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Cover: Orange Oakleaf *Kallima inachus* with colour pencils and watercolor wash by Elakshi Mahika Molur adapted from a workshop by Lenin Raj.



## INTRODUCTION

Shiwaliks are the oldest of the mountain ranges that stretch over ~2,400 km from the Indus River in Jammu & Kashmir in the north-west eastwards close to the Brahmaputra river, located between 28.9544 °N & 34.1800 °E and 73.4900 °N & 80.23972 °E, spanning the northern parts of the Indian subcontinent. Shiwaliks are also regarded as a distinct zoo-geographical sub-region from the Himalaya and represent the lower or sub-Himalaya with elevation ranging 244–1,500 m, with diverse forest types, i.e., Moist Shiwalik Sal *Shorea robusta* forests, Dry Shiwalik Sal forests, scrubland, raus and grassy banks in northern India (Sivakumar et al. 2010). The Shiwalik region in northwestern part of India is mainly forested and includes many protected areas rich in wildlife, i.e., Rajaji National Park, Corbett Tiger Reserve, Sonanadi Wildlife Sanctuary, & Nandhaur Wildlife Sanctuary in Uttarakhand state; Kalesar Wildlife Sanctuary & the Morni Hills in Haryana; Simbalbara Wildlife Sanctuary in Sirmour district of Himachal Pradesh; and Sukhna Wildlife Sanctuary in Punjab (Yadav et al. 2015). In recent years, increasing anthropogenic activity such as rapid urbanization and conversion of forest land into agriculture, introduction of exotics, grazing by livestock and lopping of trees by the Gujjar communities—the main inhabitants of this region has caused excessive deforestation and affected the fragile landscape of Shiwaliks which is today witnessing extensive soil erosion in non-forested and degraded tracts that threatens its very existence including that of the native fauna of the landscape (Kukul & Sur 1992; Sharma & Arora 2015).

Lepidoptera is an order of insects that includes moths (Heterocera) and butterflies' (Rhopalocera) that are one of the main phytophagous groups, encompassing as estimated 140,000–157,000 extant species worldwide (Nieukerken 2011; Lees & Zilli 2019), with moths constituting 89% of the known lepidoptera while the rest are butterflies. "Macro-lepidoptera" or "Macro-moth" which is a traditional, non-systematic division of Lepidoptera, largely representing moth families which have fewer traits of the earliest members of the order and tend to include those families with large body size and are usually easier to identify (<https://en.wikipedia.org/>). Macro-moths have been today used as indicators of environment quality as they depict diversity of plants and health of an ecosystem and may help in conserving microhabitats (Kitching et al. 2002; Summerville 2004). These facts make them interesting organisms for studying their ecology and diversity. They have also

been found to be climate change indicators in studies conducted in western countries (Shubhalaxmi 2018).

The moth diversity of Shiwaliks of northern India has been poorly documented. Earlier studies in the region concentrated mainly in the higher western Himalayan ranges rather than the Shiwaliks or focused on particular groups/ families of moths or are not comprehensive in nature, i.e., Dehradun hills (Roonwal et al. 1956); Nanda Devi Biosphere Reserve in Kumaon (Arora et al. 1977); Nainital area in Kumaon (Smetacek 1994, 2008, 2009, 2011). More recently, Sanyal et al. (2013) and Uniyal et al. (2013) studied the entomofauna of the Gangotri landscape, listing 468 moth species. Recently, Sondhi & Sondhi (2016) have compiled a checklist of 248 species of moths from selected areas of Mussoorie and adjoining foothills of Dehradun, excluding the Shiwaliks. 502 species have been listed from New Forest Campus in Dehradun valley (670 m in the tropical moist deciduous forest zone, excluding Shiwalik ranges), in Uttarakhand since 1956 (Singh & Lekhendra 2022). Twenty-four species of Lymantridae have been listed from Punjab and 54 species of the family Arctiidae (Kaleka 2010, 2015). While Kumar et al. (2018) have listed 36 geometrid species, Kirti et al. (2007) and Kumar et al. (2015) have reported over 20 noctuid species of moths, all from Chir Pine *Pinus roxburghii* forest areas of Himachal Pradesh state (Bilaspur, Shimla, & Solan districts). However, none of the authors gave the precise location of any of their records and most of them do not fall in the Shiwalik ranges.

Therefore, the present study was undertaken to evaluate the diversity and seasonality of macro moths across different forest habitats in the Shiwalik landscape of northern India, up till the point which forms the western most limit on the globe (30.5042 °N & 77.2430 °E) in the distribution range of tropical moist deciduous Sal forests (a forest type typical in the northern aspect of the Shiwalik mountain ranges), i.e., Simbalbara National Park/Suketi in Himachal Pradesh State.

## METHODS

### Sampling

Seasonal sampling surveys were carried out to collect data on species richness and abundance of moths from 19 sites across the Shiwalik ranges from east to west in four northern Indian states (mainly in Uttarakhand and adjoining parts of Himachal Pradesh, Uttar Pradesh, and Haryana states; Figure 1) from July 2020 to October 2022. Surveys were conducted

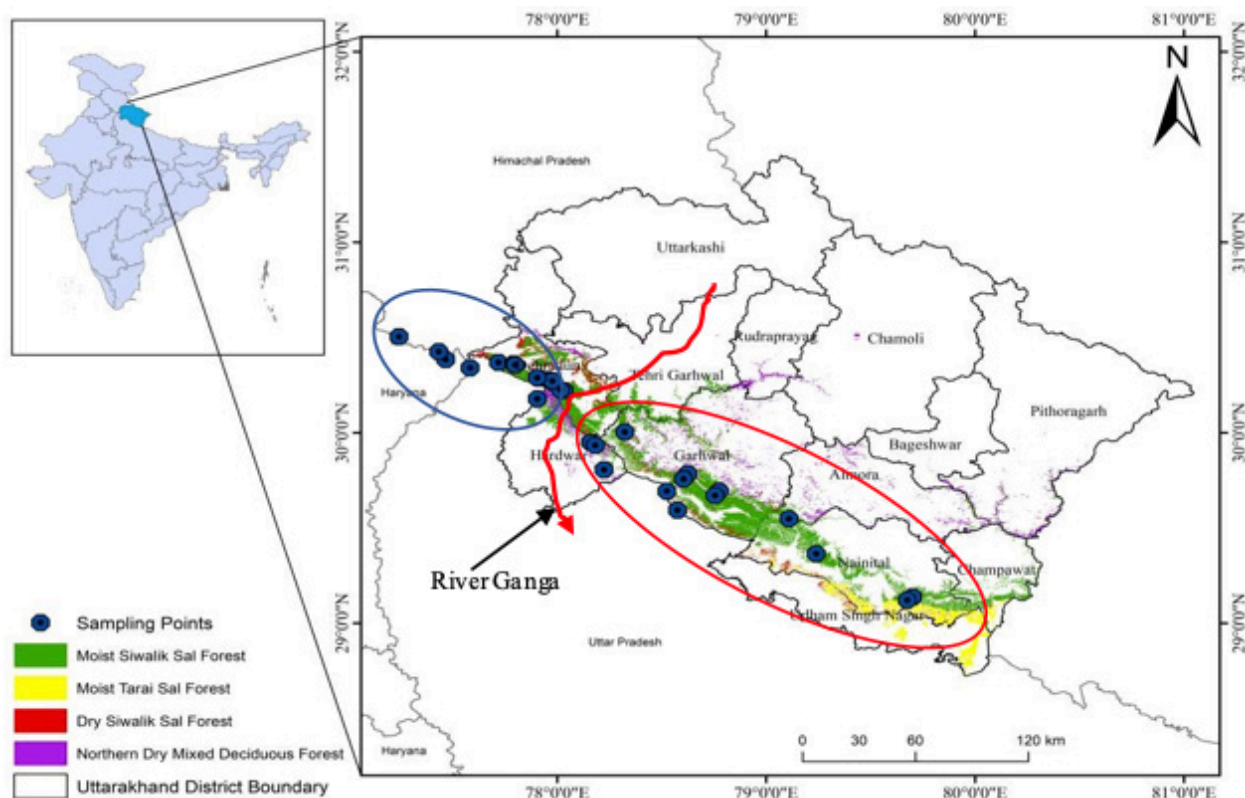


Figure 1. Location of the 19 sampling sites (dark blue dots) along different forest sub-types across the Shiwalik Landscape of Uttarakhand State and adjoining states in northern India with river Ganga intersecting the landscape.

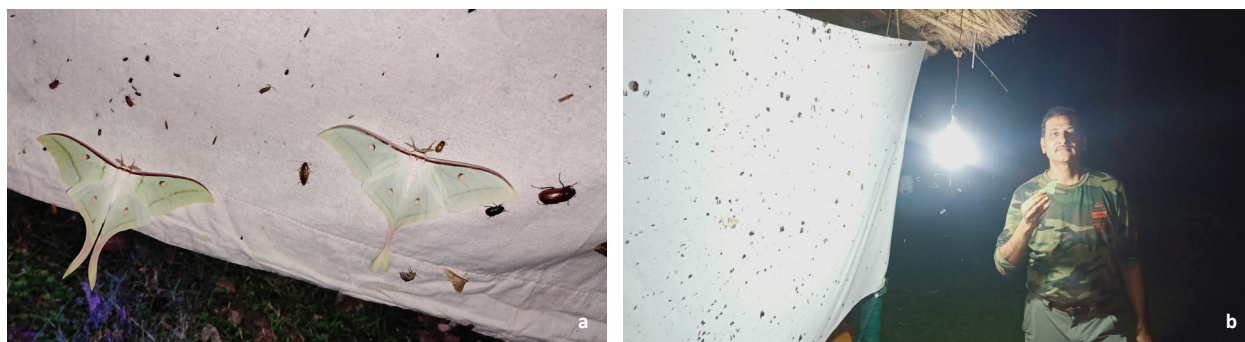


Image 1. a—Lunar moth, *Actias selene* (Saturniidae) attracted to CFL Light on moth screen during sampling (© Arun P. Singh) | b—The first author sampling moths using CFL lamp and moth screen (© Lekhendra).

during different seasons of the year, i.e., pre-monsoon (April–June), monsoon (July–August), post monsoon (September–November), when moths are in flight here except in winter and early spring (December, January, February & March) when moths undergo hibernation in the northern India. A total of 59 days of individual sampling surveys (43 tours) were carried out each night from 1900–2200 h in these sites (Figure 1, Image 1, Table 1), as this is the time most of the moths are attracted to

artificial light just after sunset. It was noted that moth species composition on moth screens altered less after mid night. We used CFL—compact fluorescent lamps (27 Watt; 220–240 Volts; Cool Daylight (6,500–7,500K); Light Color: White; 65 Lumen; Philips) hung vertically in front of a white canvas cloth as a moth screen (180 x 120mm) to attract moths (Raimondo et al. 2003). Data was collected on the date of sampling, GPS coordinates of each sampling site, moth species recorded along

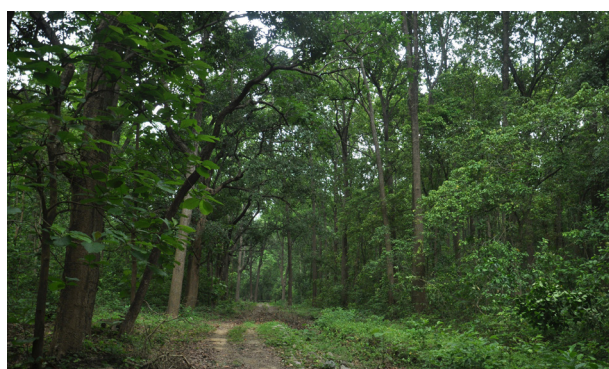




(i) 3C/C2a Moist Shiwalik Sal Forest



(ii) 5B/C2 Northern Dry Mixed Deciduous Forest



(iii) 3C/C2c Moist Tarai Sal Forest



(iv) 5B/C1a Dry Shiwalik Sal Forest

**Image 2. Four different forest types across the Shiwalik Landscape. © Arun P. Singh.**

with the number of individuals present on the moth screen, and the temperature and relative humidity at the time of sampling. Most of the species sampled were photographed live; besides, vouchers specimens were also collected for those species that could not be identified in the field (Table 1). Forest sub-types covered during sampling in these 19 sites were (i) 3C/C2a Moist Shiwalik Sal Forest, (ii) 5B/C1a Dry Shiwalik Sal Forest, (iii) 5B/C2 Northern Dry Mixed Deciduous Forest, and (iv) 3C/C2c Moist Tarai Sal Forest (Champion & Seth 1968) (Image 2, Table1).

