COMMUNICATION

NEW DISTRIBUTION AND RANGE EXTENSION RECORDS OF GEOMETRID MOTHS (LEPIDOPTERA: GEOMETRIDAE) FROM TWO WESTERN HIMALAYAN PROTECTED AREAS

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New distribution and range extension records of geometrid moths (Lepidoptera: Geometridae) from two western Himalayan protected areas

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Abstract: This article presents new distribution and range extension records (including new records from the state of Uttarakhand) of 12 species of the Geometridae family along with their taxonomic records. The records are based on field collections, where sampling was done along elevation and vegetation gradients in the buffer zones of Nanda Devi Biosphere Reserve and Kedarnath Wildlife Sanctuary, two prominent protected areas in the western Himalayan Indian state of Uttarakhand. DNA barcoding was performed for some of the species for confirmation of identification in addition to the morphological identifications. Voucher specimens are deposited in a public repository for future reference.

Keywords: DNA barcoding, Ennominae, Kedarnath Wildlife Sanctuary, Larentiinae, Nanda Devi Biosphere Reserve, Uttarakhand.
INTRODUCTION

Geometridae are the second-largest family of moths, globally distributed, known to include approximately 24,000 species worldwide (Scoble & Hausmann 2007; VanNieuwerkerken et al. 2011), whereas 2,041 species are recorded from India (Kirti et al. 2019). Most species are slenderly built, generally with weak flying ability, and nocturnal or crepuscular. At rest, the fasciae of the wing pattern are continuous. Geometrids are recognised by the presence of paired tympanal organ at the base of the abdomen in adults and the reduced prolegs in the larvae (Minet & Scoble 1999). This group has also been the subject of a number of recent large-scale taxonomic and phylogenetic works (e.g., Sihvonen & Siljander 2005; Sihvonen et al. 2011, 2020; Brehm et al. 2019; Murillo-Ramos et al. 2019). Although the taxonomy of this family is well established for the temperate regions, tropical areas still need large-scale revisions.

Geometrid moths have been established as a model group for biodiversity studies, community analyses, and ecological research in temperate and tropical regions (Axmacher et al. 2004, 2009; Brehm et al. 2013, 2018; Beck et al. 2017). They are sensitive to climate change (Cheng et al. 2018) and environmental conditions, making them an ideal indicator group to monitor forest recovery and habitat disturbance (New 2004; Beck et al. 2017).

The distribution records of this crucial group of moths with vast diversity, however, still remain scattered from India. The comprehensive work on moths of different regions of the biodiverse rough terrains of western Himalaya, a Biodiversity hotspot within the Indian territory, was mostly carried out by Hampson (1892, 1894, 1895, 1896) in his ‘Fauna of British India’ series and Cotes & Swinhoe (1887) in ‘A Catalogue of Moths of India’. Some studies later on focussed on the diversity and taxonomy of geometrid moths from this region, which include: Pajni & Walia (1984a,b), Walia & Pajni (1987), Rose (1986), Walia (1988, 2005), Smetacek (2004), Walia & Anju (2005), Kirti et al. (2007, 2008a,b, 2009, 2011, 2014), and Stüning & Walia (2009).

From the western Himalayan state of Uttarakhand, where our study was conducted, some prominent work on moth diversity include: Arora (1997), Smetacek (1994, 2008), Sanjyal et al. (2011, 2013, 2017), Dey et al. (2015, 2017), Sanjyal (2015), Sondhi & Sondhi (2016) and Dey (2019). Sanjyal et al. (2011, 2013) and Dey et al. (2015, 2017) looked into the diversity and distribution of moth assemblages. Dey et al. (2019) present a DNA barcode reference library of geometrid species from western Himalaya. Recently, Chandra et al. (2019) included moth diversity in two Protected Areas from Uttarakhand. There is a lot of area still to be studied in this mountainous state to understand the diversity and the underlying patterns in a more comprehensive way.

