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Diversity, distribution pattern and seasonal variation in moth assemblages along altitudinal gradient in Gangotri landscape area, Western Himalaya, Uttarakhand, India

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Abstract: Field survey was conducted at different altitudes and land-use areas in the two protected areas, viz., Gangotri National Park and Govind National Park of Uttarkashi District, Uttarakhand, India. A total of 475 specimens of moth representing 436 morphospecies were collected using light trap method during the survey conducted between September 2008–May 2010. Preliminary findings show a decreasing diversity with increasing altitude. Subalpine areas were least diverse and subtropical areas had the highest diversity of moths. The greatest number of specimens were collected during the summer and post-monsoon period. The lunar phase had a significant effect on catch success with new moon days resulting in the largest catches and full moon days resulting in the least number of species as well as individuals. Of the thirty two species mentioned in Appendix 1, nine species are first time record from the state Uttarakhand. Four species are new record from Western Himalaya within Indian Territory, and also first time recorded from entire Himalayan landscape. As there was no previous comprehensive study on the moth diversity of Gangotri landscape area, all the 32 species described could be regarded as new record from these two protected areas.

KeyWords: Altitudinal distribution, catch success, Gangotri landscape area, moths, seasonal variability.

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 unique assemblage of flora, fauna of considerable conservation importance. In comparison with higher plants and larger animals, the inventory of insects in Western Himalayan landscape is still fragmentary and incomplete.

Recent estimates reveal the report of over 127,000 species of moths from the world, of which over 12,000 species are recorded from India (Chandra 2007). The comprehensive work on moths of different regions of Western Himalaya within the Indian Territory was mostly carried out by Hampson (1892, 1894, 1895, 1896) and Bell & Scott (1937) in their "Fauna of British India" series and Cotes & Swinhoe (1886) in "A catalogue of moths of India". Since then not much work has been carried out on moth fauna of Western Himalaya except Arora (1997, 2000) who had published some moth species from the Nanda Devi Biosphere Reserve, Garhwal Himalaya, Uttarakhand and Smetacek (2008) who published 887 species of moth from different elevations in Nainital District, Kumaon Himalaya, Uttarakhand. So far no comprehensive work on moth fauna in Gangotri landscape area which is an important wildlife refuge in high altitudes of Uttarakhand State has been done.

Study site

The study was conducted in two high altitude protected areas of Uttarakhand (Fig. 1) Gangotri National

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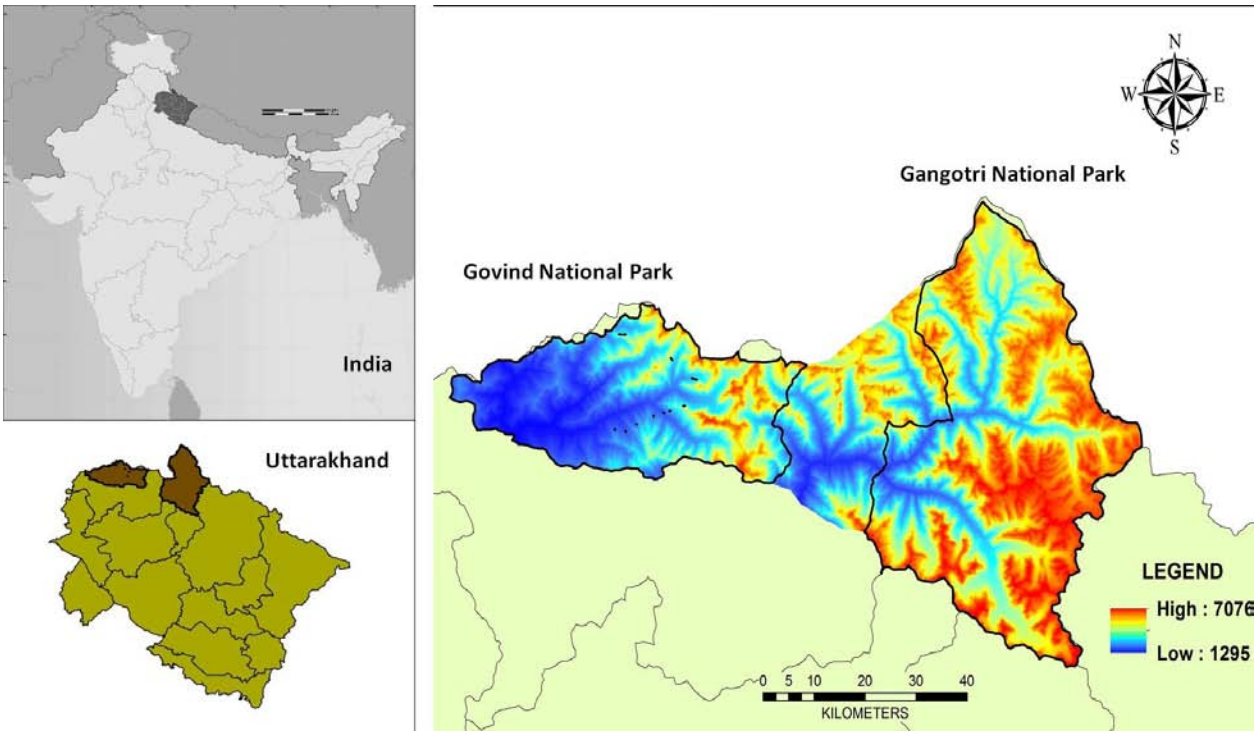