Data analysis was carried out using the programme 'Bio Diversity Professional Version 2' to draw inferences on (i) alpha diversity – Shannon, species accumulation curve, rarefaction; (ii) beta diversity – species richness estimators (Chao2; Jackknife1 & Jackknife2); (iii) multivariate analysis (correspondence analysis & cluster analysis; correlation coefficient), for individual sites and seasons. Similarity index for moths species sampled in different forest types was calculated using Jaccard coefficient (Jaccard 1901).

## RESULTS

Sampling surveys revealed a total of 321 species of macro moths (Appendix I) belonging to 19 families and 49 subfamilies. Amongst these, the family Erebiidae (95 species) was the most dominant followed by Crambidae, Geometridae, Noctuidae, Limacodidae, and others, respectively, in terms of number of species (Figure 2).

### Species richness

The species accumulation curve (Figure 4) for the entire sampling period suggests that new species were constantly being added till the last sampling and there was still a potential to add many more species when the sampling stopped.

The rarefaction plot for individual sites (Figure 4) suggests that sampling for species was comprehensive for only few sites, i.e., 'Simbalbara' (60 species) and 'Darpur' (20 species) most of the new species were added initially but later only a few species were added until the last sampling. While in Mundiapani, Timli, and Karvapani, new species were added continuously and the plot reached a higher species number (above 80) till

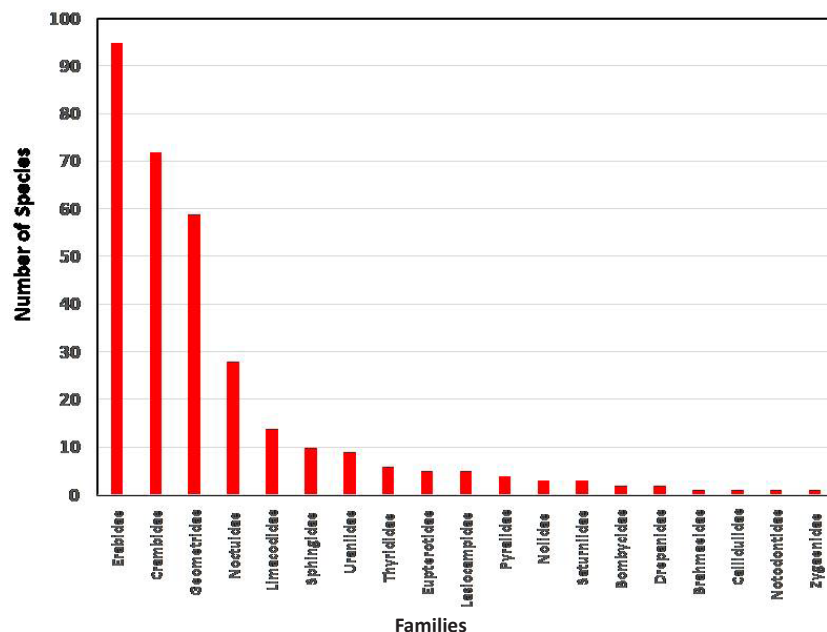


Figure 2. Four different forest types across the Shiwalik Landscape.

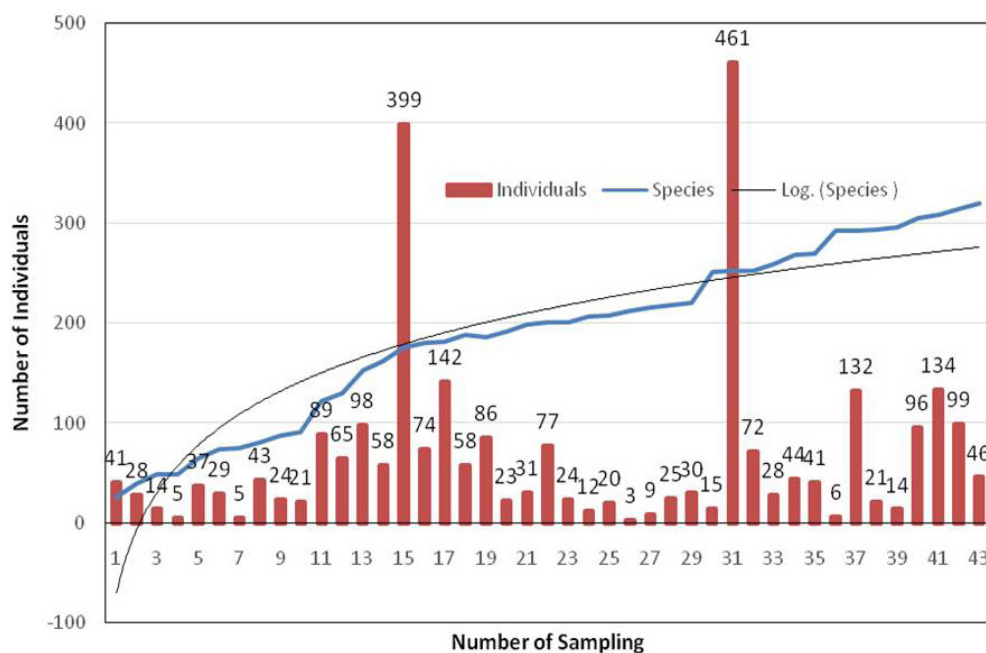


Figure 3. Species accumulation curve for the entire sampling period. 43 tours/surveys covering 59 sampling days.

the last sampling. These sites thus hold greater potential of adding more species to the list. However, sampling at Kalesar, Haridwar Chorgaliya, and Asarori was less frequent and recorded around only 40 species early till the end. In rest of the sites sampling was done only once and only a few species were recorded and more sampling effort was needed in these sites to arrive at any estimate of the number of moth species occurring

there. Species richness estimators indicate higher levels of species richness than current number of 321 species during 59 samplings (Chao 2—504; Jackknife 1—473 & Jackknife 2—562) in the study area.

### Seasonality

Seasonal trend of species richness showed two annual peaks, with the first peak occurring in August

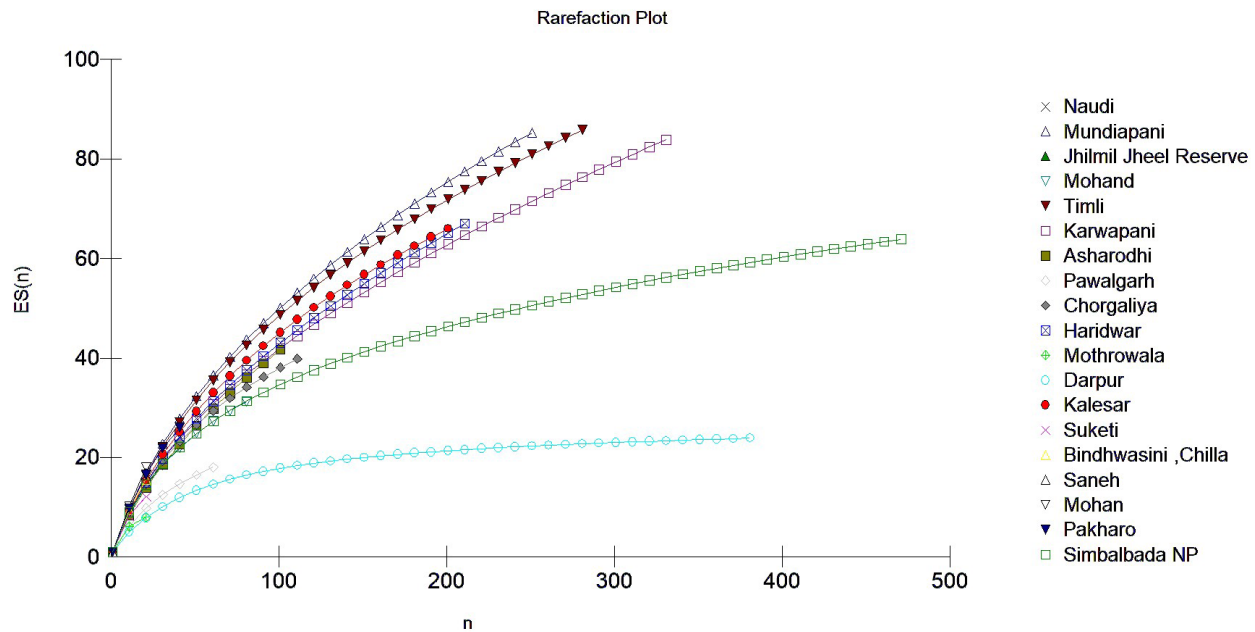


Figure 4. The rarefaction plot for moths sampled in 19 sites in Shiwaliks.

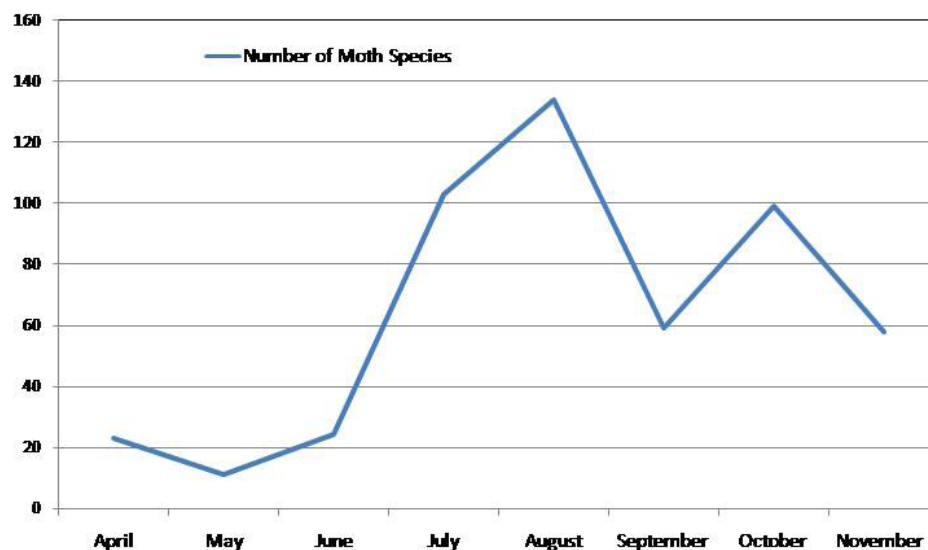


Figure 5. Species richness of moths sampled during different months of the year in Shiwaliks (2020–2022).

(monsoon season) followed by a smaller peak in October (post monsoon season) (Figure 5).

Species similarity of moths was greater between monsoon and post-monsoon seasons than for these seasons with pre-monsoon season (Figure 6), which indicates that species diversity of moths changes more rapidly with the onset of monsoon season as compared to pre-monsoon season.

#### Species diversity

Seasonal diversity: Shannon diversity index for the

three different seasons indicates that species diversity was highest during 'monsoon' followed by 'post monsoon', and 'pre-monsoon', respectively (Figure 7).

#### Site diversity

The sites with relatively higher diversity index ( $H' =$  above 1.5; Figure 8) were identified as Mundiapani, Timli, Karwapani, Haridwar, Kalesar, and Simbalbara.