Our current study was conducted in two western Himalayan protected areas: a) Nanda Devi National Park area which is a part of the Nanda Devi Biosphere Reserve (NDBR). It covers an area of 6,407.03 km² (core area: 712.12 km², buffer zone: 5148.57 km², and transition zone: 546.34 km²), with an altitudinal range of 1,800 m–7,816 m; and b) The Kedarnath Wildlife Sanctuary (KWS) (30.416–30.683 N, 78.916–79.366 E). The altitude ranges 1,160–7,068 m covering an area of 975 km². Both these protected areas are located in the Chamoli-Rudraprayag District in the state of Uttarakhand and are the prominent protected areas in the western Himalaya. The habitats range from mixed oak forests to the lush alpine meadows (Image 1). The combination of human pressure, pristine forest areas and a large altitudinal range make them ideal sites for exploring trends in moth diversity.

Here we present new geographic distribution and range extension records of 12 geometrid species from the state of Uttarakhand which will add to the distribution data of this family from a threatened and fragmented landscape of the western Himalaya.

METHODS

Sampling methodology

Specimens were collected from the buffer regions of two protected areas in the western Himalayan state of Uttarakhand, Nanda Devi Biosphere Reserve (NDBR) and Kedarnath Wildlife Sanctuary (KWS) (Image 2). The study areas were stratified on the basis of elevation and vegetation types to explore the moth diversity along these gradients. Sampling was done at every 200 m along the elevation from 1,500 m to 3,500 m (details of the collection sites in Table 1). Two light-traps with 12W solar lamps were operated for the first 3–4 hours from dusk as this is the time of maximum activity of most geometrid species. Late night sampling was not possible due to logistic constraints. In KWS, we used lepiLED (Brehm 2017) to set up the light-trap.

DNA barcoding

Specimens of some species were DNA barcoded (COI 5’ gene aiming at recovering the 658 bp barcode fragment). To do this, one dry leg was removed from
Image 1. Some of forest types where sampling was done within the two protected areas: a—Oak-Maple forest | b—Moru Oak *Quercus floribunda* forest | c—Alpine Rhododendron Forest | d—Kharsu Oak *Quercus semecarpifolia* forest | e—Western mix coniferous forest. © Pritha Dey.

Image 2. Map showing: A—The boundaries of the two protected areas in the west Himalayan state of Uttarakhand | the collection sites (marked in red circles) in B—Kedarnath Wildlife Sanctuary and C—Nanda Devi Biosphere Reserve.
each specimen with sterile forceps and transferred to a 96-well microplate preloaded with one drop of 95% ethanol in each well. DNA extraction and sequencing were performed at the Canadian Centre for DNA barcoding, University of Guelph, with standardized high-throughput protocols for DNA barcode amplification and sequencing (Ivanova et al. 2006; deWaard et al. 2008).

Species identification

Identifications of the species in this paper were done with the help of the literature mentioned in the respective species account and also by comparing with the Geometridae collections of the Zoologische Staatssammlung München, Germany, including the famous collection of Claude Herbulot. Voucher specimens are deposited at the Insect collection section of the Wildlife Institute of India, Dehradun. In some cases, DNA barcodes provided additional information on species identity. DNA barcode data are accessible in the public dataset DS-HIMALGEO on BOLD database (https://doi.org/10.5883/DS-HIMALGEO) (Ratnasingham & Hebert 2007, 2013).

Species Account

Subfamily: Ennominae

1. **Arichanna tramesata** Moore, 1868 (Image 3:1)

   *Arichanna tramesata* Moore, 1868, Proc. zool. Soc. Lond. 1867:658, pl.33, fig.2 [India: Bengal]

   *Arichanna tramesata*: Hampson (1895), Fauna of British India (Moths) 3: 290

   *Arichanna tramesata*: Wehrli (1939), in Seitz Macrolep. World Suppl. IV: 217, pl. 8 row l, (113)

   Distribution in India: Bengal, Sikkim, Khasis (Meghalaya); new record from the western Himalaya

2. **Arichanna sparsa** (Butler, 1890) (Image 3:2)

   *Icterodes sparsa* Butler, 1890, Entomologist 23:316 [India: Kangra, Dharmasala]

   *Arichanna sparsa*: Prout (1915) in Seitz Macrolep. World IV: 304, pl. 14 b

   *Arichanna sparsa*: Hampson (1895), Fauna of British India (Moths) 3: 294

   *Arichanna sparsa*: Sato (1993), Moths of Nepal. Part 2. TINEA. Vol. 13 (Supplement 3). The Japan Heterocerists’ Society, Tokyo. Pl. 34/2.