Figure 1. Digital Elevation Model of the Gangotri Landscape area showing Gangotri National Park and Govind National Park (Lowest 1295m to highest 7076m altitude)

Park (30^{0}50'–31^{0}12'N & 78^{0}45'–79^{0}02'E) and Govind National Park (31^{0}02'–31^{0}20'N & 77^{0}55'–78^{0}40'E), which represents the biogeographical zone - 2B West Himalaya (Rodgers & Panwar 1988). They are situated in Uttarkashi District of the Uttarakhand State. The altitude varies from 1200–6000 m. The Gangotri NP covers an area of 2,390km^2 harbouring the Goumukh Glacier, the origin of the river Ganges and Govind NP covers an area of 953.12km^2 encompassing the upper catchment of river Tons. The climate of the area is typically Himalayan with medium rainfall during July–August at lower altitudes. The average rainfall is 1,500mm, extreme cold with three to four month snowfall in winter with permanent snowline in the higher reaches.

The vegetation pattern in the study area resembles the broad pattern of vegetational zones of northwestern Himalaya. The lower altitude represents montane subtropical type with Chir Pine (*Pinus roxburghii* Sarg. (Pinaceae) dominating with tree rhododendron (*Rhododendron arboreum* Smith (Ericaceae), Rohini (*Mallotus philippensis* Lam. (Euphorbiaceae), Alder (*Alnus nepalensis* D. Don (Betulaceae), Wild Pear (*Pyrus pashia* Buch.-Ham. (Rosaceae), Indian Laburnum (*Cassia fistula* Linn. (Caesalpiniaceae), Amla (*Emblica officinalis* Gaertn. Euphorbiaceae), Toon (*Toona ciliata,* M.J. Roem (Meliaceae). Shrub layer is dominated by Musk Rose (*Rosa moschata* Miller (Rosaceae), Raspberry (*Rubus* sp. (Rosaceae), Wig plant (*Rhus* sp. (Anacardiaceae), *Dodonea viscosa* Linn. (Sapindaceae), *Colebrooka oppositifolia* Smith (Labiatae), *Pyracantha crenulata* M. Roemer (Rosaceae), *Ziziphus mauritiana* Lam. (Rhamnaceae). The mid altitude regions were represented by montane moist and dry temperate type of vegetation. Moist temperate vegetation consists of Grey Oak (*Quercus leucotrichophora* A. Camus (Fagaceae), Blue Pine/kail (*Pinus wallichiana* A.B. Jackson (Pinaceae), Western Himalayan Fir (*Abies pindrow* Royle (Pinaceae), Deodar (*Cedrus deodara* G. Don (Pinaceae), Horse Chestnut (*Aesculus indica* Hook. (Hippocastanaceae), Himalayan Cypress (*Cupressus torulosa* D. Don (Cupressaceae), and Yew (*Taxus baccata* Pilger (Taxaceae). The shrub layer was dominated by *Viburnum continifolium* D. Don (Sambucaceae), *Hippophae rhamnoides* Rousi (Elaeagnaceae) and *Berberis* sp. (Berberidaceae). The montane dry temperate vegetation zone was predominantly coniferous along with broad-leaved trees like oak, ash, maple. There were also deodar, juniper, high level fir (*Abies spectabilis* Mirbel. (Pinaceae) and Silver Birch (*Betula utilis* D. Don (Betulaceae). The subalpine zone around 3000m had dense coniferous forest represented by the species like *Pinus wallichiana* A.B. Jackson), Himalayan Yew (*Taxus wallichiana* Pilger (Taxaceae)) with intermixed broad-leaved trees like Kharsu oak (*Quercus*

