Building evidence for conservation globally

Journal of Threatened Taxa

10.11609/jott.2026.18.3.28455-28606
www.threatenedtaxa.org

26 March 2026 (Online & Print)
18(3): 28455–28606
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

Open Access

zooreach
Zoo Outreach Organisation
40 Years

ISSN 0974-7907 (Online); ISSN 0974-7893 (Print)

Publisher
Wildlife Information Liaison Development Society
www.wild.zooreach.org

Host
Zoo Outreach Organization
www.zooreach.org

Srivari Illam, No. 61, Karthik Nagar, 10th Street, Saravanampatti, Coimbatore, Tamil Nadu 641035, India
Registered Office: 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India
Ph: +91 9385339863 | www.threatenedtaxa.org
Email: sanjay@threatenedtaxa.org

EDITORS

Founder & Chief Editor
Dr. Sanjay Molur
Wildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO), Coimbatore, Tamil Nadu 641006, India

Assistant Editor
Dr. Chaithra Shree J., WILD/ZOO, Coimbatore, Tamil Nadu 641006, India

Managing Editor
Mr. B. Ravichandran, WILD/ZOO, Coimbatore, Tamil Nadu 641006, India

Associate Editors
Dr. Mandar Paingankar, Government Science College Gadchiroli, Maharashtra 442605, India
Dr. Ulrike Streicher, Wildlife Veterinarian, Eugene, Oregon, USA
Ms. Priyanka Iyer, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India

Board of Editors
Dr. Russel Mittermeier
Executive Vice Chair, Conservation International, Arlington, Virginia 22202, USA

Prof. Mewa Singh Ph.D., FASc, FNA, FNASc, FNAPsy
Ramanna Fellow and Life-Long Distinguished Professor, Biopsychology Laboratory, and Institute of Excellence, University of Mysore, Mysuru, Karnataka 570006, India; Honorary Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; and Adjunct Professor, National Institute of Advanced Studies, Bangalore

Stephen D. Nash
Scientific Illustrator, Conservation International, Dept. of Anatomical Sciences, Health Sciences Center, T-8, Room 045, Stony Brook University, Stony Brook, NY 11794-8081, USA

Dr. Fred Pluthero
Toronto, Canada

Dr. Priya Davidar
Sigur Nature Trust, Chadapatti, Mavinhalla PO, Nilgiris, Tamil Nadu 643223, India

Dr. John Fellowes
Honorary Assistant Professor, The Kadoorie Institute, 8/F, T.T. Tsui Building, The University of Hong Kong, Pokfulam Road, Hong Kong

Prof. Dr. Mirco Solé
Universidade Estadual de Santa Cruz, Departamento de Ciências Biológicas, Vice-coordenador do Programa de Pós-Graduação em Zoologia, Rodovia Ilhéus/Itabuna, Km 16 (45662-000) Salobrinho, Ilhéus - Bahia - Brasil

Dr. Rajeev Raghavan
Professor of Taxonomy, Kerala University of Fisheries & Ocean Studies, Kochi, Kerala, India

English Editors
Mrs. Mira Bhojwani, Pune, India
Dr. Fred Pluthero, Toronto, Canada

Copy Editors
Ms. Usha Madgunaki, Zooreach, Coimbatore, India
Ms. Trisa Bhattacharjee, Zooreach. Coimbatore, India
Ms. Paloma Noronha, Daman & Diu, India

Web Development
Mrs. Latha G. Ravikumar, ZOO/WILD, Coimbatore, India

Typesetting
Mrs. Radhika, Zooreach, Coimbatore, India
Mrs. Geetha, Zooreach, Coimbatore India

Fundraising/Communications
Mrs. Payal B. Molur, Coimbatore, India

Subject Editors 2021–2023

Fungi

Dr. B. Shivaraju, Bengaluru, Karnataka, India
Dr. R.K. Verma, Tropical Forest Research Institute, Jabalpur, India
Dr. Vatsavaya S. Raju, Kakatiay University, Warangal, Andhra Pradesh, India
Dr. M. Krishnappa, Jnana Sahyadri, Kuvempu University, Shimoga, Karnataka, India
Dr. K.R. Sridhar, Mangalore University, Mangalagangotri, Mangalore, Karnataka, India
Dr. Gunjan Biswas, Vidyasagar University, Midnapore, West Bengal, India
Dr. Kiran Ramchandra Ranadive, Annasaheb Magar Mahavidyalaya, Maharashtra, India

Plants

Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. N.P. Balakrishnan, Ret. Joint Director, BSI, Coimbatore, India
Dr. Shonil Bhagwat, Open University and University of Oxford, UK
Prof. D.J. Bhat, Retd. Professor, Goa University, Goa, India
Dr. Ferdinando Boero, Università del Salento, Lecce, Italy
Dr. Dale R. Calder, Royal Ontaro Museum, Toronto, Ontario, Canada
Dr. Cleofas Cervancia, Univ. of Philippines Los Baños College Laguna, Philippines
Dr. F.B. Vincent Florens, University of Mauritius, Mauritius
Dr. Merlin Franco, Curtin University, Malaysia
Dr. V. Irudayaraj, St. Xavier's College, Palayamkottai, Tamil Nadu, India
Dr. B.S. Kholia, Botanical Survey of India, Gangtok, Sikkim, India
Dr. Pankaj Kumar, Department of Plant and Soil Science, Texas Tech University, Lubbock, Texas, USA.
Dr. V. Sampath Kumar, Botanical Survey of India, Howrah, West Bengal, India
Dr. A.J. Solomon Raju, Andhra University, Visakhapatnam, India
Dr. Vijayasankar Raman, University of Mississippi, USA
Dr. B. Ravi Prasad Rao, Sri Krishnadevaraya University, Anantpur, India
Dr. K. Ravikumar, FRLHT, Bengaluru, Karnataka, India
Dr. Aparna Watve, Pune, Maharashtra, India
Dr. Qiang Liu, Xishuangbanna Tropical Botanical Garden, Yunnan, China
Dr. Noor Azhar Mohamed Shazili, Universiti Malaysia Terengganu, Kuala Terengganu, Malaysia
Dr. M.K. Vasudeva Rao, Shiv Ranjani Housing Society, Pune, Maharashtra, India
Prof. A.J. Solomon Raju, Andhra University, Visakhapatnam, India
Dr. Mandar Datar, Agharkar Research Institute, Pune, Maharashtra, India
Dr. M.K. Janarthanam, Goa University, Goa, India
Dr. K. Karthigeyan, Botanical Survey of India, India
Dr. Errol Vela, University of Montpellier, Montpellier, France
Dr. P. Lakshminarasimhan, Botanical Survey of India, Howrah, India
Dr. Larry R. Noblick, Montgomery Botanical Center, Miami, USA
Dr. K. Haridasan, Pallavur, Palakkad District, Kerala, India
Dr. Analinda Manila-Fajard, University of the Philippines Los Banos, Laguna, Philippines
Dr. P.A. Sinu, Central University of Kerala, Kasaragod, Kerala, India
Dr. Afroz Alam, Banasthali Vidyapith (accredited A grade by NAAC), Rajasthan, India
Dr. K.P. Rajesh, Zamorin's Guruvayurappan College, GA College PO, Kozhikode, Kerala, India
Dr. David E. Boufford, Harvard University Herbaria, Cambridge, MA 02138-2020, USA
Dr. Ritesh Kumar Choudhary, Agharkar Research Institute, Pune, Maharashtra, India
Dr. A.G. Pandurangan, Thiruvananthapuram, Kerala, India
Dr. Navendu Page, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand, India
Dr. Kannan C.S. Warrier, Institute of Forest Genetics and Tree Breeding, Tamil Nadu, India