   Distribution in India: Darjeeling (West Bengal), Dharmsala (Himachal Pradesh); new record from the state of Uttarakhand

Genetic data: BIN: BOLD: ADF3000 (BC ZSM Lep 94548, 94549).

3. **Blepharoctenucha virescens** (Butler, 1880) (Image 4:3)

   *Hemerophila virescens* Butler, 1880, Ann. Mag. Nat. Hist. (5) vi. P.126 [India: Darjeeling]

   *Boarmia virescens*: Hampson (1895), Fauna of British India (Moths) 3: 295

   *Blepharoctenucha virescens*: Yazaki (1992), Moths of Nepal. Part 1. TINEA. Vol. 13 (Supplement 2). The Japan Heterocerists’ Society, Tokyo. Pl. 10/10.

   Distribution in India: Sikkim, Darjeeling (West Bengal), Arunachal Pradesh; new record from western Himalaya

   Remarks: The distal parts of the wings show a paler coloration than in the Nepalese specimen figured in Yazaki (1992).

Subfamily: Larentiinae

4. **Costicoma exangulata** (Warren, 1909) (Image 3:3)

   *Perizoma exangulata* Warren, 1909, Novit. Zool. xvi: 127 [Kashmir: Srinagar]

   *Thera exangulata*: Prout (1914), in Seitz Macrolep. World Suppl. IV: 217, pl. 8 row l, (113)

   *Costicoma exangulata*: Choi (2000), American Museum Novitates, no.3295: 19

   Distribution in India: Kashmir: Srinagar; new record from the state of Uttarakhand (Choi 2000 mentions that the species is found in the “northern part of India”, but no other record is found from other Northern Indian states)

   Genetic data: BIN: BOLD: ADF3836 (BC ZSM Lep 94515, 94516).

5. **Dysstroma planifasciata** (Prout, 1914) (Image 3:4)

   *Cidaria planifasciata* Prout, 1914, in Seitz Macrolep. World IV: 220; pl.13 e [d]; Vol. XII: pl. 32 i [Kashmir: Koksar]

   *Dysstroma planifasciata*: Yazaki (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists’ Society, Tokyo: 10; Pl. 162/8.

   Distribution in India: Kashmir: Koksar (now in Himachal Pradesh); new record from the state of Uttarakhand

   Genetic data: BIN: BOLD:ADFS836 (BC ZSM Lep 94515, 94516).