#### Site similarity

In the ordination plot (Figure 9), two clusters of sites



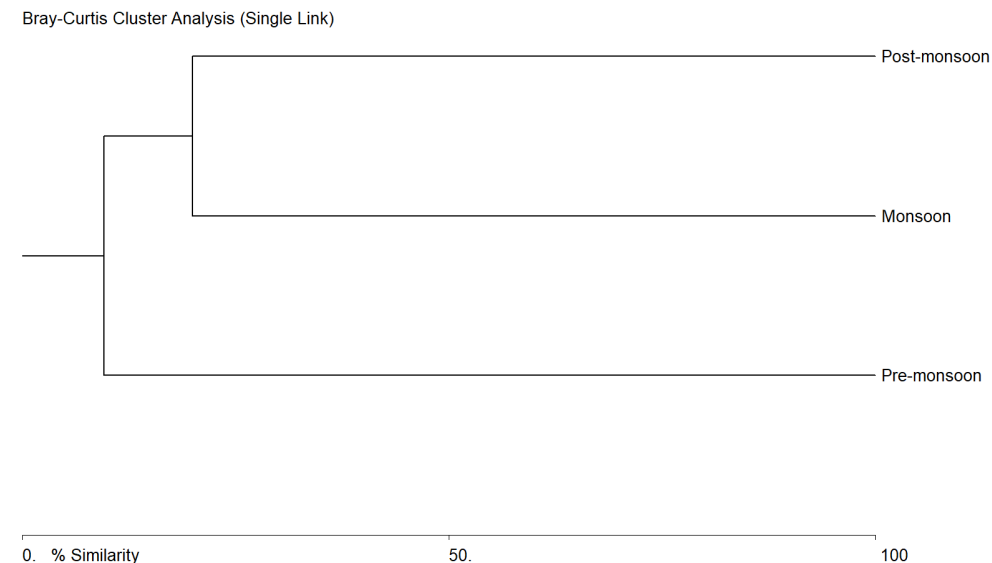


Figure 6. Moth species similarity amongst different seasons.

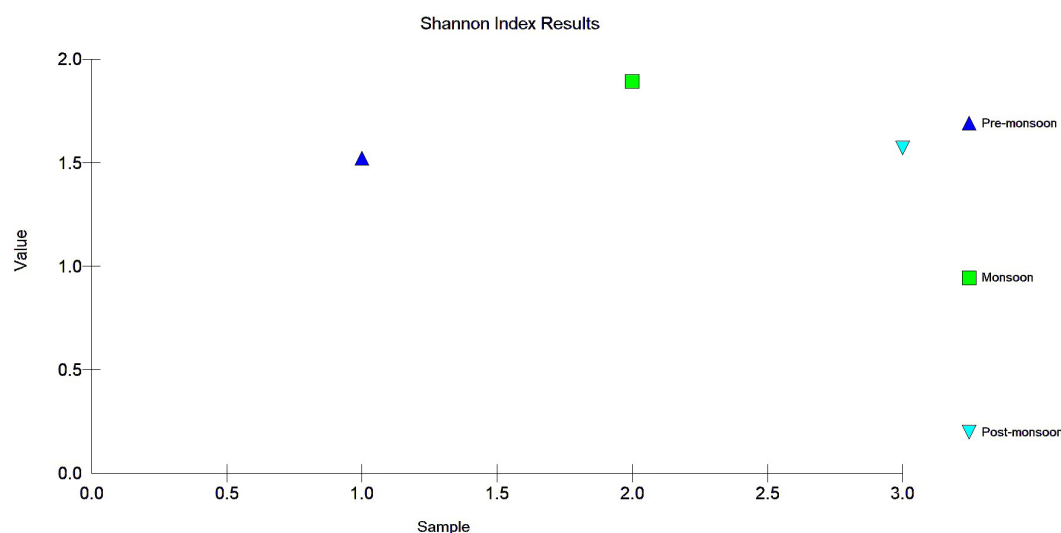


Figure 7. Shannon diversity index of moths during three different seasons of the year in Shiwaliks (2020–2022).

are formed, the first cluster 1 (red circle) consists of seven sites above Axis 2 that lie east of the river Ganga, while another cluster 2 (blue dash circle) of 12 sites lie below or on the Axis 2 that lie west of the river Ganga. The vegetation in the cluster 2 is mainly characterized by forests with high moisture regime (One site with 3C/C2c Moist Tarai Sal Forest & others with 3C/C2a Moist Siwalik Sal Forest) (Figure 10) as compared to cluster 2 (5B/C2 Northern Dry Mixed Deciduous Forest; a few sites having 3C/C2a Moist Siwalik Sal Forest and one site with 5B/C1a Dry Siwalik Sal Forest; Figure 10). This clearly indicates the changing vegetation structure in the

Shiwaliks as we move from east to west, hence changing moth communities with changing vegetation. However, only three sites with high diversity index, Mundiapani (3C/C2a Moist Siwalik Sal Forest), Chorgaliya (3C/C2c Moist Tarai Sal Forest) and Simbalbara (5B/C2 Northern Dry Mixed Deciduous Forest) were identified as sites with unique moth communities from the rest (Figure 9, 10 & 11).

#### Forest types similarity

Index of similarity or Jaccard's Coefficient (Jaccard 1901) amongst the four forest sub-types suggests that

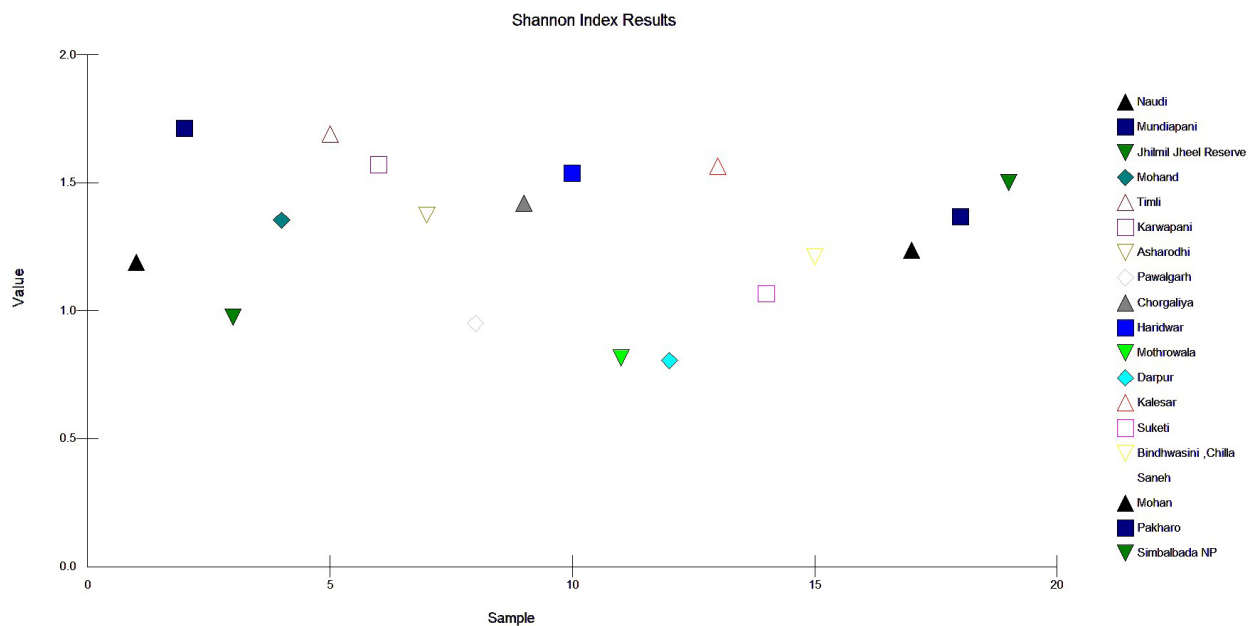


Figure 8. Shannon diversity index of moths for 19 different sites sampled across the Shiwaliks (2020–2022).

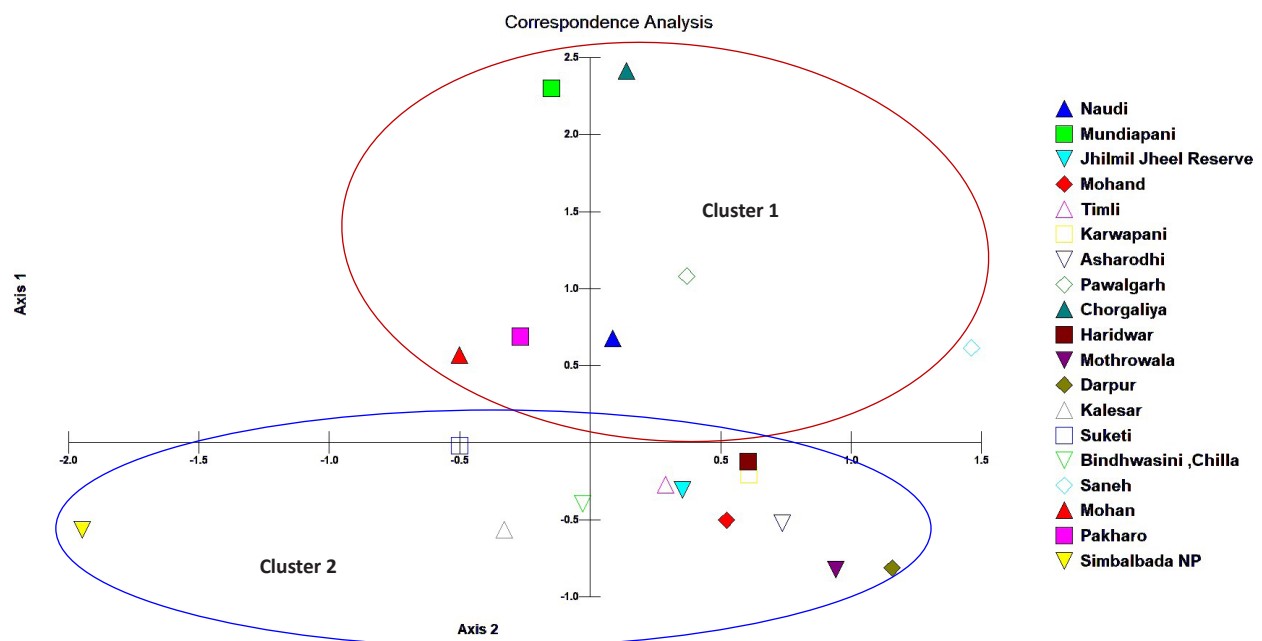


Figure 9. Correspondence analysis ordination graph of plots realised from species abundance data showing relative position of 19 sites.

all forest sub-types show low similarity with each other (less than 0.3157; Table 2) and the maximum similarity exists between 3C/C2a Moist Shiwalik Sal Forest and 5B/C2 Northern Dry Mixed Deciduous Forest. This is an indicator of diverse and distinct moth fauna existing in these four forest sub-types across the landscape.