Invertebrates

Dr. R.K. Avasthi, Rohtak University, Haryana, India
Dr. D.B. Bastawade, Maharashtra, India
Dr. Partha Pratim Bhattacharjee, Tripura University, Suryamaninagar, India
Dr. Kailash Chandra, Zoological Survey of India, Jabalpur, Madhya Pradesh, India
Dr. Ansie Dippenaar-Schoeman, University of Pretoria, Queenswood, South Africa
Dr. Rory Dow, National Museum of natural History Naturalis, The Netherlands
Dr. Brian Fisher, California Academy of Sciences, USA
Dr. Richard Gallon, llandudno, North Wales, LL30 1UP
Dr. Hemant V. Ghate, Modern College, Pune, India
Dr. M. Monwar Hossain, Jahangirnagar University, Dhaka, Bangladesh

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope
For Article Submission Guidelines, visit https://threatenedtaxa.org/index.php/JoTT/about/submissions
For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: Digital illustration of Smooth-coated Otter *Lutrogale perspicillata* by Dupati Poojitha. Reference from the picture taken by Rana & Sugandhi.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 March 2026 | 18(3): 28495–28509

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

https://doi.org/10.11609/jott.9730.18.3.28495-28509

#9730 | Received 04 March 2025 | Final received 23 February 2026 | Finally accepted 09 March 2026

ARTICLE

Diversity and distribution pattern of geometrid moths (Insecta: Lepidoptera: Geometridae) along the altitudinal gradient, Kumaun Himalaya, India

Narendra Singh Lotani [1] & **Chandra Singh Negi** [2]

[1,2] Ecology & Biodiversity Laboratory, Department of Zoology, Motiram Baburam Government Postgraduate College, Haldwani (Nainital), Uttarakhand 263139, India.
[1] nsleco25@gmail.com, [2] csnsacred1@gmail.com (corresponding author)

Abstract: Altitudinal gradients are frequently used to study Lepidoptera diversity. The study site, situated in the Munsiari Subdivision of Pithoragarh District, Kumaun Himalaya, was divided into transects along the altitudinal gradient, each 200 m wide, spanning elevations from 1,200–4,000 m. In each transect, a minimum of five sampling plots were established. Furthermore, the study area was divided into five broad zones based on vegetational cover. Moths were collected using automated light traps between 1900 h and 2300 h. The specimens were identified using the available literature and following standard protocols. Indicator species analysis was carried out as per Dufrêne & Legendre. The present paper deals exclusively with the status and altitudinal distribution pattern of the Geometridae moths. Zone II, lying between 1,800–2,600 m, harboured highest species richness (98 species), as well as abundance (4,686 individuals), while the least species richness was encountered in Zone III. In terms of species diversity across the subfamilies, Ennominae comprised 93 species, followed by Larentiinae (49), Geometrinae (14), Sterrhinae (4), and Desmobathrinae (1). In terms of distribution, 23 species, restricted to just one transect and exhibiting distribution for one month, could be categorised as highly specialized, while two species—*Euphyia subangulata* and *Eustroma melancholicum venipicta* (Larentiinae)—exhibiting distribution throughout the altitudinal gradient, along with an additional 23 species (all Ennominae) exhibiting presence across five or more transects, could be defined as generalists. Both categories are considered 'indicator species.'

Keywords: Alpine, ecotone, environmental factor, habitat, indicator species, light trap, specialists, species richness, transects, western Himalaya.

सार: ऊँचाई के आधार पर होने वाले परिवर्तन (आल्टिट्यूडिनल ग्रेडिएंट) का उपयोग प्रायः लेपिडोप्टेरा की विविधता के अध्ययन के लिए किया जाता है। अध्ययन क्षेत्र, जो मुनस्यारी उपखंड (जिला , पिथौरागढ़, कुमाऊं हिमालय) में स्थित है, को ऊँचाई के अनुसार ट्रांसेक्टों में विभाजित किया गया। प्रत्येक ट्रांसेक्ट की चौड़ाई 200 मीटर थी तथा यह 1,200–4,000 मीटर की ऊँचाई तक फैला हुआ था। प्रत्येक ट्रांसेक्ट में कम से कम पाँच नमूना प्लॉट स्थापित किए गए। इसके अतिरिक्त, अध्ययन क्षेत्र को वनस्पति आवरण के आधार पर पाँच प्रमुख क्षेत्रों (ज़ोन) में बाँटा गया। पतंगों का संग्रह सायं 7:00 बजे से रात्रि 11:00 बजे तक स्वचालित प्रकाश फंदों की सहायता से किया गया। नमूनों की पहचान उपलब्ध साहित्य और मानक विधियों के अनुसार की गई। संकेतक प्रजाति विश्लेषण Dufrêne & Legendre की विधि के अनुसार किया गया। यह शोधपत्र विशेष रूप से Geometridae कुल के पतंगों की स्थिति तथा ऊँचाई के अनुसार उनके वितरण पैटर्न पर केंद्रित है। ज़ोन II (1,800–2,600 मीटर) में सर्वाधिक प्रजाति समृद्धि (98 प्रजातियाँ) तथा अधिकतम संख्या (4686 व्यक्तियों) दर्ज की गई, जबकि न्यूनतम प्रजाति समृद्धि ज़ोन III में पाई गई। उपपरिवार स्तर पर, Ennominae में 93 प्रजातियाँ, इसके बाद Larentiinae में 49, Geometrinae में 14, Sterrhinae में 4 तथा Desmobathrinae में 1 प्रजाति दर्ज की गई। वितरण के आधार पर, 23 प्रजातियाँ केवल एक ही ट्रांसेक्ट तक सीमित थीं और केवल एक माह तक ही पाई गईं, जिन्हें अत्यधिक विशिष्ट (विशेषज्ञ) श्रेणी में रखा जा सकता है। वहीं, दो प्रजातियाँ–*Euphyia subangulata* तथा *Eustroma melancholicum venipicta*—पूरे ऊँचाई क्षेत्र में पाई गईं। इसके अतिरिक्त, 23 अन्य प्रजातियाँ (सभी Ennominae) पाँच या उससे अधिक ट्रांसेक्टों में उपस्थित रहीं, जिन्हें सामान्यवादी श्रेणी में रखा जा सकता है। इन दोनों श्रेणियों को संकेतक प्रजातियाँ माना गया है।