   Remarks: Further research is required to clarify distribution and species delimitation of the species
| Subfamily | Genus   | Species | Author       | Location | Lat. | Long. | Elevation (in m) | Forest type |
|-----------|---------|---------|--------------|----------|------|------|------------------|-------------|
| Ennominae | Arichanna | tramesata | Moore, 1868 | NDBR (Lata vill.), KWS (Kanchula, Jatholi) | 30.492 | 79.714 | 2399 | MO          |
| Ennominae | Arichanna | sparsa   | Butler, 1890 | NDBR (Lata) | 30.494 | 79.713 | 2320 | WMC         |
|           |          |          |              |          | 30.494 | 79.713 | 2339 | WMC         |
|           |          |          |              |          | 30.495 | 79.721 | 2544 | WMC         |
| Ennominae | Blepharoctenucha | virescens | Butler, 1880 | KWS (Anasuya, Jatholi, Kanchula, Mandal) | 30.472 | 79.288 | 1766 | MO          |
|           |          |          |              |          | 30.460 | 79.230 | 2636 | OM          |
|           |          |          |              |          | 30.460 | 79.270 | 1617 | MO          |
| Larentiinae | Costicoma | exangulata | Warren, 1909 | NDBR (Lata gradient) | 30.495 | 79.721 | 2526 | WMC         |
|           |          |          |              |          | 30.495 | 79.727 | 2913 | WMC         |
|           |          |          |              |          | 30.496 | 79.738 | 2905 | WMC         |
|           |          |          |              |          | 30.499 | 79.743 | 3310 | WHBF        |
| Larentiinae | Dysstroma | planifasciata | Prout, 1914 | NDBR (Joshimath, Lata) | 30.554 | 79.547 | 2107 | LLBP       |
|           |          |          |              |          | 30.546 | 79.554 | 2414 | WMC         |
|           |          |          |              |          | 30.520 | 79.559 | 3141 | KO          |
|           |          |          |              |          | 30.521 | 79.559 | 3152 | KO          |
|           |          |          |              |          | 30.495 | 79.727 | 2913 | WMC         |
|           |          |          |              |          | 30.496 | 79.738 | 2905 | WMC         |
|           |          |          |              |          | 30.499 | 79.743 | 3310 | WHBF        |
|           |          |          |              |          | 30.499 | 79.743 | 3272 | WHBF        |
| Larentiinae | Cidaria | basharica | Bang-Haas, 1927 | NDBR (Malari village) | 30.684 | 79.889 | 3042 | Inside village |
| Larentiinae | Trichoplites | lateritata | Moore, 1888 | NDBR (Lata gradient) | 30.495 | 79.722 | 2553 | WMC         |
|           |          |          |              |          | 30.495 | 79.721 | 2544 | WMC         |
| Larentiinae | Rheumaptera | melanoloplia | Hampson, 1902 | NDBR, KWS | 30.522 | 79.564 | 2977 | WHUOF       |
|           |          |          |              |          | 30.520 | 79.559 | 3141 | KO          |
| Larentiinae | Photoscotosia | dejuncta | NDBR (Lata, Ghangariya) | 30.494 | 79.728 | 2766 | WMC         |
|           |          |          |              |          | 30.500 | 79.744 | 3733 | WHBF        |
|           |          |          |              |          | 30.497 | 79.749 | 3775 | WHBF        |
|           |          |          |              |          | 30.497 | 79.749 | 3768 | WHBF        |
|           |          |          |              |          | 30.699 | 79.592 | 3213 | Inside village |
| Larentiinae | Perizoma | conjuncta | Warren, 1893 | NDBR (Joshimath Lata) | 30.555 | 79.547 | 2108 | LLBP       |
|           |          |          |              |          | 30.495 | 79.705 | 2126 | LLBP       |
|           |          |          |              |          | 30.494 | 79.705 | 2152 | LLBP       |
|           |          |          |              |          | 30.494 | 79.705 | 2164 | LLBP       |
|           |          |          |              |          | 30.495 | 79.705 | 2143 | LLBP       |
|           |          |          |              |          | 30.495 | 79.727 | 2913 | WMC         |
|           |          |          |              |          | 30.496 | 79.738 | 2905 | WMC         |
|           |          |          |              |          | 30.499 | 79.743 | 3310 | WHBF        |
|           |          |          |              |          | 30.499 | 79.743 | 3310 | WHBF        |
| Larentiinae | Perizoma | plumbreata | Moore, 1888 | KWS (Gondi) | 30.468 | 79.261 | 1638 | MO          |
|           |          |          |              |          | 30.478 | 79.216 | 3067 | AR          |
| Larentiinae | Perizoma | hockingii | Butler, 1889 | KWS (Shokharak) | 30.545 | 79.554 | 2433 | WMC        |

NDBR—Nanda Devi Biosphere Reserve | KWS—Kedarnath Wildlife Sanctuary | MO—Mixed Oak | WMC—Western Mix Coniferous | OM—Oak-Maple | WHBF—Western Himalayan Birch-Fir | LLBP—Low level blue Pine | WHUOF—Western Himalayan upper oak-fir | AR—Alpine rhododendron.
Range extension records of geometrid moths

Dey & Hausmann

6. **Cidaria basharica** Bang-Haas, 1927 (Image 3:5)

*Cidaria basharica* Bang-Haas, 1927, Horae. Macrolep.: 93, pl. XI: 20 [India: Poo-Bashahr State, Schipki-la]

*Cidaria basharica*: Prout (1914), in Seitz, Macrolep. World IV. Suppl (110), pl. 11 b

*Cidaria basharica*: Yazaki (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists’ Society, Tokyo. Pl. 162/16.