### New range extensions

During recent surveys of moths in the Shiwalik ranges of northern India the authors have already reported *Lymantria tadora* (Erebidae) from Shiwaliks of Haryana State as a new range extension from central Nepal (Singh & Lekhendra 2023). Other five new range extensions from the two sampling sites, (i) Simbalbada WS, Sirmaur District, H.P., & (ii) Mundiapani, Kalagarh



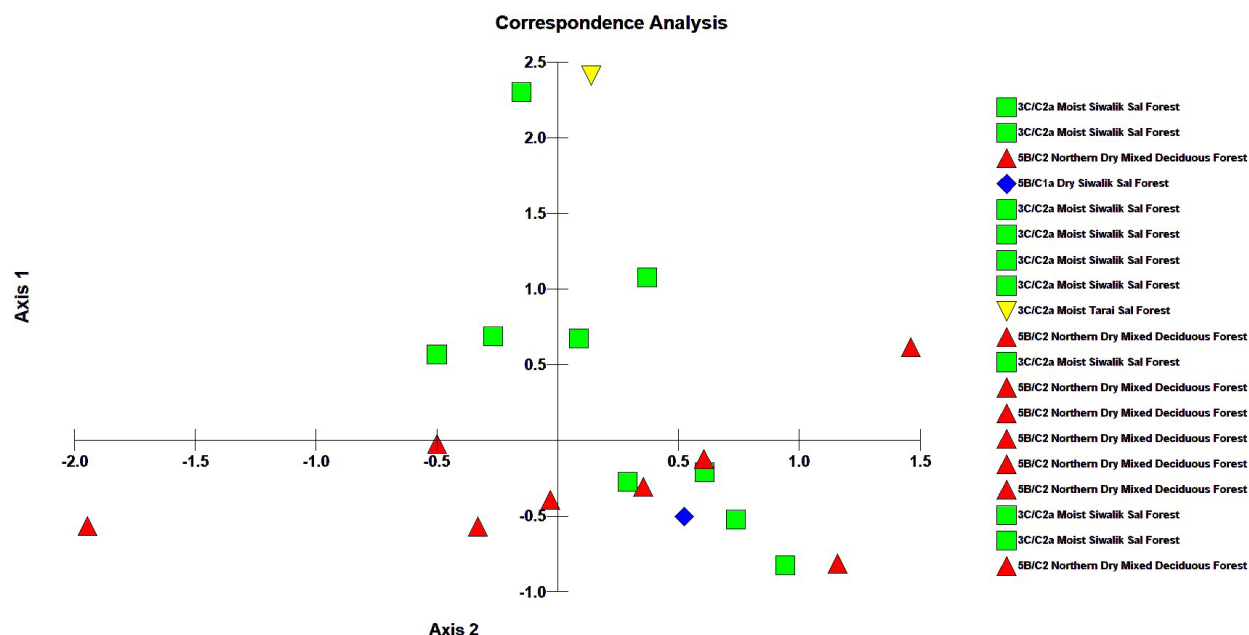


Figure 10. Correspondence analysis ordination graph of plots realised from species abundance data showing relative position of four forest type groups for 19 sampling sites.

Forest Division, Sonandi WS in Uttarakhand (Figure 11, sites marked in red circles) are reported for the first time in this paper for species otherwise known from central Nepal and northeastern India.

### 1. *Chlorozancla falcatus* (Butler, 1889) (Geometridae: Geometrinae: Geometrini)

One individual of *C. falcatus* (Image 3) was recorded during monsoon season (18.viii.2022; Temp 28.6°C & RH 84%) at Mundiapani [29.6947 °N & 78.7760 °E, 521 m; Forest type - 3C/C2a Moist Shiwalik Sal Forest (Champion & Seth 1968)] in Kalagarh Forest Division, Uttarakhand Shiwaliks, India. *Chlorozancla* genus occurs in Asia [Japan, China, India (Himalaya, Khasi hills)], Sumatra, Java & Borneo (Hampson, 1895). The type species *falcatus* was described from Sikkim, and India (Chhattisgarh, Karnataka, Kerala) (Kirti et al. 2012; Chandra et al. 2019; Anonymous 2023a) and is also known from Nepal (Haruta 1995). The larval food plant of the species is *Lagerstroemia speciosa* (Lythraceae) (Robinson et al. 2010). The moth is dull grey-green. Fore wing with the base yellowish; a pale straight erect post medial line; a yellow fascia below costa towards apex, with a hyaline spot on it. Hind wing with a hyaline medial band, wider and with yellow edges towards inner margin; traces of a sub marginal straight line. Expanse 28 mm (Hampson 1895). This record from Mundiapani is the first confirmed record of this species from the

Shiwaliks, which is ~900 km from Mechi Godok (964 m) in eastern Nepal, the nearest known site record of this species.

### 2. *Cynaeda dichroalis* (Hampson, 1903) (Crambidae: Odontiinae: Odontiini)

One individual of *C. dichroalis* (Image 4) was recorded during monsoon (18.viii.2022; Temp. 28.6 °C & RH 84%) at Mundiapani [29.6947 °N & 78.7760 °E, 521m; Forest type - 3C/C2a Moist Shiwalik Sal Forest (Champion & Seth 1968)] in Kalagarh Forest Division, Uttarakhand Shiwaliks, India. The species occurs in Ceylon, Sri Lanka, Sabah, China (Yunnan) in Lowland primary & disturbed forest (Hampson 1903). The species has also been reported from East Karbi Analog District, Assam; South Garo Hills District, Meghalaya; Coimbatore, Tamil Nadu in India (Anonymous 2023b). However, there is no record of this species from northern India. The species is identified by Palpi being slightly marked with black towards extremity; frontal prominence black at sides; abdomen with the first three segments mostly black on dorsum and the next two largely marked with black. Forewings with the inner area fuscous black to beyond middle and confluent with spots on base of costa. Hind wing with the basal area fuscous. Wing expanse 18 mm (Hampson 1903). This record from Mundiapani is the first confirmed record of this species from the Shiwaliks, which is ~1,300 km from South Garo Hills District (349

Table 1. Details of sampling sites, dates and weather parameters at the time of sampling.

	Sampling site	Forest status	District	State	Forest type (Champion & Seth 1968)	Altitude (m)	Sampling date	Season	Temperature (°C)	Relative humidity (%)
1.	Naudi FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	765	20.vii.2020	Monsoon	27.0	85
2.	Naudi FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	765	21.vii.2020	Monsoon	26.3	86
3.	Mundiapani FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	521	22.vii.2020	Monsoon	27.7	86
4.	Mundiapani FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	521	23.vii.2020	Monsoon	26.8	84
5.	Jhimil Jheel Reserve FRH	Conservation Reserve	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous Forest	303	26.x.2022	Post-monsoon	20.5	75
6.	Mohand FRH	Reserve Forest	Saharanpur	Uttar Pradesh	5B/C1a Dry Siwalik Sal Forest	462	27.x.2020	Post-monsoon	21.5	64
7.	Timili FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	574	28.x.2020	Post-monsoon	14.5	71
8.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	596	01.vii.2021	Monsoon	30.8	73
9.	Sabhawala, Malhan FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	520	02.vii.2021	Monsoon	29.1	70
10.	Timili FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	574	03.vii.2021	Monsoon	29.6	60
11.	Mohand FRH	Reserve Forest	Saharanpur	Uttar Pradesh	5B/C1a Dry Siwalik Sal Forest	462	08.vii.2021	Monsoon	28.1	71
12.	Asharodhi FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	642	09.vii.2021	Monsoon	29.4	78
13.	Mundiapani FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	521	10.viii.2021	Monsoon	27.2	87
14.	Mundiapani FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	521	11.viii.2021	Monsoon	30.7	93
15.	Pawalgarh FRH	Conservation Reserve	Nainital	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	466	12.vii.2021	Monsoon	27.2	90
16.	Pawalgarh FRH	Conservation Reserve	Nainital	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	466	13.viii.2021	Monsoon	27.3	84
17.	Chorgaliya FRH	Nandhaur WLS edge	Haldwani	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	327	14.vii.2021	Monsoon	28.2	92
18.	Kalesar FRH	Reserve Forest	Yamuna Nagar	Haryana	5B/C2 Northern Dry Mixed Deciduous Forest	384	21.ix.2021	Post-monsoon	27.8	83
19.	Darapur FRH	Reserve Forest	Yamuna Nagar	Haryana	5B/C2 Northern Dry Mixed Deciduous Forest	347	22.ix.2021	Post-monsoon	29.3	74
20.	Timili FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	574	23.ix.2021	Post-monsoon	27	77
21.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	596	13.x.2021	Post-monsoon	25.4	71
22.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	596	14.x.2021	Post-monsoon	25.8	67
23.	Mohand FRH	Reserve Forest	Saharanpur	Uttar Pradesh	5B/C1a Dry Siwalik Sal Forest	462	20.x.2021	Post-monsoon	22.6	86
24.	Mohand FRH	Reserve Forest	Saharanpur	Uttar Pradesh	5B/C1a Dry Siwalik Sal Forest	462	21.x.2021	Post-monsoon	20.8	81
25.	Asharodhi FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	685	22.x.2021	Post-monsoon	20.1	78
26.	Asharodhi FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	685	22.x.2021	Post-monsoon	17.8	83
27.	Asharodhi FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	685	22.x.2021	Post-monsoon	16.4	86



	Sampling site	Forest status	District	State	Forest type (Champion & Seth 1968)	Altitude (m)	Sampling date	Season	Temperature (°C)	Relative humidity (%)
28.	Mathrowala FRH	Rajaji National Park edge	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	537	27.x.2021	Post-monsoon	19.1	81
29.	Simbalbada FRH	Simbalbara National Park edge	Sirmour	Himachal Pradesh	5B/C2 Northern Dry Mixed Deciduous Forest	468	22.xi.2021	Post-monsoon	17.9	70
30.	Kalesar FRH	Reserve Forest	Yamuna Nagar	Haryana	5B/C2 Northern Dry Mixed Deciduous Forest	384	23.xi.2021	Post-monsoon	17.8	72
31.	Suketi FRH	Reserve Forest	Sirmaur	Himachal Pradesh	5B/C2 Northern Dry Mixed Deciduous Forest	404	24.xi.2021	Post-monsoon	18.2	76
32.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	596	25.xi.2021	Post-monsoon	19.2	73
33.	Haridwar -Chandighat Temple	Reserve Forest	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous Forest	349	12.iv.2022	Pre-monsoon	28.8	49
34.	Haridwar-Chandighat Temple	Reserve Forest	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous Forest	349	12.iv.2022	Pre-monsoon	29.2	52
35.	Mohand FRH	Reserve Forest	Saharanpur	Uttar Pradesh	5B/C1a Dry Siwalik Sal Forest	462	13.iv.2022	Pre-monsoon	27.1	39
36.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	596	14.iv.2022	Pre-monsoon	24.6	46
37.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	596	15.iv.2022	Pre-monsoon	23.9	46
38.	Bindwasini Village	Rajaji National Park Forest Edge	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous	464	22.iv.2022	Pre-monsoon	25.6	40
39.	Timil FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	574	14.vi.2022	Pre-monsoon	31	59
40.	Timil FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	574	15.vi.2022	Pre-monsoon	27	66
41.	Haridwar -Chandighat Temple	Reserve Forest	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous	349	03.vi.2022	Pre-monsoon	32	35
42.	Simbalbada FRH	Simbalbara National Park edge	Sirmour	Himachal Pradesh	5B/C2 Northern Dry Mixed Deciduous	468	02.vii.2022	Monsoon	28.3	86
43.	Simbalbada FRH	Simbalbara National Park edge	Sirmour	Himachal Pradesh	5B/C2 Northern Dry Mixed Deciduous	468	03.vii.2022	Monsoon	29.8	84
44.	Kalesar FRH	Reserve Forest	Yamuna Nagar	Haryana	5B/C2 Northern Dry Mixed Deciduous	384	03.vii.2022	Monsoon	30.2	80
45.	Timil FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	574	04.vii.2022	Monsoon	29.8	87
46.	Haridwar -Chandighat Temple	Reserve Forest	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous	349	09.vii.2022	Monsoon	31.2	75
47.	Haridwar -Chandighat Temple	Reserve Forest	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous	349	10.vii.2022	Monsoon	25.7	87
48.	Pakharo FRH Kalagarh	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	301	16.viii.2022	Monsoon	30.9	72
49.	Pakharo FRH Kalagarh	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	301	17.viii.2022	Monsoon	29.5	80
50.	Sanah FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	310	17.viii.2022	Monsoon	31	79
51.	Mundiapani FRH	Sonandi Wildlife Sanctuary	Pauri Garhwal	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	521	18.vii.2022	Monsoon	28.6	84
52.	Mohan FRH	Reserve Forest	Almora	Uttarakhand	3C/C2a Moist Siwalik Sal Forest	515	19.viii.2022	Monsoon	27.9	86

	Sampling site	Forest status	District	State	Forest type (Champion & Seth 1968)	Altitude (m)	Sampling date	Season	Temperature (°C)	Relative humidity (%)
53.	Chorgaliya FRH	Nandhaur Wildlife Sanctuary edge	Haldwani	Uttarakhand	3C/C2a Moist Tarai Sal F	327	20.viii.2022	Monsoon	28.5	85
54.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Shiwalik Sal Forest	596	01.x.2022	Post-monsoon	24.3	87
55.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Shiwalik Sal Forest	596	04.x.2022	Post-monsoon	25.6	89
56.	Haridwar-Chandighat Temple	Reserve Forest	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous	349	02.x.2022	Post-monsoon	26.8	78
57.	Haridwar-Chandighat Temple	Reserve Forest	Haridwar	Uttarakhand	5B/C2 Northern Dry Mixed Deciduous	349	03.x.2022	Post-monsoon	26.6	82
58.	Timil FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Shiwalik Sal Forest	596	08.x.2022	Post-monsoon	24.8	88
59.	Karwapani FRH	Reserve Forest	Dehradun	Uttarakhand	3C/C2a Moist Shiwalik Sal Forest	583	16.x.2022	Post-monsoon	25.1	83

m) in northeastern India, the nearest known site record of this species.