Editor: Jatishwor Singh Irungbam, Centrum Algatech, Třeboň, Czech Republic.

Date of publication: 26 March 2026 (online & print)

Citation: Lotani, N.S. & C.S. Negi (2026). Diversity and distribution pattern of geometrid moths (Insecta: Lepidoptera: Geometridae) along the altitudinal gradient, Kumaun Himalaya, India. *Journal of Threatened Taxa* 18(3): 28495–28509. https://doi.org/10.11609/jott.9730.18.3.28495-28509

Funding: The research received no external funding.

Competing interests: The authors declare no competing interests.

Author details: Narendra Singh Lotani is a research scholar in the Ecology & Biodiversity Laboratory, M B Government Postgraduate College, pursuing an interest in lepidoptera, more specifically, the habitat ecology of moths. Chandra Singh Negi, PhD, is a professor at the MB Government Postgraduate College, with a wide interest in ecology, conservation biology, and traditional knowledge-based systems, and is an expert on the habitat ecology of the caterpillar mushroom and the Institution of sacred.

Author contributions: Both authors contributed to the study. NSL: Field work, formal analysis of the raw data, review, and manuscript writing (original draft). CSN: Conceptualization, methodology, formal analysis, supervision, and editing of the draft.

Acknowledgements: The authors gratefully acknowledge the principal, MB Government Postgraduate College, Haldwani (Nainital), for extending the infrastructural support. To Pardeep Kumar Sharma, Ms. Priya Bisht, Ms. Ranjana Goswami, and Ms. Divya Rawat, our colleagues in the laboratory, for extending help from time to time. To the residents of Kultham and Dheelam villages for their help with the fieldwork.

INTRODUCTION

Moths and butterflies belong to the insect order Lepidoptera, characterized by two pairs of scale-covered wings, and, in most groups, reduced mandibles. Butterflies are primarily day-flying and usually brightly coloured, while most moths are nocturnal and tend to be more cryptically coloured. Currently, approximately 158,000 Lepidoptera species have been reported worldwide; new discoveries are made each year, and the actual total is estimated to range 300,000–400,000 (Kristensen et al. 2007). Even though butterflies are relatively better known than moths, the latter, outnumber the butterflies by at least 10 to one (Hill et al. 2021). Moths are a significant component of terrestrial ecosystems as herbivores and pollinators, and they also play a role in nutrient cycling; therefore, disturbances to their natural habitats, primarily due to anthropogenic activities, affect their population dynamics (Lomov et al. 2006). In fact, on account of their sensitivity towards habitat change, moths have been recently targeted as 'indicator species' that reflect upon habitat changes, such as forest fragmentation, land-use patterns, deforestation, and regeneration (Ricketts et al. 2001; Enkhtur et al. 2017). In terms of distribution and habitat preferences, moths exhibit both narrow and wide distributions. Both narrow, highly niche specialized (confined to 200–400 m breadth segments), and widely distributed – the generalists, could act as ecological indicators; for any change in their availability or numbers would relate to habitat change or its quality. The distribution of moths across an altitudinal gradient, thus, provides an opportunity to study the range of their distribution pattern, the diversity – both richness and abundance, and relate these with the above-ground vegetation profile, as well as the anthropogenic disturbance. Moreover, any depletion in numbers, as well as the availability of specialist moths in particular, could be monitored, since moths exhibit 'assemblages' that are easy to monitor.

Variation in moth diversity along altitudinal gradients can be an effective way to study the effects of climate change on ecological communities (Kitching et al. 2011). Forested elevational gradients representing sets of adjacent climates are excellent tools for such studies; encompassing, in a small geographical area, a range of environmental factors that shift predictably (Rahbek 2005; Fiedler & Beck 2008; Fischer et al. 2011; Kitching et al. 2011). For example, it is well established that for every 100 m increase in elevation, the temperature decreases by approximately 0.6 °C (Jacobson 2005). Concomitantly, a set of other biotic-abiotic factors, for example, mean annual temperature, precipitation change, and others, too, shift in concert, inclusive of soil physico-chemical properties (Strong et al. 2011), along elevational gradients (Stevens 1992; Kessler et al. 2001; Lomolino 2001; Foster 2010).

Understanding how moth assemblages change along the altitudinal gradient is therefore important for assessing likely future changes in diversity, for example, climate change (Doran et al. 2003). It will also allow us to observe the current distributions of different species, and make predictions about how they would respond to climate change based on their current climatic envelopes, thereby leading us to identify species (indicator species), which would then be used to monitor future range shifts (Kitching & Ashton 2014; Nakamura et al. 2016). Moths are ideal as 'Indicator species' for use in climate monitoring, since (i) they are sensitive to environmental variables, and (ii) their herbivorous life histories bind them invariably to larger community-level shifts (Schulze et al. 2001). Other features, like their being easy to sample in large numbers (principally, making use of automated light traps), giving strong statistical power, and their being relatively well known taxonomically (Holloway 1985ab–1997) make them ideal species to monitor climate change.