semecarpifolia Smith (Fagaceae)). The common shrubs were *Rosa webbiana* Wallich (Rosaceae, *Cotoneaster* sp.(Rosaceae) and *Berberis* sp. etc. The herbaceous species like *Delphinium* sp.(Ranunculaceae), *Swertia* sp. (Gentianaceae) and *Pedecularis* sp. (Scrophulariaceae) were found common.

Materials & Methods

The moths were collected using light trap running for four hours from 19:00–23:00 hr in the three seasons, viz, summer (April–May), monsoon (June–July), and post Monsoon (August–September). Wherever electricity was available, light traps were set by placing a 120W Tungsten filament bulb in front of a white 10'x 6' cloth sheet hung between two vertical poles in a way that it touches the surface and extends forward over the ground slightly and the data collected by this method were used for the inventory purpose, not for diversity analysis. In higher areas of subalpine zone, light traps were set by solar powered lantern which had significantly low light intensity than tungsten filament bulb. After collecting, moths were killed by Benzene vapour in killing jar. The collected specimens were processed for pinning, setting and preserved in air-tight wooden boxes. First the specimens were sorted into morphospecies. Identifications were done with the help of available literature and also by comparing with the reference collection available at Zoological Survey of India. The classification used mainly follows Hampson (1892, 1894, 1895, 1896) and subsequent changes in the families based on Kristensen (1999).

Result

Altitudinal distribution: Diversity of moth fauna in terms of morphospecies collected showed a decreasing trend along increasing altitude. For comparison between different nightly catches at different altitudes, species were collected in same season, weather condition and moon phase. The data provided in Table 1 shows the average number (total morphospecies collected/ sampling night) of moth species collected in the four different altitudes with their respective broad vegetation type.

The four altitudinal zones sampled were categorized into three elevational ranges: The lower zone is represented by 500–1500 m which is characterized by montane subtropical and moist temperate type of forest. This zone came out as the most diverse zone (Fig. 2) in respect to moth species collected. The mid altitude zone is represented by 1500–2500 m, which is characterized by montane dry temperate type of forest. This zone had medium diversity. The higher altitude zone is represented by 2500–3500 m, which is characterized by subalpine vegetation. This zone contained significantly less diversity of moth species.

Seasonal variation: The data provided in Table 2 shows the total number of specimens collected in different seasons. For comparing the catch success in different season, the average value of catch success per night were used as a simple mean of total species collected by total trap nights.

Catch success was highest in summer months (April–May) followed by post monsoon (August–September) and monsoon (June–July) (Fig. 3).

Effect of moon phase: To observe whether the moon

Table 1. Number of species collected in different altitude with their representative broad vegetation zones.