### 3. *Dichocrocis pyrrhalis* (Walker, 1859) (Crambidae: Spilomelinae)

One individual of *D. pyrrhalis* (Image 5) was also recorded during monsoon season (02.vii.2022; Temp 29.8 °C; RH-84%) in the Shiwaliks range of Simbalbara NP, [30.4253 °N & 77.4332 °E; 468 m; forest sub-type-5B/C2 Northern Dry Mixed Deciduous Forest (Champion & Seth 1968)] Sirmaur District, Himachal Pradesh. The genus *Dichocrocis* is found in Asia, North America, Africa, Australia, and Ceylon (Hampson 1896). *D. pyrrhalis* is known from Borneo, Sarawak, Nilgiri's Ceylon (Wing expanse 26 mm) (Walker 1859; Hampson 1896). In India *D. pyrrhalis* found Maharashtra, Karnataka (Anonymous 2023c). Palpi curved hardly rising above the vertex; second joint with a slight luteous mark on the outer side; abdomen extending rather far beyond the hind wings, with a luteous stripe along each side and with a black apical mark. Fore wings with six luteous bands; Hind wings with four luteous bands, wing expanse 30 mm (Walker 1859). This record from Simbalbara is the first confirmed record of this species from the Shiwaliks, which is ~1,400 km from the nearest known site record of this species.

### 4. *Acropteris iphiata* (Guenée, 1857) (Uraniidae: Microniinae)

One individual of *Acropteris iphiata* (Image 6) was recorded during monsoon season (11.viii.2021; Temp. 28.6 °C; RH 84%) at Mundiapani [29.6947 °N & 78.7760 °E, 521m; Forest type - 3C/C2a Moist Shiwalik Sal Forest (Champion & Seth 1968)] in Kalagarh Forest Division, Uttarakhand Shiwaliks, India. The genus occurs in Japan and throughout the Oriental and Australian regions (Hampson 1895). *Acropteris iphiata* is found in Japan, Burma, China, Himalaya, Khasi, & eastern Himalaya (Hampson 1895; Sanyal et al. 2018) and northeastern India (Arunachal Pradesh, Assam, Meghalaya, West Bengal) (Anonymous 2023f). The species *iphiata* differs from *striataria* in the cell of the fore wing being suffused with fuscous; the first line single and well defined; the marginal line of both wings almost black. Expanse: 3,236 mm (Hampson 1895). This record from Mundiapani is the first confirmed record of this species from the Shiwaliks, which is ~1,000 km from the nearest known site record of this species.



Image 3. *Chlorozancla falcatus* (Butler, 1889)Image 4. *Cynaeda dichroalis* (Hampson, 1903)Image 5. *Dichocrocis pyrrhalis* (Walker, 1859).Image 6. *Acropteris iphiata* (Guenée, 1857)Image 7. *Glyphodes canthusalis* Walker, 1859

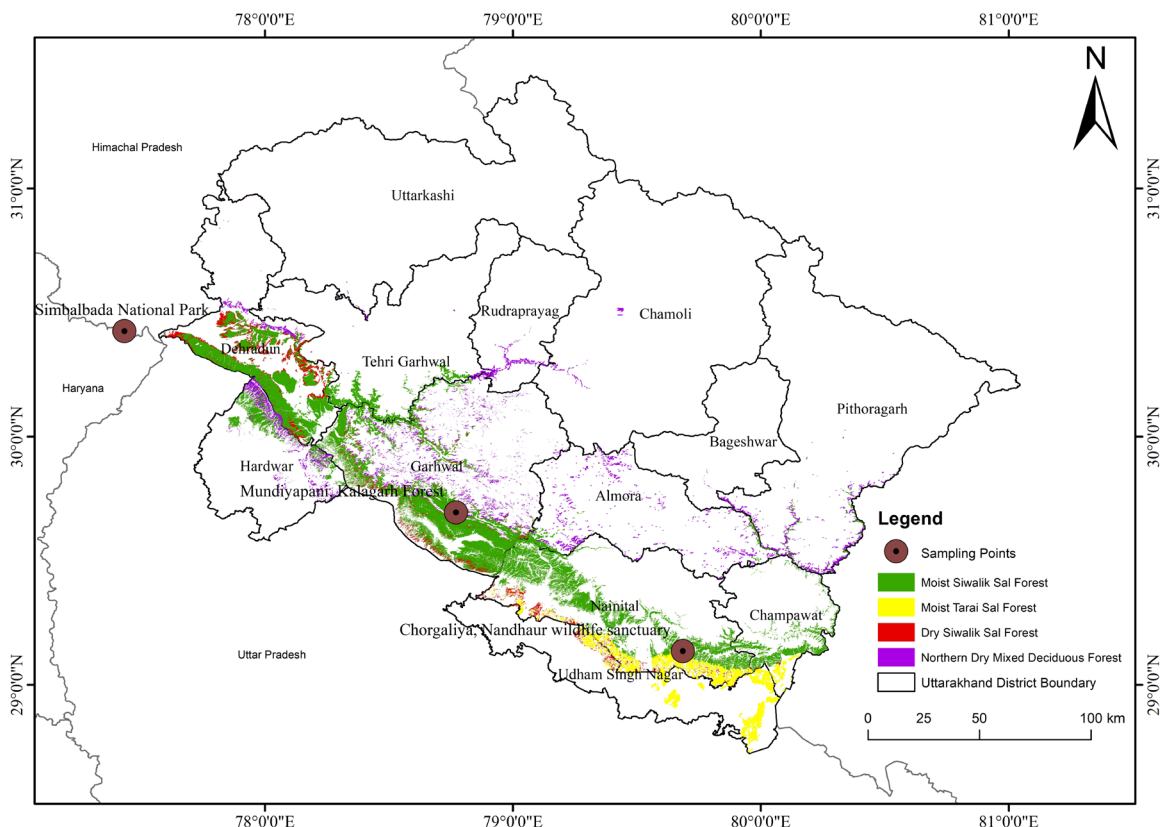
##### 5. *Glyphodes canthusalis* Walker, 1859 (Crambidae: Spilomelinae: Margaroniini)

One individual (Image 7) was recorded during monsoon season (11.viii.2021; Temp 28.6 °C; RH 84%) at Mundiapani [29.6947 °N & 78.7760 °E, 521 m; Forest type - 3C/C2a Moist Shiwalik Sal Forest (Champion & Seth 1968)] in Kalagarh Forest Division, Uttarakhand Shiwaliks, India. The genus is found in tropical and warmer temperate Zones (Hampson 1896). The species *Glyphodes canthusalis* occurs in Sarawak, Borneo, Nepal, Bhutan, Sri Lanka, Myanmar, China, Taiwan, Indonesia (Sumatra, Borneo), Australia, Nigeria, central Himalaya, Bhutan (Walker 1859; Haruta 1995; Irungbam 2016; Sanyal et al. 2018; Chandra et al. 2019). In India, the species is found in Andamans, Sikkim, Assam, West Bengal, Andhra Pradesh, Arunachal Pradesh, Meghalaya, Maharashtra, Chhattisgarh, Jharkhand, Karnataka (Hampson 1896; Shah et al. 2018; Chandra et al. 2019; Anonymous 2023f). The moth is ferruginous red and yellow, spotted and irrorated with white; frons white; abdomen with paired white spots on basal segments. Fore wings with series of indistinct antemedial white spots. Hind wing with a large dark edged hyaline white post-medial patch from costa to vein 2. Wing expanse 30–36 mm. The larval food plant of the species is *Ficus religiosa* (Moraceae) (Hampson 1896; Robinson et al.

Table 2. Moth species similarity amongst forest sub-types.

	Forest sub-type	Similarity index		
		2.	3.	4.
		5B/C2 Northern Dry Mixed Deciduous Forest	3C/C2c Moist Tarai Sal Forest	5B/C1a Dry Shiwalik Sal Forest
1.	3C/C2a Moist Shiwalik Sal Forest	0.3157*	0.091*	0.105*
2.	5B/C2 Northern Dry Mixed Deciduous Forest	-	0.095*	0.071*
3.	3C/C2c Moist Tarai Sal Forest	-	-	0.042*

2010). This record from Mundiapani is the first confirmed record of this species from the Shiwaliks, which is ~600 km from Devi Ghat Narayangarh (519 m) in central Nepal, the nearest known site record of this species.



**Figure 11.** Conservation priority sites (red circles—left to right: i—Simbalbada | ii—Mundiyanpatti | iii—Chorgalyia) and the locations of new moth range extensions are reported as mentioned in the text.

## DISCUSSION

During the present study we were able to sample approximately 2/3 (64–68 %) of the estimated number of moth species occurring in the study area of Shiwaliks of northern India. The flight period of moths was recorded from April–October, but the species richness and abundance were both high only during July–October months, i.e., monsoon & post-monsoon seasons, and a pattern of two peaks (August & October) in species richness of moths annually was visible during this period. A total of 232 species showed occurrence in only one season and 140 species amongst them occurred only during the ‘monsoon’ season indicating a Univoltine habit or a short flight period of these species. Species richness of moths correlated positively with relative humidity ( $r^2 = 0.100$ ;  $p = 0.0142$ ;  $n = 59$ ) during the sampling period from April–November, with maximum number of species recorded (80–90 % RH) during the ‘monsoon’ season. Lunar phase correlated negatively with both species richness ( $r^2 = 0.0508$ ;  $p = -0.2253$ ;  $n = 59$ ) and abundance ( $r^2 = 0.0401$ ;  $p = -0.1551$ ;  $n = 59$ ) of moths attracted to light on moth screen.

This trend of seasonality for species richness and abundance of moths in the Shiwaliks is a bit different from that of moths occurring in the higher temperate Himalaya, i.e., Gangotri landscape of Uttarakhand, where catch success per night was recorded to be maximum during April–May (pre-monsoon season) and also during August–September (monsoon & early post-monsoon season), but was lower during June–July (early monsoon season) (Sanyal et al. 2013).

The families Crambidae, Erebiidae, Geometridae, and Noctuidae, respectively dominated the northern Indian Shiwalik landscape. In another study carried out on moths limited to the Nandhaur Wildlife Sanctuary, in the Shiwaliks in Uttarakhand state, the peak abundance of moths was recorded during the monsoon season and the family Erebiidae (10 species and 174 individuals) was the most dominant followed by Crambidae (four species and 148 individuals) out of the total six families and 347 individuals (Arya et al. 2021). In a recent assessment of the moth diversity of New Forest Campus in Dehradun valley (670 m; in the tropical moist deciduous forest zone, lying between the lower Himalayan ranges and the Shiwaliks), in Uttarakhand, the family Erebiidae

dominated (165 species), followed by Geometridae (74), Noctuidae (63), and Nolidae (27) respectively, and the maximum number of species was reported during July (monsoon) and October (post-monsoon season) (Singh et al. 2022). Another study carried out in Dehradun District and Devalsari Village in Tehri Garhwal (sub-tropical & temperate), Uttarakhand revealed 246 species with the family Erebidae to be the most dominant (96 species) (Sondhi & Sondhi 2016). Besides, in the higher western Himalaya from Gangotri Landscape, the family Geometridae dominated (113 species) followed by Erebidae (61) and Noctuidae (58), respectively (Sanyal et al. 2013). In the study conducted at Kedarnath WS, Uttarakhand, the family Geometridae (86 species) dominated followed by Erebidae (18) (Dey 2019). A study of moth diversity at various altitudes in the Nainital district, Kumaun (temperate & sub-tropical Himalayan region of Uttarakhand) revealed 887 different species of moths with the family Erebidae (260 species) being most dominant followed by the Geometridae (198) and Noctuidae (155), respectively (Smetacek 2008). Most of these studies in the north Indian landscape show a trend of seasonality and dominating families similar to the present study.