An elevational change of just 200 m drives significant changes in moth assemblage composition, particularly for forest-inhabiting moths (Ashton et al. 2016); these changes have considerable implications for conservation under climate change scenarios. Because moths, as herbivores, are closely linked to the availability of appropriate larval host plants, this could lead to a mismatch between the upward movement of herbivores and their host plants when host plants respond more slowly and track climatic envelopes (Rehm 2014). To understand how species respond to climate change, we need to generate baseline data on their current distributions. By examining species distributions and investigating how their altitudinal ranges are driven by environmental variables across altitudes, we will be better able to predict how these species may respond to further climate warming.

Many recent studies on altitude-diversity patterns have been conducted in tropical systems, including studies of moths (e.g., Axmacher et al. 2004; Brehm et al. 2007; Beck & Chey 2008; Fiedler et al. 2008; Beck & Kitching 2009). Comparable data regarding methods and studies are conspicuously lacking for the temperate moths. Consequently, little is known about the altitudinal diversity patterns of temperate taxa, and information on the seasonal variation in these patterns is scarce (Summerville & Crist 2003). Also, as concerns India, most studies related to the diversity and distribution of moths along the altitudinal gradient are restricted to tropical or sub-temperate regions (Axmacher et al. 2004; Beck & Chey 2008; Beck & Kitching 2009; Ashton et al. 2016), with an exception (Dey et al. 2015) conducted across four protected areas within the state of Uttarakhand. Further, only one single attempt (Sanyal et al. 2017) has addressed the 'indicator properties' of moth assemblages in assessing habitat quality. The present study aims to address this gap. Further, most, if not all, studies on moths are relegated to macromoths, and micromoths, if any, remain mostly unexplored. This fact becomes all the more obvious when it concerns studies in the sub-alpine and alpine zones of the Himalaya, which remain unexplored. However, one positive outcome of such a scenario is that the likelihood of discovering entirely new species or documenting their presence increases, as evidenced by the present study.

Geometrid moths occur in large numbers and have a wide elevational distribution, making them an ideal group for studies along elevational transects (Toko et al. 2023). Their sensitivity to habitat alteration and climate variation, as reflected in their distribution patterns, makes them a valuable bioindicator of environmental change (Scoble 1992; Choi 2006; Ashton et al. 2011; Alonso-Rodrigue et al. 2017; Enkhtur et al. 2020). Approximately 24,000 species of Geometridae have been described worldwide (Brehm et al. 2005). The present study thus examines (i) the diversity of the family Geometridae, and (ii) indicator species vis-à-vis the spatial distribution of each individual species, along the elevational gradient.

MATERIALS & METHODS

The study site (Figure 1), situated in Munsiari Subdivision, Pithoragarh District, Kumaun Himalaya, between 30.111°–30.144° N and 80.254°–80.304° E, extending from base 1,200 m to 4,000 m, was divided along the altitudinal gradient into transects, measuring 200 m in breadth. In each transect, a minimum of five sampling plots were established, spaced at least 20 m apart, ensuring that a light device (UV light source) did not impede the other light device. Light traps were set using a light-sensitive solar-powered lantern. Solar light traps remained an effective tool for insect collection; they are fully automatic, switch on at night, and are absolutely safe to handle. The solar light trap was positioned at a right angle in relation to the direction of movement of the sun during daytime, for charging the battery to a maximum, so that it lasts for the complete duration (4 h) of the insect trap. Since temporal distribution remained one component of the study (though not included in the present manuscript), moth collections, in each transect, were carried out on average between 2–3 days per month, compounding to 10–15 days for the complete duration of the study of five months, annually, and replicated for two years.

The study area was further divided into five zones (I–V) based on vegetational cover and other features, such as interspersed habitat types and anthropogenic disturbance. Moths were collected using automated light traps, between 1900 h and 2300 h. The collected specimens were then pinned and partially spread according to standard techniques (Krogmann et al. 2010). The specimens were sorted into morphospecies and identified using the available literature, following standard protocols (Haruta 2000; Scoble & Hausmann 2007). The identification of moth specimens was based entirely on morphological features, following the BOLD system of taxonomy for moths of India, Nepal, and Borneo (Ratnasingham & Hebert 2007). The identified species were further classified into families, subfamilies, and genera.

Characteristic moth species restricted to specific transect/s were identified across the altitudinal gradient using the indicator species analysis (Dufrêne & Legendre 1997). For the calculation of the indicator value, abundance figures of each species confined either to a single or two belt transects were selected (since species spread out across more than two transects had a p-value greater than 0.01). Species with indicator values greater than 70% produced from ISA were regarded as good indicators for each habitat, while those with the Indicator Value lying between 50–70 % were regarded as detector species, i.e., as a detector of a change in habitat (McGeoch et al. 2002). At each level of cluster (species group), indicator values (Ind. Val.) and their associated *p*-values for all moth species were calculated. We selected species with an indicator value greater than 70%. The Bray-Curtis similarity index was calculated as per Bray & Curtis (1957). Lastly, the data analysis was conducted using Past 4.17 and Excel Stat. The correlation coefficient between species richness and the altitudinal gradient was calculated using Pearson's (1895) method.

While Zone I can be classified as sub-temperate or warm-temperate, the subsequent zones are classified as temperate or cool-temperate, sub-alpine, timberline,