Altitude (m)	Vegetation type	Morphospecies collected
1440	Montane Subtropical	76
1530	Montane Moist Temperate	31
2550	Montane Dry Temperate	12
3450	Subalpine	7

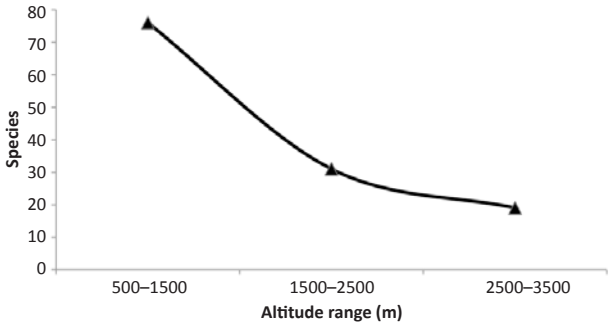

Figure 2. Trend of moth species diversity along increasing altitude.

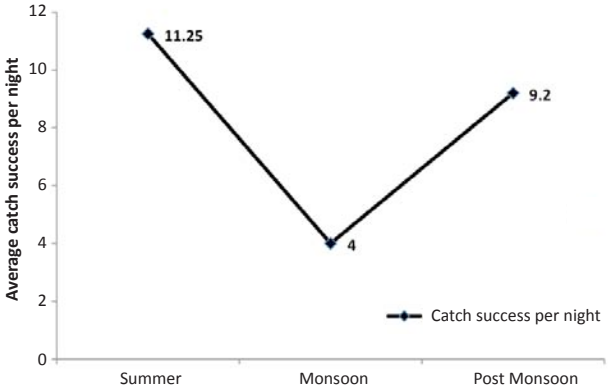

Figure 3. Catch success per night in three different seasons.

Table 2. Species collected of moth in different seasons.

Season	Specimens collected	Sampling night	Catch success per night
Post monsoon	65	7	9.2
Summer	135	12	11.25
Monsoon	8	2	4

phase has any significant effect on catch success, a light trap was run on daily basis for one month period in the month of April at an altitude of 1440m from 20:00–24:00 hr. The result of the observed species catch and individual catch per day in a complete lunar cycle is shown in Fig. 4. Most species as well as individuals were attracted in and around no moon nights and declined as the ambient moon light started to increase and came to a minimum around full moon nights when the ambient moon light was at its best.

Species list: Although a total of 475 specimens were collected representing 436 morphospecies in different seasons, only 32 were identified up to species rank representing six superfamilies and nine families within the short span of study time. The identified species list with their collection locality (GVNP: Govind National Park, GTNP: Gangotri National Park) and altitude at which they were collected is given in Table 3. Current valid names are provided after consulting from LepIndex (Global Lepidoptera Species Database 2007 & The Natural History Museum, London).

Discussion

In tropical or subtropical landscapes, two patterns of diversity are typically reported on altitudinal gradients: diversity either declines (linearly or nonlinearly) with increasing altitude, or, more commonly, unimodal patterns (mid-elevation peak) are found (Rahbek 1995, 2005; McClain et al. 2007). Our study result, although a preliminary one, has indicated the previous trend, i.e., moth diversity declining linearly with increasing altitude. As the study does not cover the entire elevational range, it is hard to predict the underlying cause of such pattern. The lower altitude zone represented by montane subtropical and moist temperate type of forest is in comparatively better condition than the upper reaches, which are under pressure from increasing human settlements and grazing-related problems. The sampling related issues may also have a significant effect on this pattern as setting up light traps in lower altitude zone was easier than the alpine areas due to availability of good logistic support like electricity. Whereas in lower areas the light trap was run by tungsten filament bulb run from main power source, for sub-alpine areas solar powered light was the only feasible option with much lower intensity.

