% species were recorded of tribe Geometrini, 29% species were of tribe Pseudoterpnini and 23% of Hemitheini. Among Sterrhinae, nearly 50% specimens were of Scopulini, whose identification up to species level was not very successful except one species, viz. *Scopula pulchellata*.

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 5a). 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 5b).

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 1000 m for 12 species: *Abraxas irrorata* (2000 m to 3400 m), *Abraxas picaria* (2000 m to 3400 m), *Heterolocha phoenicotaeniata* (2000 m to 3200 m), *Odontopera heydena* (1500 m to 3200 m), *Odontopera lentiginosaria* (600 m to 3200 m), *Arichanna tenebraria* (2000 m to 3400 m), *Psyra debilis* (2100 m to 3400 m), *Eupithecia rajata* (1500 m to 2800 m), *Docirava aequilineata* (Indian plains to 3400 m), *Docirava pudicata* (Central India to 3200 m); for 2 species, around 1000 m expanse were recorded: *Laciniodes plurilinearia* (2400 m to 3200 m) and *Xanthorhoe hampsoni* (2200 m to 3200 m).

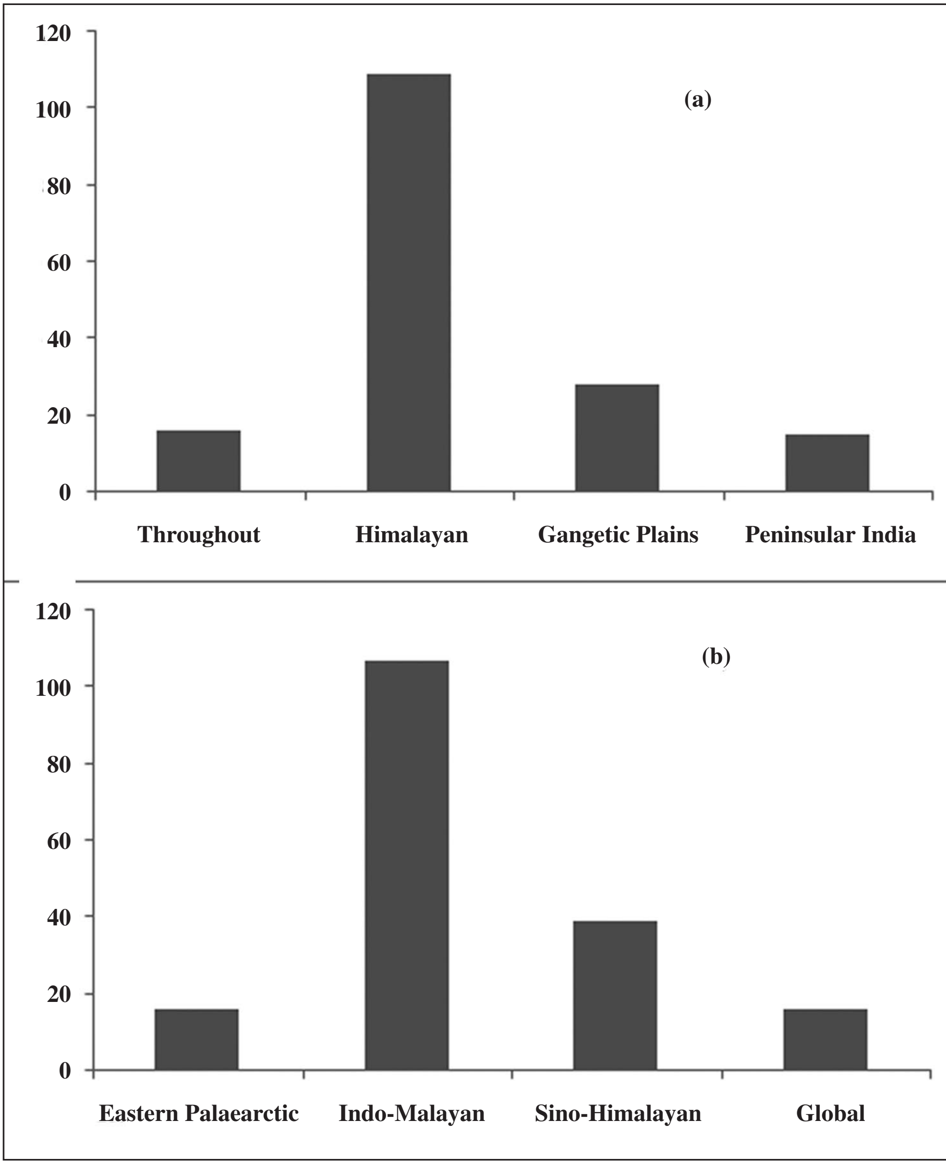

Fig. 5.– Biogeographic composition of sampled Geometridae assemblage: (a) Within Indian Subcontinent, Himalayan species dominated, the rest commonly distributed throughout. (b) The global pattern was dominated by Indo-Malayan species distributed along entire Himalayan breadth. There was significant proportion 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: *Arichanna 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, WHUOF: 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	*Arichanna 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

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 small, 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 the Andean rainforest and found a maximum diversity between 1040 m and 2670 m, 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 1400 m, 2600 m, and 3200 m.

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 weaker 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 600 m to 3800 m spread across different protected areas of Uttarakhand. Still there is a gap in moth samples between 1000 m to 1500 m, 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 cases, the previous records being more than hundred years old and the shift recorded more than 1000 m, 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.

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*A. K. S., P. D., V. P. U.
Department of Landscape Level Planning and Management
Wildlife Institute of India
Post Box-18
Chandrabani
Dehradun-248001, Uttarakhand
INDIA / *INDIA*
*E-mail: abeshsanyal@gmail.com
https://orcid.org/0000-0001-5948-8180

E-mail: dey.pritha126@gmail.com
https://orcid.org/0000-0003-3586-9235

E-mail: uniyalvp@gmail.com
https://orcid.org/0000-0001-5757-6383

K. C., A. R.
Zoological Survey of India
M Block
New Alipore
Kolkata 700053, West Bengal
INDIA / *INDIA*
E-mail: kailash611@rediffmail.com
https://orcid.org/0000-0003-4627-2397

E-mail: adroitangshuman@gmail.com