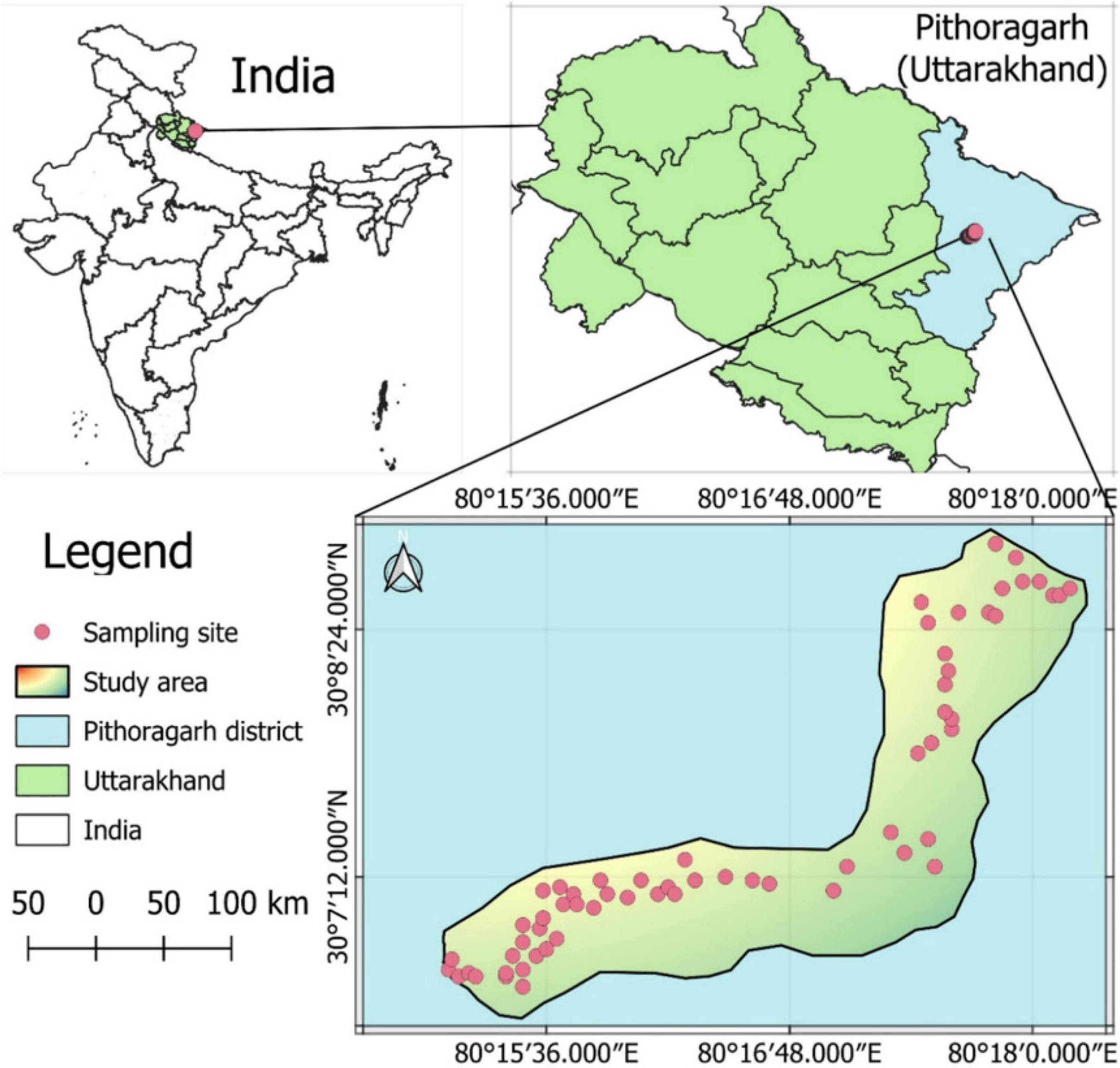

Figure 1. The study site: red dots represent the sampling sites of different altitudinal transects.

and alpine, respectively. Because the altitudinal range was extensive, changes in vegetation profiles across the altitudinal gradient were also observed, as were ecotones. The dominant plant species were *Quercus* spp., *Rhododendron* spp., *Alnus nepalensis*, *Neolitsea umbrosa*, and *Acer*; the was characterized by *Betula utilis*, while the alpine meadow was dominated by herbaceous species.

RESULTS

A total of five subfamilies, representing 99 genera, and 161 species were collected. The maximum species richness (98) and abundance (4,686 ind.) were encountered in zone II (1,800–2,600 m), followed by zone I (68 species and abundance 2,586 ind.) (Table 1). Species abundance declined with altitude; it increased rapidly in zone V (Table 1). The subfamily Ennominae exhibits the highest species richness, represented by 93 species (58% of the total, Figure 2), with the highest diversity encountered in the mid-altitudinal zone (1,800–2,400 m), and with transects at 2,200–2,400 m exhibiting the maximum diversity (58 species), followed by steady decline with an increase in altitude (Figure 3). The most dominant genera include *Arichanna* (7 spp.), followed by *Cleora* (4 spp.), *Opisthograptis* (4 spp.), and *Psyra* (4 spp.). The genera, *Abraxas*, *Alcis*, *Biston*, *Dalima*,

Table 1. A brief statement of the five different zones, and their habitat description.

Altitudinal zone	Altitude (m)	Species	Species abundance	Temperature (°C)	Humidity (%)	Habitat description
Zone- I (warm temperate forest)	1200–1800	68	2586	21.19 ± 0.26	63.81 ± 1.12	Mixed forest, dominated by *Engelhardtia spicata* Lesch. ex-Blume and *Quercus leucotrichophora* A.Camus, with interspersed *Rhus punjabensis*. J.L.Stewart ex Brandis; and characterized by riverine ecosystem on its lower end, and interspersed grass-dominant patches.
Zone- II (Cool temperate forest)	1800–2600	98	4686	19.99 ± 0.19	67.22 ± 0.90	Mixed forest, dominated by *Quercus leucotrichophora* A. Camus and *Rhododendron arboreum* Sm., with interspersed *Alnus nepalensis* D.Don, *Neolitsea umbrosa* (Nees) Gamble., *Acer pseudoplatanus* L., and *Q. semecarpifolia* Sm. towards the upper reaches. The forest is marked by interspersed grass habitats and agricultural land
Zone- III (Timberline Forest)	2600–3000	35	1098	18.08 ± 0.27	70.33 ± 0.25	Mixed forest, dominated by *Q. semecarpifolia* and *R. arboreum* Sm., and further marked by *R. barbatum*. and *Acer acuminatum* Wall. ex D.Don, towards upper reaches. This zone is disturbed, characterized by lopping and removal of grass cover.
Zone- IV (Sub-alpine forest)	3000–3400	41	606	15.70 ± 0.85	72.81 ± 0.27	Ecotone, marked out by treeline and alpine meadow. The treeline is dominated by *Acer acuminatum* Wall. ex D.Don., *R. barbatum, R. campanulatum* D.Don. The tree line is marked by a steep slope and is dominated by grass cover
Zone- V (Alpine meadow)	3400–4000	46	1118	11.69 ± 0.95	78.02 ± 0.75	Alpine meadow, characterized by herbaceous vegetation, with few individuals of *R. campanulatum*.