Distribution in India: Himachal Pradesh; new record from the state of Uttarakhand

Remarks: Further research is required to clarify distribution and species delimitation of the species pair *Cidaria basharica* and *C. antauges* Prout, 1938, the latter described from Kashmir/Kokser. Wing pattern of our record from Uttarakhand is well matching the figure for a Nepalese specimen in Yazaki (2000), whilst the type of *C. basharica* shows a much narrower medial area. It is not excluded that the populations of Uttarakhand and Nepal belong to *C. antauges*.

7. **Trichoplites lateritiata** (Moore, 1888) (Image 3:6)

*Anticlea lateritiata* Moore, 1888, in Hewitson & Moore, Descr. new Indian lepid. Insects Colln late Mr Atkinson: 273. [India: Darjeeling]

*Trichoplites lateritiata*: Yazaki (1993). Moths of Nepal. Part 2. TINEA. Vol. 13 (Supplement 3). The Japan Heterocerists’ Society, Tokyo. Pl. 60/2.

**Distribution in India**: Darjeeling (West Bengal), new record from western Himalaya

8. **Rheumaptera melanoplagia** (Hampson, 1902) (Image 3:7)

*Scotosia melanoplagia* Hampson, 1902, J. Bombay Nat. Hist. Society 14: 512 [Tibet: Yatong; Sikkim]

*Calocalpe melanoplagia*: Prout (1941), in Seitz, Macrolep. World XII, pl. 33 h

*Calocalpe melanoplagia*: Fletcher (1961), Veröff. Zool. Staatssamml. München 6: 171.

*Rheumaptera melanoplagia*: Yazaki (1995), Moths of Nepal. Part 4. TINEA. Vol. 14 (Supplement 2). The Japan Heterocerists’ Society, Tokyo. Pl. 97/20.

*Triphosa melanoplagia*: Scoble (ed., 1999). Geometrid Moths of the World, a Catalogue.

Distribution in India: Sikkim (Dudgeon); new record from western Himalaya

Genetic data: BIN: BOLD:ADF4467 (BC ZSM Lep 94466, 94484)

Remarks: Sanyal et al. 2017 mentions this record by PD. A long series of this species from Western Nepal province shows a broader forewing costal spot in almost all of the >200 specimens.

9. **Photoscotosia dejuncta** Prout, 1937 (Image 3:8)

*Photoscotosia dejuncta* Prout, 1937: in Seitz, Macrolep. World IV, Suppl.: 103, pl. 10 d [Kashmir: Gulmarg]

Distribution: Kashmir, Himachal Pradesh, Spiti Valley (Herbulot Collection, ZSM), new record from the state of Uttarakhand

Genetic data: BIN: BOLD:AAE6530 (BC ZSM Lep 94391), BIN-sharing with nominotypical *P. dejuncta*, but slightly diverging.

Remarks: Identified in the collection Herbulot in Zoologische Staatssammlung Munich, Germany, as "Photoscotosia dejuncta occidens Herbulot" which apparently is an unpublished manuscript name intended for the populations from Himachal Pradesh which differ from nominotypical *P. dejuncta* by a more greyish coloration and the missing pale costal spot near the forewing apex. This name was used in Dey et al. (2019) without description (nomen nudum). Yazaki (1995) described *Photoscotosia pallidimacula* based on specimens from central Nepal, showing paler forewings and a broadly white hindwing costa. More research is needed to clarify the taxonomy and species delimitation in this group.

10. **Perizoma conjuncta** Warren, 1893 (Image 3:9)

*Perizoma conjuncta* Warren, 1893: Proc. Zool. Soc. Lond.: 381. [Burma: E Pegu]

*Larentia conjuncta*: Hampson (1895), Fauna of British India (Moths) 3: 374.

*Perizoma conjuncta*: Prout (1939), in Seitz, Macrolep. World XII: 279

*Perizoma conjuncta*: Inoue (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists’ Society, Tokyo. Pl. 166/20.