There is changing vegetation structure in the Shiwaliks as we move from east to west across the landscape in the study area (Figure 1). Forest sub-type 3C/C2c Moist Tarai Sal Forest (Figure 1, yellow colour) occurs in the extreme eastern part of the Shiwaliks and is characterized by high moisture regime whereas 5B/C2 Northern Dry Mixed Deciduous Forest (Figure 1, purple colour) occurs further west across the river Ganges while 5B/C1a Dry Siwalik Sal Forest (Figure 1, red colour) lies in the extreme western part of the study area. As moths are surrogates of plant diversity with their larval host plants occurring in the habitats where they live, the changing vegetation structure also indicated a changing moth community and this is reflected in the ordination plot (Figure 9,10) amongst the 19 sampling sites being separated into different clusters of forest types and proximity amongst them on the land.

Amongst the forest sub-types, 3C/C2a Moist Shiwalik Sal Forest sub-type holds the maximum number moth species occurring in the north Indian Shiwaliks as compared to the other forest sub-types owing to the large area of occupancy. Moths like *Chabula telphusalis* Walker, [1859] and *Cretonotos gangis* Linnaeus, 1762 were two such species whose abundance dominated and showed preference for '3C/C2a Moist Shiwalik Sal Forest' and similarly both *Cretonotos transiens* (Walker, 1855) and *Aegocera venulia* Cramer, 1777 abundance

dominated and preferred for '5B/C2 Northern Dry Mixed Deciduous Forest' (Appendix I).

The three sampling locations (Mundiapani, Chorgaliya & Simbalbara) in three different representative forest sub-types in the Shiwalik ranges were identified having unique (Figure 10) and relatively higher moth diversity than other sites, and can be recommended as priority areas for conservation of Shiwalik moth diversity and biodiversity in general. One of the reasons for this uniqueness is the well preserved and intact natural forest habitats here due to their legal protection status (i) Mundiapani-Sonanadi WS; (ii) Chorgaliya-Nandhaur WS & (iii) Simbalbara-Simbalbara/Col. Sher Jung NP). Besides, these sites revealed the occurrence of some unique and uncommon moths, i.e., *Brahmaea hearseyi* (Brahmaeidae), *Pidorus glaucopis* (Zygaenidae), *Antheraea assamensis* and *Antheraea mylitta* (Saturniidae) in Mundiapani; *Hypolamprus* sp. (Thyrididae) in Chorgaliya and Lunar Moth *Actias selene* (Saturniidae) in Simbalbara NP.

The five new range extensions recorded into the Shiwaliks of northern India are from central Himalaya and northeastern India indicate the affinity of these moths to the Oriental tropics, as tropical vegetation and climate over here is also mainly influenced and characterised by the monsoon rains. The pattern of new range extensions indicates the changing/expanding range margins of these moths, typically known from northeastern India /southeastern Asia, which may be associated with the current global climate change.

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**Appendix 1. Systematic list of moths (Heterocera) recorded in the Shiwaliks of northern India along with their relative number of individuals recorded on moth screen during the 43 field surveys covering 59 days of sampling at 19 locations (2020–2022) from Nandhaur Wildlife Sanctuary ,Uttarakhand to Simbalbara National Park, Himachal Pradesh.**

	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
A.	Bombycidae	Bombycinae	1.	<i>Penicillifera apicalis</i> (Walker, 1862)****	1	Mon
			2.	<i>Trilocha varians</i> (Walker, 1855)	1	Mon
B.	Brahmaeidae	-	3.	<i>Brahmaea hearseyi</i> White, 1862*	1	Mon
C.	Callidulidae	Callidulinae	4.	<i>Tetragonus catamitus</i> Geyer, 1832*	1	Mon
D.	Crambidae	Acentropinae	5.	<i>Eoophyla peribocalis</i> (Walker, 1859)	7	Mon
			6.	<i>Eoophyla</i> sp. Swinhoe, 1900	2	Mon
			7.	<i>Paracymoriza vagalis</i> (Walker, 1866)	3	Mon
			8.	<i>Parapoynx bilinealis</i> (Snellen, 1876) **	1	Post
			9.	<i>Parapoynx</i> sp. Hübner, [1825] *	1	Post
		Odontiinae	10.	<i>Cynaeda dichroalis</i> (Hampson, 1903) *	1	Mon
			11.	<i>Ategumia adipalis</i> (Lederer, 1863) *	3	Mon
		Pyraustinae	12.	<i>Hyalobathra illectalis</i> (Walker, 1859) **	2	Post
			13.	<i>Lamprosema poeonalis</i> Walker, 1859*	1	Mon
			14.	<i>Pagyda salvalis</i> Walker, 1859*	1	Post
			15.	<i>Pyrausta phoenicealis</i> Hubner, 1818***	1	Post
			16.	<i>Agathodes ostentalis</i> (Geyer, 1837) *	2	Mon
		Spilomelinae	17.	<i>Agrotera scissalis</i> Walker, [1866]]	4	Mon
			18.	<i>Agrotera basinotata</i> Hampson, 1981*	1	Mon
			19.	<i>Arthroschista hilaralis</i> (Walker, 1859)	1	Post
			20.	<i>Bradina admixtalis</i> (Walker, [1859]) *	1	Post
			21.	<i>Bradina diagonalis</i> Guenée, 1854*	9	Mon
			22.	<i>Chabula telfusalis</i> (Walker, 1859) *	20	Mon; Post
			23.	<i>Cirrhochrista brizoalis</i> (Walker, 1859)	1	Post
			24.	<i>Cirrhochrista fumipalpis</i> Felder & Rogenhofer, 1875	1	Mon
			25.	<i>Cnaphalocrocis medinalis</i> (Guenée, 1854)	65	Post
			26.	<i>Cnaphalocrocis rutilalis</i> (Walker, [1859])	310	Post
			27.	<i>Cnaphalocrocis trebiusalis</i> (Walker, 1859)	13	Post
			28.	<i>Conogethes punctiferalis</i> (Guenée, 1854)	1	Mon
			29.	<i>Cydalima lacticostalis</i> (Guenée, 1854) **	2	Mon
			30.	<i>Diaphania indica</i> (Saunders, 1851)	9	Post
			31.	<i>Dichocrocis pyrrhalis</i> (Walker, 1859)	1	Mon
			32.	<i>Endocrossis flavibasalis</i> (Moore, [1868])	1	Mon; Post
			33.	<i>Glyphodes bicolor</i> (Swainson, 1821)	19	Mon; Post
			34.	<i>Glyphodes bivitalis</i> Guenée, 1854	3	Mon; Post
			35.	<i>Glyphodes caesalis</i> (Walker, 1859) *	1	Mon
			36.	<i>Glyphodes canthusalis</i> Walker, 1859*	1	Mon
			37.	<i>Endocrossis flavibasalis</i> (Moore, [1868])	2	Mon
			38.	<i>Haritalodes derogata</i> (Fabricius, 1775) *	1	Post
			39.	<i>Herpetogramma basalis</i> (Walker, [1866])	1	Post
			40.	<i>Herpetogramma bipunctalis</i> (Fabricius, 1794)	2	Mon
			41.	<i>Herpetogramma luctuosale</i> (Guenée, 1854)	6	Mon

	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
			42.	<i>Herpetogramma phaeopteralis</i> (Guenée, 1854)	3	Pre; Mon; Post
			43.	<i>Herpetogramma</i> sp. Lederer, 1863**	4	Mon
			44.	<i>Herpetogramma</i> sp. Lederer, 1863	2	Mon
			45.	<i>Hodebertia testalis</i> (Fabricius, 1794)	3	Mon
			46.	<i>Hymenia perspectalis</i> (Hübner, 1796)	4	Mon
			47.	<i>Leucinodes orbonalis</i> Guenée, 1854**	1	Mon
			48.	<i>Maruca vitrata</i> Fabricius, 1787	25	Pre; Post
			49.	<i>Nausinoe perspectata</i> (Fabricius, 1775) **	2	Post
			50.	<i>Nomophila noctuella</i> (Denis & Schiffermüller, 1775)	6	Pre
			51.	<i>Notarcha aurolinealis</i> (Walker, 1859)*	3	Mon
			52.	<i>Omiodes analis</i> Snellen, 1880	82	Mon; Post
			53.	<i>Omiodes indicata</i> (Fabricius, 1775) *	3	Mon; Post
			54.	<i>Omiodes milvinalis</i> (Swinhoe, [1886]) *	3	Mon
			55.	<i>Omiodes</i> sp. Guenée, 1854	10	Pre; Mon; Post
			56.	<i>Omiodes</i> sp. Guenée, 1854	9	Post
			57.	<i>Orphnophanes eucerusalis</i> (Walker, 1859)	1	Post
			58.	<i>Pachynoa sabelialis</i> (Guenée, 1854) **	5	Mon; Post
			59.	<i>Paliga damastesalis</i> (Walker, 1859)	1	Mon; Post
			60.	<i>Palpita vitrealis</i> (Rossi, 1794)	1	Post
			61.	<i>Parotis marginata complex</i> (Hampson, 1893)	1	Mon
			62.	<i>Patania caletoralis</i> (Walker, 1859)	1	Mon
			63.	<i>Patania</i> sp. Moore, 1888*	1	Mon
			64.	<i>Pilocrocis milvinalis</i> Swinhoe, 1886**	3	Post
			65.	<i>Poliobotys ablactalis</i> (Walker, 1859) *	1	Mon
			66.	<i>Pycnarmon alboflavalis</i> (Moore, 1888) *	1	Mon
			67.	<i>Pycnarmon cribrata</i> (Fabricius, 1794) *	2	Post
			68.	<i>Pygospila tyres</i> (Cramer, [1780]) **	1	Post
			69.	<i>Rehimena phrynealis</i> (Walker, 1859)****	2	Mon
			70.	<i>Sameodes cancellalis</i> (Zeller, 1852) *	1	Mon
			71.	<i>Scirpophaga excerptalis</i> (Walker, 1863) *	1	Mon
			72.	<i>Scirpophaga incertulas</i> (Walker, 1863)	4	Mon; Post
			73.	<i>Spoladea recurvalis</i> (Fabricius, 1775)	27	Mon; Post
			74.	<i>Syllepte concatenalis</i> (Walker, 1865)	39	Mon
			75.	<i>Tysponodes linealis</i> (Moore, [1868]) *	1	Mon
			76.	<i>Udea ferrugalis</i> Hübner, 1796***	1	Post
E.	Drepanidae	Drepaninae	77.	<i>Tridrepana albonotata</i> (Moore, 1879) *	1	Post
			78.	<i>Teldenia vestigiata</i> Butler, 1880	5	Mon; Post
F.	Erebidae	Aganainae	79.	<i>Asota caricae</i> (Fabricius, 1775)	43	Pre; Mon; Post
		Arctiinae	80.	<i>Argina astrea</i> (Drury, 1773)*	1	Post
			81.	<i>Aloa lactinea</i> (Cramer, [1777]) **	1	Mon
			82.	<i>Asura calamaria</i> (Moore, 1888) **	2	Post
			83.	<i>Barsine orientalis bigamica</i> (Cerny & Pinratana, 2009)	8	Mon
			84.	<i>Brunia antica</i> (Walker, 1854)	9	Mon; Post
			85.	<i>Creatonotos gangis</i> (Linnaeus, 1763)*	17	Mon; Post
			86.	<i>Creatonotos transiens</i> (Walker, 1855) **	23	Mon; Post