https://orcid.org/0000-0001-6992-7056

*Autor para la correspondencia / *Corresponding author*

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Appendix I.– The complete species account of 168 Geometridae recorded and identified 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, Year	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*	Guenée, 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 violacea*	Moore, 1888	Gangotri NP, Govind WLS, NDBR	1800-3200	2000 (1881: West Bengal)	No Record
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*	Guenée, 1858	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),* apindaceae *(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 patularia*	Walker, 1860	Dehradun	600-800	450-1500 (2008: Uttarakhand)	No Record
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 subtessellata*	Walker, 1863	Govind WLS, Dehradun	600-800, 1400-1600	450-1500 (2008: Uttarakhand)	Fabaceae *(Acacia sp., Mimosa sp.)*
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 albidaria*	Walker, 1866	Govind WLS, Gangotri NP, NDBR	1400-3200	1500 (2008: Uttarakhand)	Pinaceae *(Pinus 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 NDBR	Govind WLS,	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*	Guenée, 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 luteola*	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*	Guenée, 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*	Guenée, 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*	Guenée, 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*	Guenée, 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 NDBR	Govind WLS,	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*	Guenée, 1858 NDBR	Gangotri NP, 2400-2800	1400-1600,	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*	Guenée, 1858	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*	Guenée, 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*	Guenée, 1858	Govind WLS	1200-1600	1500 (2008: Uttarakhand)	Apocynaceae *(Carissa sp., Holarrhena sp., Nerium sp., Tabernaemontana sp.)*
Geometrinae	*Agathia hilarata*	Guenée, 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*	Guenée, 1858	Askot WLS, *Govind WLS,*	600-800, 1200-1400	450-1500 (2008: Uttarakhand)	No Record
Geometrinae	*Hemithea 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)	Apocynaceae
Geometrinae	*Chlorissa gelida*	Butler, 1889	Askot WLS, Govind WLS	600-800, 1200-1400, 1800-2000	2100 (1889: Uttarakhand) / 1500 (2008: Uttarakhand)	Apocynaceae (*Carissa sp.),* Fabaceae *(Acacia sp.)*
Geometrinae	*Comibaena quadrinotata*	Butler, 1889	Gangotri NP	2600-2800	2100 (1889: Uttarakhand)	Fagaceae *(Quercus sp.),* Rosaceae *(Malus sp.),* Betulaceae *(Betula sp.),* Juglandaceae *(Juglans sp.),* Anacardiaceae *(Rhus sp.)*
Geometrinae	*Argyrocosma inductaria*	Guenée, 1858	Govind WLS	1400-1600	No old altitude record	No Record
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	*Comibaena pictipennis*	Butler, 1880	Govind WLS	2400-2600	2000 (1888: West Bengal)	Fagaceae *(Quercus sp.),* Myrtaceae *(Syzigium sp.)*