Significant seasonal variation in catch success per night was observed with the highest catch success in summer time followed by post-monsoon season and the monsoon time which had significantly lowest success. High rainfall in monsoon months resulted in low catches, suspecting that flight may be restricted in such conditions. Post-monsoon months observed a significantly high

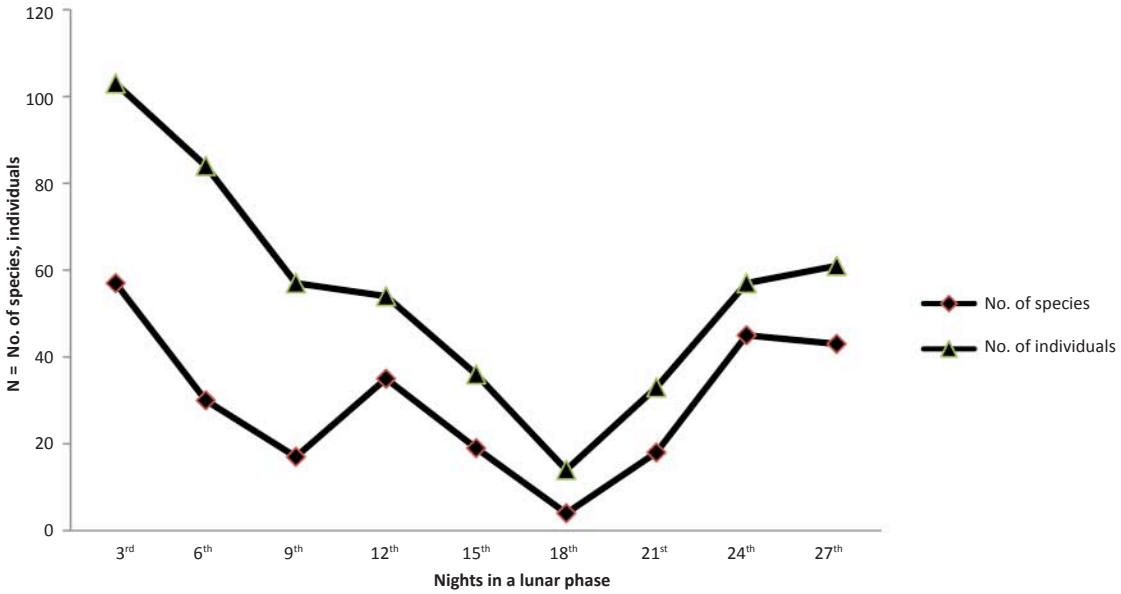

Figure 4. Effect of lunar phase on catch success.

Table 3. Thirty two identified species with their taxonomic position and collection locality and altitude.