Medasina, and *Ourapterix*, are represented by three species each. Ennominae is followed by Larentiinae (49 species, and 31.05% dominance, Figure 2); exhibiting dominancy in the high-altitudinal zone (2,800–4,000m, Figure 3). Important genera include *Euphyia* (6 spp.), *Photoscotosia* (5 spp.), *Entipheria* (5 spp.), *Eustroma* (4 spp.), and *Eupithecia* (2 spp.). The subfamily Geometrinae did not exhibit a consistent altitudinal gradient pattern, although it comprises 14 species (9% dominance, Figure 2) and is restricted to 2,800 m in distribution (Figure 3). *Pachyodes* was the dominant genus, with three species. The subfamily Sterrhinae was confined to the lower and mid-altitudinal zones (1,200–2,600 m) and comprised four species (Genera 3, Figure 2). Desmobathrinae was represented by a single species, distributed across three transects (2,000–2,600 m, Figure 3).

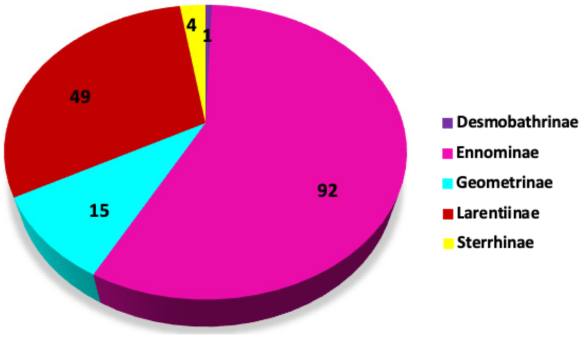

Figure 2. Geometrid species diversity within subfamilies.

The Bray-Curtis Similarity Index (Bray & Curtis 1957) between the distribution pattern and species richness, along the altitudinal gradient, shows that the subfamily Ennominae exhibits maximum diversity at 1,600–2,400 m, and is represented throughout the altitudinal gradient; while Larentiinae exhibits maximum diversity at 3,400–3,600 m, as well as reciprocates Ennominae in its wide distribution, while the rest of the three subfamilies- Desmobathrinae, Geometrinae, and Sterrhinae, are restricted in distribution (Figure 4). Pearson correlation analysis revealed a significant negative relationship between altitude and the species richness of Ennominae ($r = -0.597$, $p = 0.024$), Geometrinae ($r = -0.545$, $p = 0.044$), and Sterrhinae ($r = -0.684$, $p = 0.007$). In contrast, Larentiinae exhibits a strong positive correlation with altitude ($r = 0.730$, $p = 0.003$), indicating an increase in species richness with elevation (Brehm et al. 2007). Desmobathrinae show no significant correlation with altitude ($r = 0.290$, $p = 0.320$), likely due to their extremely low and rare occurrence across the altitudinal gradient (Table 3).

Across transects and the altitudinal gradient, many species exhibit restricted distributions or highly specialized niches. These include 17 species restricted to just one transect, 37 species restricted to just two transects, totalling 54 species, which could be categorised as highly specialized, while two species—*Euphyia subangulata* and *Eustroma melancolicum venipicta* (Larentiinae)—exhibited distribution throughout the

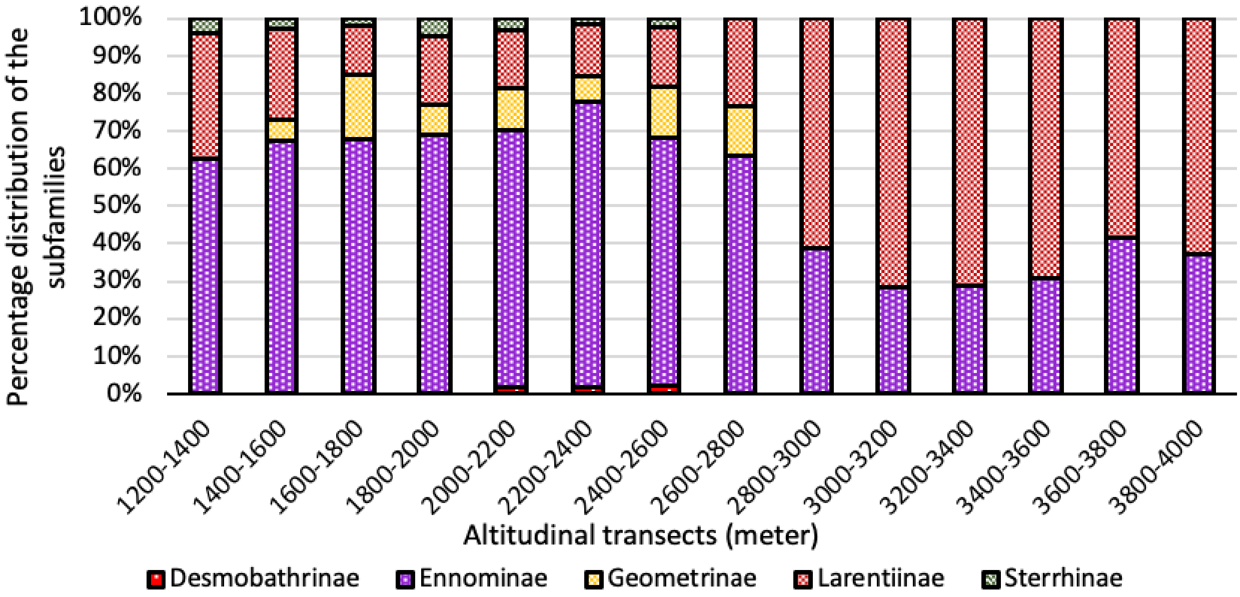

Figure 3. Distributional pattern of each geometrid subfamily along the altitudinal gradient.