**Distribution in India**: Khasis (Meghalaya), new record from western Himalaya

Genetic data: BIN: BOLD:ADF4467 (BC ZSM Lep 94466, 94484)

11. **Perizoma plumbeata** (Moore, 1888) (Image 4:1)

*Anticlea plumbeata* Moore, 1888, Descr. new Indian lepid. Insects Colln. Late Mr. W.S. Atkinson (3): 273.
Range extension records of geometrid moths

**Dey & Hausmann**

*Journal of Threatened Taxa* | www.threatenedtaxa.org | 26 June 2021 | 13(7): 18817–18826

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**Image 3. Moth species recorded and collected from Nanda Devi Biosphere Reserve:**

1. *Arichanna tramesata* | 2. *Arichanna sparsa* | 3. *Costicoma exangulata* | 4. *Dysstroma planifasciata* | 5. *Cidaria basharica* | 6. *Trichoplites lateritata* | 7. *Rheumaptera melanoplagia* | 8. *Photoscotosia dejuncta* | 9. *Perizoma conjuncta*. © Pritha Dey

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**Image 4. Moth species recorded from Kedarnath Wildlife Sanctuary:**

1. *Perizoma plumbeata* | 2. *Perizoma hockingii* | 3. *Blepharoctencha virescens*. © Pritha Dey

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[India: Darjeeling]

*Larentia plumbeata*: Hampson (1895), Fauna of British India (Moths) 3: 376

*Perizoma plumbeata*: Inoue (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists’ Society, Tokyo. Pl. 166/23.

Distribution in India: Himachal Pradesh, Bengal, Sikkim, Arunachal Pradesh; new record from the state of Uttarakhand

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12. *Perizoma hockingii* (Butler, 1889) (Image 4: 2)

*Eupithecia hockingii* Butler, 1889: Illust. typical lepid. Heterocera Colln Br. Mus. 7: 115, pl. 137: 12. [India: Kangra, Dharamsala]

*Larentia hockingii*: Hampson (1895), Fauna of British India (Moths) 3: 376

*Perizoma hockingii*: Inoue (2000), Moths of Nepal. Part 6. TINEA. Vol. 16 (Supplement 1). The Japan Heterocerists’ Society, Tokyo. Pl. 166/28.

Distribution in India: Sikkim, Dharamsala (Himachal Pradesh); new record from the state of Uttarakhand.
DISCUSSION

Our study clearly highlights the gaps in the existing distributional data for moths, especially in western Himalaya and reiterates the effectiveness of an integrative biodiversity assessment in a hyper-diverse taxon. So far, the moth diversity of the western Himalayan state of Uttarakhand has just been investigated sporadically. Roonwal et al. (1963), a report of the entomological collections of the Forest Research Institute, Dehradun was among the first publications recording moths from this state. Later on, several other publications, as mentioned in the introduction have contributed to the understanding of the diversity and distribution of moths from this western Himalayan state. Sanyal et al. (2017), Dey et al. (2019), and Dey et al. (2021) have focussed on the diversity and distributions of geometrid moths specifically; however, serious gaps still remain as these studies could not cover the entire elevational/habitat range, which would provide a more comprehensive understanding of the diversity and the ecological processes governing their distributions. Recently, global insect decline has been in the spotlight (Hallmann et al. 2017; Lister & Garcia 2018) and it is time that concerted efforts towards documenting and monitoring insect populations are set in place, specifically in the global biodiversity hotspots. Rapid deforestation and urbanization magnify the problem, whereby we might lose critical habitats for the survival of specialised species. Such declines are a sober warning of wider environmental changes, and new distribution records will increase the biological knowledge required to understand the wider impact of such changes. Also, it will work towards fostering increased interest towards moths, which is critical in this endeavour. Some new records reported in this paper from the surroundings of Kedarnath Wildlife sanctuary were a part of a moth-survey project (https://www.rufford.org/projects/pritha-dey/high-altitude-moth-lepidoptera-heterocera-assemblages-assessing-the-diversity-and-potential-bio-indicator-species-in-kedarnath-wildlife-sanctuary-india/) which simultaneously allowed us (a) to document moths from a hitherto unexplored area and (b) to conduct citizen-science workshops to spread awareness on moths. Our findings highlight the need for more such surveys to document the moth diversity across the wide elevation and habitat gradients in the western Himalayan region, where the Oriental and Palearctic biogeographic elements overlap, and which is home to unique biodiversity (Meinertzhagen 1928). Future endeavours of such kind will not only add to the current database, but will help in bringing the spotlight on the need for moth conservation in a fragmented, threatened landscape, in the largest mountain system in the world.

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