Superfamily	Family	Subfamily	Species	Collected From
Pyraloidea	Crambidae	Spilomelinae	*Sameodes cancellalis* Zeller	GVNP, 1440m
			Goniorhynchus signatalis Hampson (Image 1)	GVNP, 1440m
			Cirrhochrista brizoalis Walker	GVNP, GTNP, 1440m, 2550m
	Pyralidae	Epipaschiinae	*Lista haraldusalis* Walker (Image 2)	GTNP, 2550m
Lasiocampoidea	Lasiocampidae	Lasiocampinae	*Trabala vishnou* Lefebre	GVNP, 1440m
			Gastropacha pardalis Walker	GTNP, 2550m
Geometroidea	Geometridae	Ennominae	*Oxymacaria temeraria* Swinhoe	GTNP, 2550m
			Trichopterigia rufinotata Butler (Image 3)	GVNP, GTNP, 1530m, 2550m
			Medasina albidaria Walker (Image 4)	GTNP, 3450mt
			Psyra similaria Moore (Image 5)	GVNP, 1440m
			Anonychia grisea Butler	GTNP, 3450m
		Larentiinae	*Photoscotosia miniosata* Walker (Image 6)	GTNP, 2550m
Drepanoidea	Drepanidae	Drepaninae	*Nordstromia* lilacina Moore (Image 7)	GVNP, 1440m
Bombycoidea	Sphingidae	Smerinthinae	*Leucophlebia lineata* Westwood (Image 8)	GTNP, GVNP, 1440m, 2550m, 3450m
		Macroglossinae	*Macroglossum* bombylans Boisduval	GTNP, GVNP, 2550m, 3450m
			Hippotion boerhaviae Fabricius	GVNP, 1440m
Noctuoidea	Lymantridae		*Lymantria concolor* Walker (Image 9)	GTNP, 1530m
	Arctiidae	Lithosiinae	*Macrobrochis pallens* Hampson	GTNP, 1530m
			Chrysorabdia bivittata Walker	GTNP, GVNP, 2550m, 1440m
			Cyana horsfieldi	GVNP, 1440m
			Asura calamaria Moore	GTNP, 2550m
			Barsine gratiosa Guerin-Meneville (Image 10)	GVNP, GTNP, 1440m, 1530m, 2550m
		Arctiinae	*Spilosoma* sp.1	GTNP, 1530m, 2550m.
			Spilosoma sp.2	GVNP, 1440m
			Spilosoma sp.3	GVNP, GTNP, 1440m, 1550m
	Noctuidae	Catocalinae	*Catocala inconstans* Butler (Image 11)	GTNP, 2550m
			Dysgonia latifascia Walker	GVNP, 1440m
		Plusiinae	*Chrysodeixis acuta* Walker	GVNP, 1440m.
			Thysanoplusia orichalcea Fabricius (Image 12)	GTNP, GVNP, 2550m, 3450m.
			Erythroplusia pyropia Butler	GTNP, 2550m
		Heliothinae	*Helicoverpa armigera* Hardwick	GTNP, GVNP, 1440m, 1530m, 2550m
		Noctuinae	*Diarsia albipennis* Butler (Image 13)	GTNP, GVNP, 1440m, 2550m

moth abundance and species richness perhaps by increased availability of fresh plant material stimulated by rain. Summer (April–May) was the best season for sampling. Moon phase or the monthly lunar cycle had a significant effect on the light trap catch success. Yela & Holyoak (1997) from their study recommended to restrict the light trapping to periods without strong moonlight because moths are not attracted to artificial light in the presence of high ambient moonlight, though their activity remains at it's peak. Our study documented the same phenomenon where maximum number of species as well as individuals were attracted to light traps in the beginning and end of lunar cycle, i.e. from 3rd to 6th day and 24th to 28th day when there was apparently no ambient moon light. Catch success eventually dropped as the ambient moon light started to increase and became almost zero in the full moon period from 14th to 18th day. One factor that masked this general pattern was the presence of cloud cover evident from the slightly increased catch success in 12th day when there was strong moon light but its effect was nullified by the clouds.

The present work gives an idea about previous and new distribution record of the 32 species mentioned

Image 1. *Goniorhynchus signatalis* Hampson

Image 2. *Lista haraldusalis* Walker

Image 3. *Trichopterigia rufinotata* Butler

Image 4. *Medasina albidaria* Walker

Image 5. *Psyra similaria* Moore

Image 6. *Photoscotosia miniosata* Walker

Image 7. *Nordstromia lilacina* Moore

Image 8. *Leucophlebia lineata* Westwood

Image 9. *Lymantria concolor* Walker

Image 10. *Barsine gratiosa* Guerin-Meneville

Image 11. *Catocala inconstans* Butler

Image 12. *Thysanoplusia orichalcea* Fabricius

Image 13. *Diarsia albipennis* Butler

(Table 3). Of these, nine species are first records from Uttarakhand State, viz., *Goniorhynchus signatalis, Lista haraldusalis, Trichopterigia rufinotata, Psyra similaria, Nordstromia lilacina, Spilosoma obliqua, Diarsia albipennis, Cyana horsfieldi* and *Spilosoma strigulata*.

As the area is under tremendous pressure from the threat of loss of biodiversity due to various anthropogenic activities like increasing human population, conversion of forested land to agricultural patch, shifting cultivation and livestock grazing of pastoral people, it is very important to know about the overall picture of diversity of an important indicator group like moth calling for the need of a more thorough investigation.

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