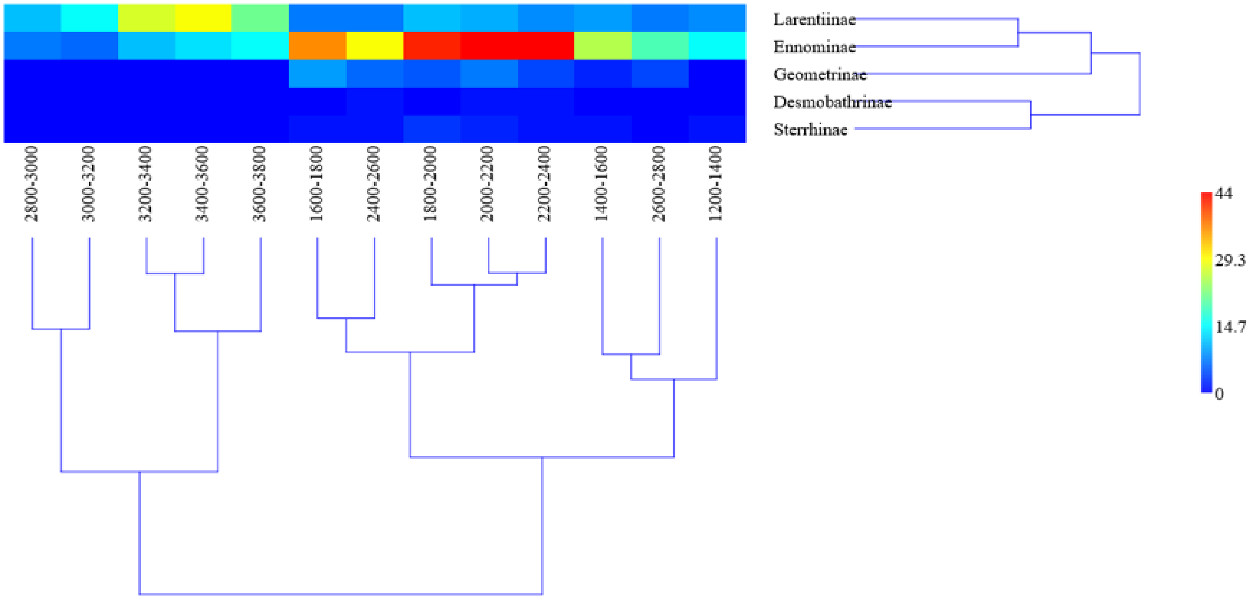

Figure 4. Bray-Curtis similarity index between distribution pattern and species richness, along the altitudinal transects. The subfamilies are distinguished by different colour scales, highlighting their diversity and their wide distribution within the broad study area.

altitudinal gradient. However, in terms of relative distribution, the subfamily Ennominae, represented by 23 species and present across five or more transects, outperforms other families, principally Larentiinae. This is because these species are mostly polyphagous and hence relatively more widely distributed (Lindström et al. 1994).

The indicator values range 53.33–100 %. However, the indicator value of a species was compounded with the *p*-value, which in the present study, should be less than 0.01. Of the 23 species analyzed, 13 exhibited high indicator values (70–100 %) and were therefore categorized as good indicator species, indicating a strong association with specific habitat conditions. The remaining 10 species, exhibiting moderate indicator values of 50–70 %, were classified as detector or early-

Table 2. Distribution profile of individual species along the altitudinal gradient.

	Species	Distribution of species across the transects*													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Subfamily Desmobathrinae (01)															
1	*Ozola* sp.					■	■	■	■						
Subfamily Ennominae (93)															
2	*Abaciscus tristis* Butler, 1889	■	■	■	■	■									
3	*Abraxas permutans* Wehrli, 1931									■	■	■	■		
4	*Abraxas praepiperata* Wehrli, 1935											■	■	■	■
5	*Abraxas* sp.											■	■	■	■
6	*Alcis paraclarata* Sato, 1993		■	■	■										
7	*Alcis praevariegata* Prout, 1929				■	■	■	■							
8	*Alcis variegata* Moore, 1888				■	■	■	■	■						
9	*Anonychia grisea* Butler, 1883										■	■	■	■	■
10	*Anonychia lativitta* Moore, 1888										■	■	■	■	■
11	*Arichanna furcifera* Moore, 1888	■	■	■	■	■									
12	*Arichanna flavinigra* Hampson, 1907	■	■	■	■	■									
13	*Arichanna interplagata* Guenee, 1857	■	■	■	■	■									
14	*Arichanna sparsa* Butler, 1890			■	■	■	■	■	■						
15	*Arichanna tramesata* Moore, 1867			■	■	■									
16	*Arichanna* sp. 1												■	■	■
17	*Arichanna* sp. 2												■	■	■
18	*Blepharoctenucha virescens* Butler, 1880								■	■					
19	*Biston bengaliaria* Guenee, 1858	■	■												
20	*Biston falcata* Warren, 1893			■	■	■	■	■	■						
21	*Biston sionitibetica* Warren, 1941								■						
22	*Cabera quadrifasciaria* Packard, 1873		■	■											
23	*Cassyma deletaria* Moore, 1888				■	■	■								
24	*Chiasmia cymatodes* Wehrli, 1932				■	■	■	■	■						
25	*Chiasmia* sp.						■	■	■	■					
26	*Chorodna vulpinaria* Moore, 1867					■	■	■	■						
27	*Cleora alienaria* Walker, 1860					■	■	■	■	■					
28	*Cleora fraternal* Moore, 1888				■	■	■	■	■	■	■				
29	*Cleora* sp. 1		■	■	■	■	■	■	■						
30	*Cleora* sp. 2			■	■	■	■	■							
31	*Corymica pryeri* Butler, 1878			■	■	■									
32	*Corymica spatiosa* Prout, 1925	■													
33	*Dalima apicata* Moore, 1868				■	■	■	■	■						
34	*Dalima schistacearia* Moore, 1868				■	■	■	■	■						
35	*Dalima truncataria* Moore, 1868					■	■	■	■						
36	*Deinotrichia scotosiaria* Warren, 1893									■	■	■			
37	*Euclidiodes meridionalis* Wallengren, 1860								■	■					
38	*Epigynopteryx* sp.					■	■	■							
39	*Erebabraxas metachromata* Walker, 1862					■	■	■	■						
40	*Erebomorpha fulgurita* Walker, 1860					■									
41	*Eutoea heteroneurata* Guenee, 1858						■	■	■						