Geometrinae	*Comostola subtiliaria*	Bremer, 1864	Govind WLS	1200-2000	1500 (2008: Uttarakhand)	Theaceae *(Eurya sp.),* Rosaceae *(Malus sp.),* Adoxaceae *(Viburnum sp.)*
Geometrinae	*Dysphania militaris*	Linnaeus, 1758	Dehradun	600-800	450-1500 (2008: Uttarakhand) Oriental region), *Carallia brachiata,*	Rhizophoraceae (*Carallia sp.* recorded from *(Kandelia candel* recorded from Hongkong)
Geometrinae	*Hemithea tritonaria*	Walker, 1863	Govind WLS	1400-1600	1500 (2008: Uttarakhand)	Fabaceae *(Acacia sp.)*
Geometrinae	*Herochroma cristata*	Warren, 1894	Govind WLS, Dehradun	600-800, 2000-2400	450-2400 (2008: Uttarakhand)	Araliaceae *(Araliaceae Schefflera* recorded from Hongkong)
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)	Fabaceae *(Quercus sp.* specially *Quercus incana*)
Geometrinae	*Ornithospila avicularia*	Guenée, 1858	Govind WLS, Dehradun	600-800, 2200-2400	450-2400 (2008: Uttarakhand)	No Record
Geometrinae	*Pingasa alba*	Swinhoe, 1891	Govind WLS	1200-1400	1500 (2008: Uttarakhand)	Fabaceae *(Dalbergia sp.),* Lauraceae *(Litsea sp.),* Malvaceae *(Sterculia sp.)*
Geometrinae	*Pingasa lariaria*	Walker, 1860	Dehradun	600-800	No old altitude record	No Record
Geometrinae	*Pingasa rubicunda*	Warren, 1894	Govind WLS	1200-1400	No old altitude record	Dipterocarpaceae *(Shorea* recorded from Malaysia)
Geometrinae	*Pingasa ruginaria*	Guenée, 1858	Govind WLS	1200-1800	No old altitude record	Fabaceae *(Dalbergia monetaria, Xylia xylocarpa),* Lauraceae *(Litsea elongata),* Malvaceae *(Sterculia villosa),* Rubiaceae *(Wendlandia notoniana)*
Geometrinae	*Tanaorhinus reciprocata*	Walker, 1861	Govind WLS	1200-1400	450-2400 (2008: Uttarakhand)	Fagaceae *(Quercus* recorded from Japan), *Quercus cerris, Q. serrata)*
Geometrinae	*Thalassodes veraria*	Guenée, 1858	Askot WLS, Govind WLS, Dehradun, NDBR	600-800, 2200-3200	450-2400 (2008: Uttarakhand)	Fabaceae *(Xylia sp.)*
Desmobathinae	*Eumelea rosalia*	Stoll, 1781	Govind WLS, Dehradun	600-800, 1400-1600	450-1500 (2008: Uttarakhand)	Euphorbiaceae *(Mallotus sp., Macaranga sp.),* Zingiberaceae *(Elettaria sp.)*