	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
	Erebidae	Arctiinae	87.	<i>Cyana arama</i> (Moore, 1859) *	1	Pre; Mon; Post
			88.	<i>Cyana coccinea</i> (Moore, 1878)	8	Post
			89.	<i>Cyana puella</i> (Drury, 1773) *	1	Post
			90.	<i>Cyana</i> sp. Walker, 1854	1	Mon; Post
			91.	<i>Eilema cf. costalis</i> Moore, 1878	15	Mon; Post
			92.	<i>Eressa confinis</i> (Walker, 1854) *	1	Mon
			93.	<i>Juxtartia multiguttata</i> (Walker, 1855) **	1	Post
			94.	<i>Macrobrochis gigas</i> (Walker, 1854)	41	Mon
			95.	<i>Mangina argus</i> (Kollar, [1844]) **	1	Mon
			96.	<i>Miltochrista dharma</i> (Moore, 1879)	38	Mon; Post
			97.	<i>Miltochrista</i> sp. Hübner, [1819]	1	Mon
			98.	<i>Miltochrista terminospota</i> N. Singh, Kirti & Joshi, 2015	1	Mon
			99.	<i>Macotasa nubecula</i> (Moore, 1879)	15	Mon; Post
			100.	<i>Nyctemera adversata</i> (Schaller, 1788) *	2	Post
			101.	<i>Olepa ricini</i> (Fabricius, 1775)	8	Mon
			102.	<i>Phragmatobia fuliginosa</i> (Linnaeus, 1758)	1	Post
			103.	<i>Zadadra distorta</i> (Moore, 1872)	27	Post
			104.	<i>Rajendra biguttata</i> (Walker, 1855) **	1	Mon
			105.	<i>Rema tetraspila</i> Walker, 1865 **	1	Mon
			106.	<i>Spilosoma virginica</i> (Fabricius, 1798) **	2	Post
			107.	<i>Syntomoides imaon</i> (Cramer, [1779])	29	Pre; Mon; Post
			108.	<i>Wittia</i> sp.	9	Post
		Boletobiinae	109.	<i>Ataboruza divisa</i> (Walker, 1862) **	1	Post
			110.	<i>Diomea lignicolora</i> (Walker, [1858]) *	5	Mon
			111.	<i>Enispa</i> sp. Walker, [1866] **	1	Post
			112.	<i>Eublemma accedens</i> Felder & Rogenhofer, 1874)	2	Post
			113.	<i>Gesonina obeditalis</i> Walker, [1859] *	2	Post
			114.	<i>Zurobata vacillans</i> (Walker, 1864) **	1	Mon; Post
		Calpinae	115.	<i>Calyptra ophideroides</i> (Guenée, 1852) **	1	Post
			116.	<i>Episparis liturata</i> Fabricius, 1787*	1	Mon
			117.	<i>Eudocima cajeta</i> Cramer, ([1775]) **	1	Post
			118.	<i>Oraesia emarginata</i> (Fabricius, 1794)	2	Pre; Mon; Post
		Erebinae	119.	<i>Attatha ino</i> (Drury, 1782) **	1	Mon
			120.	<i>Artena dotata</i> (Fabricius, 1794)	4	Post
			121.	<i>Chalciope mygdon</i> (Cramer, [1777])	2	Post
			122.	<i>Bastilla arcuata</i> (Moore, 1877) *	1	Post
			123.	<i>Bastilla crameri</i> (Moore, [1885])	7	Mon; Post
			124.	<i>Entomogramma fautrix</i> Guenée, 1852 *	1	Post
			125.	<i>Erebus albicincta</i> Kollar, [1844] *	1	Post
			126.	<i>Erebus caprimulgus</i> (Fabricius, 1775)*	1	Mon
			127.	<i>Erebus hieroglyphica</i> (Drury, 1773) **	3	Post
			128.	<i>Fodina pallula</i> Guenée, 1852	8	Pre; Mon; Post
			129.	<i>Fodina stola</i> (Guenée, 1852) **	1	Mon
			130.	<i>Grammodes geometica</i> (Fabricius, 1775)	1	Mon



	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
		Erebinae	131.	<i>Homaea clathrum</i> Guenée, 1852****	3	Mon
			132.	<i>Hamodes propitia</i> (Guérin-Méneville, [1831])	1	Mon
			133.	<i>Ischyja marapok</i> Holloway, 2005****	3	Mon
			134.	<i>Mocis frugalis</i> (Fabricius, 1775)	23	Mon; Post
			135.	<i>Mocis undata</i> (Fabricius, 1775)	3	Mon; Post
			136.	<i>Nagia linteola</i> Guenée, 1852*	1	Mon
			137.	<i>Pericyma umbrina</i> (Guenée, 1852)	2	Mon; Post
			138.	<i>Spirama retorta</i> Clerck, 1764	2	Pre; Mon; Post
			139.	<i>Thyas coronata</i> (Fabricius, 1775) **	1	Mon
		Herminiinae	140.	<i>Adrapsa ereboides</i> (Walker, [1863]) *	1	Mon
			141.	<i>Progonia oileusalis</i> (Walker, [1859]) *	1	Post
		Hypeninae	142.	<i>Dichromia pullata</i> Moore, 1885*	4	Post
			143.	<i>Hypena iconicalis</i> Walker, [1859]	2	Post
			144.	<i>Hypena</i> spp. Schrank, 1802	2	Mon; Post
			145.	<i>Hypena</i> spp. Schrank, 1802	1	Mon
			146.	<i>Hypena</i> spp. Schrank, 1802	1	Post
			147.	<i>Hypena</i> spp. Schrank, 1802	5	Post
			148.	<i>Hypena laceratalis</i> Walker, [1859]	18	Mon; Post
			149.	<i>Hypena obacerralis</i> Walker, [1859] *	1	Post
		Hypocalinae	150.	<i>Hypocala deflorata</i> Fabricius, 1794*	1	Mon
		Lymantriinae	151.	<i>Artaxa digramma</i> (Boisduval, [1844])	3	Mon; Post
			152.	<i>Artaxa guttata</i> Walker, 1855	11	Pre; Mon; Post
			153.	<i>Artaxa</i> sp. Walker, 1855	1	Post
			154.	<i>Arctornis lactea</i> (Moore, 1879) *	1	Mon
			155.	<i>Arctornis comma</i> (Hutton, 1865) ***	1	Mon; post
			156.	<i>Arctornis submarginata</i> (Walker, 1855)**	1	Post
			157.	<i>Arctornis</i> sp. Germar, 1810	10	Mon; Post
			158.	<i>Calliteara</i> sp. Butler, 1881**	1	Mon
			159.	<i>Euproctis lunata</i> Walker, 1855**	1	Post
			160.	<i>Euproctis magna</i> (Swinhoe, 1891) *	1	Post
			161.	<i>Lymantria concolor</i> Walker, 1855*	9	Post
			162.	<i>Lymantria detersa</i> Walker, 1865**	1	Post
			163.	<i>Lymantria incerta</i> Walker, 1855	3	Mon; Post
			164.	<i>Lymantria marginata</i> Walker, 1855*	4	Pre; Mon
			165.	<i>Lymantria mathura</i> Moore, [1866]	8	Mon; Post
			166.	<i>Lymantria</i> sp. Hübner, [1819]	1	Pre
			167.	<i>Lymantria todara</i> Moore, 1879**	1	Post
			168.	<i>Olene</i> sp. Hübner, 1823	1	Post
			169.	<i>Orgyia postica</i> (Walker, 1855)	9	Mon; Post
			170.	<i>Somena scintillans</i> Walker, 1856	9	Pre; Mon; Post
		Scoliopteryginae	171.	<i>Anomis flava</i> (Fabricius, 1775)	1	Post
			172.	<i>Anomis fulvida</i> Guenée, 1852	2	Post
		Tinoliinae	173.	<i>Calesia dasypterus</i> Kollar, 1844**	1	Pre; Post

	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
G.	Eupterotidae	Eupterotinae	174.	<i>Eupterote bifasciata</i> Kishida, 1994	55	Mon
			175.	<i>Eupterote mollifera</i> Walker, 1865*	1	Mon
			176.	<i>Eupterote undata</i> Blanchard, [1844]	16	Mon
			177.	<i>Ganisa plana</i> Walker, 1855	7	Mon
			178.	<i>Ganisa</i> sp. Walker, 1855**	2	Mon
H.	Geometridae	Ennominae	179.	<i>Abraxas</i> sp. Leach, 1815	2	Post
			180.	<i>Abraxas</i> sp. Leach, 1815	1	Post
			181.	<i>Anonymia grisea</i> (Butler, 1883)	2	Mon; Post
			182.	<i>Biston suppressaria</i> (Guenée, [1858]) **	3	Pre; Mon
			183.	<i>Calletaera subexpressa</i> (Walker, 1861) **	1	Post
			184.	<i>Chiasmia eleonora</i> (Cramer, [1780])	10	Pre; Mon; Post
			185.	<i>Chiasmia emersaria</i> (Walker, 1861)**	6	Post
			186.	<i>Chiasmia</i> sp. Hübner, [1823]	1	Mon
			187.	<i>Chorodna strixaria</i> (Guenée, [1858]) **	1	Mon
			188.	<i>Cleora contiguata</i> (Moore, [1868])****	1	Mon
			189.	<i>Corymica</i> sp. Walker, 1860	2	Post
			190.	<i>Cusiala boarmoides</i> Moore, [1887] *	2	Mon
			191.	<i>Cusiala</i> sp. Moore, [1887]	1	Mon
			192.	<i>Dasyboarmia subpilosa</i> (Warren, 1894)	3	Post
			193.	<i>Dalima patularia</i> (Walker, 1860) *	1	Pre
			194.	<i>Ectropidia shoreae</i> (Prout, 1934) *	1	Mon; Post
			195.	<i>Eumelea</i> sp. Duncan [ & Westwood], 1841	2	Pre; Mon; Post
			196.	<i>Fascellina chromataria</i> Walker, 1860*	1	Mon
			197.	<i>Gonodontis clelia</i> (Cramer, [1780]) **	1	Post
			198.	<i>Hypochrosia abstractaria</i> (Walker, [1863])	3	Mon
			199.	<i>Hypomecis procursaria</i> (Walker, 1860) **	3	Post
			200.	<i>Heterostegane</i> sp. Hampson, 1893	1	Mon
			201.	<i>Heterostegane tritocampsis</i> (Prout, 1934)	5	Mon; Post
			202.	<i>Hypomecis cineracea</i> (Moore, 1888)	52	Pre; Mon; Post
			203.	<i>Hypomecis separata</i> (Walker 1860) *	16	Pre; Mon; Post
			204.	<i>Hypomecis</i> sp. Hübner, 1821	3	Post
			205.	<i>Hypomecis</i> sp. Hübner, 1821	1	Post
			206.	<i>Hydatocapnia marginata</i> (Warren, 1893)	1	Post
			207.	<i>Hydatocapnia</i> sp. Warren, 1895	1	Post
			208.	<i>Hyposidra talaca</i> Walker, 1860	28	Pre; Mon; Post
			209.	<i>Iridoplecta ferrifera</i> (Moore, 1888) ****	1	Mon
			210.	<i>Phazaca</i> sp. Walker, 1863****	1	Mon
			211.	<i>Scardamia</i> sp. Guenée, 1857*	1	Post
			212.	<i>Zamarada Euphrosyne</i> Oberthür, 1912	2	Post
			213.	<i>Zamarada</i> sp. Moore, [1887]	5	Mon; Post
		Geometrinae	214.	<i>Agathia lycaenaria</i> (Kollar, 1848)	3	Mon; Post
			215.	<i>Chlorozancla falcatus</i> (Butler, 1889) *	1	Mon
			216.	<i>Comibaena cassidara</i> (Guenée, [1858]) *	1	Mon
			217.	<i>Episothalma robustaria</i> (Guenée, 1858)	1	Post

	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
	Geometridae	Geometrinae	218.	<i>Hemithea tritonaria</i> (Walker, [1863]) **	4	Pre; Mon; Post
			219.	<i>Herochroma</i> sp. Swinhoe, 1893	1	Pre
			220.	<i>Maxates veninotata</i> (Warren, 1894)	4	Post
			221.	<i>Ornithospila avicularia</i> (Guenée, 1857) *	3	Mon
			222.	<i>Protulioenemis biplagiata</i> (Moore, [1887])	2	Pre; Post
			223.	<i>Pelagodes falsaria</i> (Prout, 1912)	1	Pre; Post
			224.	<i>Pelagodes</i> sp. Holloway, 1986	1	Post
			225.	<i>Pelagodes veraria</i> (Guenée, 1857)	2	Mon
			226.	<i>Pingasa ruginaria</i> (Guenée, [1858])	3	Post
			227.	<i>Pingasa</i> sp. Moore, [1887]	6	Pre
			228.	<i>Spaniocentra lyra</i> (Swinhoe, 1982)	4	Pre;post
			229.	<i>Thalassodes quadraria</i> Guenée, 1857*	1	Post
		Larentiinae	230.	<i>Eupithecia abisinthiata</i> Clerck, 1759*	2	Mon
			231.	<i>Photoscotosia miniosata</i> (Walker, 1862)	1	Post
		Sterrhinae	232.	<i>Scopula cuneilinea</i> (Walker, [1863])	1	Pre
			233.	<i>Anisephyra ocularia</i> (Fabricius, 1775) *	5	Mon
			234.	<i>Problepsis albidior</i> Warren, 1899	3	Mon
			235.	<i>Scopula cuneilinea</i> (Walker, [1863])	1	Mon
			236.	<i>Scopula</i> sp. Schrank, 1802***	6	Pre; Mon; Post
			237.	<i>Scopula</i> sp. Schrank, 1802**	1	Mon; Post
			238.	<i>Scopula</i> sp. Schrank, 1802	3	Pre; Post
			239.	<i>Traminda mundissima</i> (Walker, 1861) *	4	Mon
I.	Lasiocampidae	Lasiocampinae	240.	<i>Gastropacha</i> sp. Ochsenheimer, 1810**	1	Mon; Post
			241.	<i>Kunugia</i> sp. Nagano, 1917	3	Mon; Post
			242.	<i>Metanastria</i> sp. Hübner, [1820]**	3	Mon
			243.	<i>Trabala vishnou</i> (Lefèbvre, 1827)	3	Mon; Post
		Pinarinae	244.	<i>Lebeda trifascia</i> Walker, 1855	1	Mon
J.	Limacodidae	Limacodinae	245.	<i>Aergina hilaris</i> (Westwood, 1848)	30	Mon; Post
			246.	<i>Altha subnotata</i> (Walker, 1865)	33	Mon
			247.	<i>Cania bilinea</i> (Walker, 1855)	1	Mon
			248.	<i>Cheromettia apicata</i> (Moore, 1879) **	9	Mon
			249.	<i>Cheromettia</i> sp. Moore, 1883	1	Mon
			250.	<i>Miresa argentifera</i> Walker, 1855*	1	Mon
			251.	<i>Miresa bracteata</i> Butler, 1880	25	Mon
			252.	<i>Miresa fulgida</i> Wileman, 1910*	1	Mon
			253.	<i>Parasa lepida</i> Cramer, 1799*	2	Mon
			254.	<i>Phocoderma velutina</i> (Kollar, [1844])	66	Mon; Post
			255.	<i>Thespea bicolor</i> (Walker, 1855)*	2	Mon
			256.	<i>Thosea</i> sp. Walker, 1855	42	Mon; Post
			257.	<i>Scopelodes testacea</i> Buttler, 1886	34	Mon
			258.	<i>Scopelodes venosa</i> Walker, 1855**	2	Mon

	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
K.	Noctuidae	Agaristinae	259.	<i>Aegocera venulia</i> Cramer, [1777]**	17	Mon; Post
			260.	<i>Episteme adalatrix</i> (Kollar, [1884])*	1	Mon
		Amphipyriinae	261.	<i>Callyna jugaria</i> Walker, 1858	10	Pre; Mon; Post
			262.	<i>Callyna monoleuca</i> Walker, 1858	12	Mon
			263.	<i>Callyna</i> sp. Guenée, 1852	6	Mon
		Bagisarinae	264.	<i>Chasmina candida</i> Walker, 1865	2	Mon
			265.	<i>Chasmina</i> sp. Walker, 1856	1	Pre; Mon
		Condicinae	266.	<i>Bagada spicea</i> (Guenée, 1852)	2	Pre; Mon
			267.	<i>Condica conducta</i> Walker 1857	1	Pre; Mon; Post
			268.	<i>Condica</i> sp. Walker, 1856***	1	Mon
		Eustrotiinae	269.	<i>Amyra axis</i> (Guenée, 1852)	19	Mon; Post
			270.	<i>Maliattha quadripartita</i> (Walker, 1865)	10	Mon
			271.	<i>Maliattha separata</i> Walker, 1863	2	Mon; Post
			272.	<i>Maliattha</i> sp. Walker, 1863	1	Post
		Hadeninae	273.	<i>Athetis delecta</i> (Moore, 1881) **	1	Pre
			274.	<i>Leucania</i> sp. Ochsenheimer, 1816*	1	Mon
			275.	<i>Mythimna (Aletia) hamifera</i> (Walker, 1862)	2	Mon
		Heliothinae	276.	<i>Helicoverpa armigera</i> (Hübner, [1808]) *	6	Pre; Mon; Post
		Noctuinae	277.	<i>Axylyia</i> sp. Hübner, [1821]	1	Post
			278.	<i>Leucania yu</i> Guenée, 1852 *	1	Post
			279.	<i>Spodoptera litura</i> (Fabricius, 1775)	32	Pre; Mon; Post
			280.	<i>Spodoptera</i> sp. Guenée, 1852****	1	Mon; Post
		Plusiinae	281.	<i>Chrysodeixis eriosoma</i> Doubleday, 1843*	5	Mon; Post
			282.	<i>Thysanoplusia intermixta</i> (Warren, 1913)	2	Post
			283.	<i>Thysanoplusia orichalcea</i> (Fabricius, 1775)	2	Pre; Post
			284.	<i>Thysanoplusia reticulata</i> (Moore, 1882)	1	Post
			285.	<i>Thysanoplusia</i> sp. Ichinosé, 1973****	1	Mon
			286.	<i>Thysanoplusia</i> sp. Ichinosé, 1973	3	Pre; Mon
L.	Nolidae	Chloephorinae	287.	<i>Carea angulata</i> (Fabricius, 1793)	1	Mon
		Eligminae	288.	<i>Selepa celtis</i> Moore, [1860]*	2	Post
		Westermanniinae	289.	<i>Westermannia superba</i> Hübner, 1823**	3	Mon; Post
M.	Notodontidae	Phalerinae	290.	<i>Phalera grotei</i> Moore, 1859	70	Mon
N.	Pyralidae	Pyralinae	291.	<i>Arippe indicator</i> Walker, [1864]*	1	Mon; Post
			292.	<i>Zitha torridalis</i> (Lederer, 1863)	1	Mon
O.	Sphingidae	Macroglossinae	293.	<i>Acosmeryx pseudonaga</i> Butler, 1881*	1	Mon
			294.	<i>Eupanacra mydon</i> (Walker, 1856)	1	Mon
			295.	<i>Macroglossum corythus</i> Walker, 1856	2	Pre
			296.	<i>Nephele hespera</i> (Fabricius, 1775) *	3	Pre
		Smerinthinae	297.	<i>Anambulyx elwesi</i> (Druce, 1882) *	1	Mon
			298.	<i>Marumba cristata</i> (Butler, 1875) *	1	Mon
			299.	<i>Marumba dyras</i> (Walker, 1856) **	1	Mon
			300.	<i>Marumba indicus</i> (Walker, 1856) **	14	Mon
			301.	<i>Marumba</i> sp. Moore, 1882	1	Mon
		Sphinginae	302.	<i>Dolbina inexacta</i> (Walker, 1856)*	1	Mon



	Family	Sub-family		Scientific name	No. of individuals sampled	Flight period/ Seasons #
P.	Saturniidae	Saturniinae	303.	<i>Actias selene</i> (Hübner, [1807])	6	Mon; Post
			304.	<i>Antheraea assamensis</i> Helfer, 1837*	1	Mon
			305.	<i>Antheraea mylitta</i> Drury, 1773*	1	Mon
		Siculodinae	306.	<i>Herdonia thaiensis</i> Inoue, 1993*	1	Mon
			307.	<i>Herdonia</i> sp. Walker, 1859	1	Mon
			308.	<i>Hypolamprus</i> sp. Hampson, [1893]****	2	Mon
			309.	<i>Opula</i> sp. Walker, 1869	1	Post
			310.	<i>Strigina scitaria</i> (Walker, 1862)	3	Mon; Post
			311.	<i>Strigina</i> sp. Guenée, 1877**	1	Mon
Q.	Uraniidae	Epileminae	312.	<i>Dysaethria lilacina</i> (Moore, [1887])*	2	Mon; Post
			313.	<i>Epilema fulvilinea</i> (Hampson, 1891) **	2	Mon; Post
			314.	<i>Epilema ruptaria</i> Moore, 1883*	1	Mon
			315.	<i>Epilema</i> sp. Herrich-Schäffer, [1855]	4	Mon
			316.	<i>Epilema</i> sp. Herrich-Schäffer, [1855]	1	Mon; Post
			317.	<i>Orudiza protheclaria</i> Walker, 1861	4	Mon
			318.	<i>Phazaca</i> sp. Walker, 1863****	1	Mon
		Microniinae	319.	<i>Acropteris iphiata</i> Guenée, 1857*	2	Mon
			320.	<i>Pseudomicronia</i> sp. Moore, 1887	1	Mon
R.	Zygaenidae	Chalosiinae	321.	<i>Pidorus glaucopsis</i> (Drury, 1773) *	1	Mon

\*Forest Sub-types (Champion & Seth 1968): \*— 3C/C2a Moist Shiwalik Sal Forest | \*\*—5B/C2 Northern Dry Mixed Deciduous Forest | \*\*\*—5B/C1a Dry Shiwalik Sal Forest | \*\*\*\*—3C/C2c Moist Tarai Sal Forest.

# Seasons: Pre—pre-monsoon | Mon—monsoon | Post— post-monsoon.

## Appendix II. GPS Coordinates of Sampling sites (Figure 1, East to West).

	Site	Coordinates	
		North	East
1	Chorgaliya	29.69797222	79.70508333
2	Pawalgarh	29.36477778	79.23961111
3	Mohan	29.54863889	79.10980556
4	Mundiapani	29.69475000	78.77605556
5	Naudi	29.78497222	78.62586111
6	Pakharo Kalagarh	29.59313889	78.57655556
7	Saneh	29.69316667	78.52483333
8	Bindhwasini	30.00361111	78.32363889
9	Jhilmil Jheel	29.80602778	78.22480556
10	Haridwar-Chandighat	29.93400000	78.18238889
11	Mothrowala	30.22136111	78.03466667
12	Asharodhi	30.26022222	77.98191667
13	Mohand	30.17672222	77.90030556
14	Karwapani	30.28725000	77.91250000
15	Timli	30.36897222	77.71991667
16	Kalesar	30.34075000	77.58341667
17	Darpur	30.38427778	77.46677778
18	Simbalbada	30.42536111	77.43325000
19	Suketi	30.50425000	77.24308333





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