	Species	**Distribution of species across the transects***													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
42	*Fascellina plagiata* Walker, 1866			■	■	■									
43	*Gareus* sp.		■												
44	*Harutalcis vialis* Moore, 1888	■	■	■	■	■									
45	*Hirasa scripturaria* Walker, 1866					■	■								
46	*Hyalinetta circumflexa* Kollar, 1848					■	■	■							
47	*Hypephyra cyanargentea* Wehrli, 1925			■	■	■									
48	*Hypochrosis amaurospila* Yazaki, 1995					■	■	■							
49	*Lassaba albidaria* Walker, 1866	■	■	■	■	■	■								
50	*Lomographa vestaliata* Guenee, 1857			■	■										
51	*Loxaspilates hastigera* Butler, 1889											■	■	■	■
52	*Luxiaria amasa* Butler, 1878				■	■	■								
53	*Medasina albidaria* Walker, 1866	■	■	■	■	■									
54	*Medasina combustaria* Walker, 1866			■											
55	*Medasina* sp.	■	■												
56	*Micronidia simpliciata* Moore, 1868					■	■	■							
57	*Mimomiza cruentaria* Moore, 1867			■	■	■	■	■							
58	*Menophra nigrifasciata* Hampson, 1891					■	■								
59	*Menophra* sp.							■	■	■					
60	*Odontopera kanchia* Moore, 1883						■								
61	*Odontopera* sp.							■							
62	*Ophthalmitis cordularia* Swinhoe, 1893			■	■										
63	*Opisthograptis luteolata* L., 1758			■	■	■	■	■							
64	*Opisthograptis tridentifera* Moore, 1888											■	■	■	■
65	*Opisthograptis rumiformis* Hampson, 1902												■	■	■
66	*Opisthograptis sulphurea* Butler, 1880											■	■	■	■
67	*Orthofodonia* sp. 1										■	■	■	■	■
68	*Orthofodonia* sp. 2										■	■	■	■	
69	*Ourapteryx clara* Butler, 1880		■	■	■	■	■								
70	*Ourapteryx consociata* Inoue, 1993		■	■	■	■	■								
71	*Ourapteryx sambucaria* L. 1758		■	■	■	■	■	■	■						
72	*Oxymacaria penumbrata* Warren, 1896				■	■									
73	*Paradarisa consonaria* Hübner, 1799		■	■											
74	*Paraleptomiza bilinearia* Leech, 1897			■	■	■	■	■	■	■					
75	*Parectropis subflava* Bastelberger, 1909			■	■	■	■	■							
76	*Percnia belluaria* Guenee, 1858						■	■	■	■					
77	*Percnia foraria* Guenee, 1858		■	■	■	■	■								
78	*Plagodis inustaria* Moore, 1868							■	■						
79	*Plutodes costatus* Butler, 1886		■												
80	*Pseudomiza cruentaria* Moore, 1867			■	■	■	■	■							
81	*Pseudopanthera himalayica* Kollar, 1848				■	■	■	■	■	■	■				
82	*Psilalcis conspicuata* Moore, 1888	■	■	■											
83	*Psyra angulifera* Walker, 1867							■							
84	*Psyra cuneata* Walker, 1860				■	■	■								
85	*Psyra falcipennis* Yazaki, 1994						■								

	Species	Distribution of species across the transects*													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
86	*Psyra spurcataria* Walker, 1863		■	■	■										
87	*Racotis petrosa* Butler, 1879													■	
88	*Scioglyptis externaria* Walker, 1866					■	■	■	■						
89	*Sirinopteryx rufivinctata* Walker, 1862	■	■	■	■	■									
90	*Stenorumia ablunata* Guenee, 1858		■	■	■	■	■								
91	*Stenorumia duplicilinea* Hampson, 1895											■	■	■	
92	*Tanaoctenia haliaria* Walker, 1861	■	■												
93	*Thinopteryx crocoptera* Kollar, 1844						■								
94	*Xandrames albofasciata* Moore, 1868			■	■	■									
Subfamily Geometrinae (14)															
95	*Chloroglyphica variegata* Butler, 1889			■	■										
96	*Chlororithra fea* Butler, 1889							■							
97	*Comostola minutata* Druce, 1893			■	■										
98	*Dichorda* sp.						■	■	■						
99	*Gelasma inaptaria* Walker, 1863			■	■										
100	*Idiochlora approximans* Warren, 1897		■	■	■	■	■	■							
101	*Lotaphora iridiocolor* Butler, 1880							■	■						
102	*Orothalassodes falsaria* Prout, 1912						■	■	■						
103	*Pachyodes erionoma* Swinhoe, 1893			■	■	■									
104	*Pachyodes moelleri* Warren, 1893					■	■	■	■						
105	*Pachyodes ornataria* Moore, 1888					■	■	■	■						
106	*Pelagodes* sp. 1		■	■	■										
107	*Pelagodes* sp. 2				■	■									
108	*Tanaorhinus formosanus* Okano, 1959			■											
Subfamily Larentiinae (49)															
109	*Agnibesa pictaria brevibasis* Prout, 1938			■	■	■	■								
110	*Amnesicoma bicolor* Oberthur, 1893									■	■	■	■	■	■
111	*Amnesicoma* sp.											■	■	■	■
112	*Baynia odontata* Prout, 1910													■	■
113	*Colostygia* sp.		■	■	■	■									
114	*Dysstroma* sp. 1											■	■		
115	*Dysstroma* sp. 2													■	■
116	*Ecliptopera postpallida* Prout, 1940										■	■	■		
117	*Ecliptopera umbrosaria* Motschulsky, 1861										■	■	■	■	■
118	*Elophos* sp.	■	■	■											
119	*Entephria caesiata* Denis & Schiffermuller, 1775										■	■	■	■	■
120	*Entephria nobiliaria* Herrich-Schaffer, 1852											■	■	■	■
121	*Entephria* sp. 1											■	■	■	■
122	*Entephria* sp. 2											■	■	■	■
123	*Entephria* sp. 3										■	■	■		
124	*Epirrita dilutata* Schiffermuller, 1775									■	■	■	■		
125	*Epirrita* sp.											■	■	■	■
126	*Epirrhoe galiata* Denis & Schiffermuller, 1775	■	■	■											
127	*Eupithecia* sp. 1										■	■	■	■	

	Species	Distribution of species across the transects*													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
128	*Eupithecia* sp. 2			■	■	■	■	■	■	■					
129	*Euphyia coangulata* Prout, 1914				■	■	■	■	■	■					
130	*Euphyia setellata* Warren, 1893									■	■	■	■	■	■
131	*Euphyia subangulata* Kollar, 1844	■	■	■	■	■	■	■	■	■	■	■	■	■	
132	*Euphyia* sp. 1						■	■	■	■					
133	*Euphyia* sp. 2										■	■	■	■	■
134	*Euphyia* sp. 3											■	■	■	
135	*Eustroma chalcoptera* Hampson, 1895												■	■	
136	*Eustroma melencolicum venipicta* Butler, 1878	■	■	■	■	■	■	■	■	■	■	■	■	■	■
137	*Eustroma* sp. 1				■	■	■								
138	*Eustroma* sp. 2										■	■	■	■	
139	*Heterothera sororcula* Bastelberger, 1909											■	■	■	
140	*Hydrelia bicolorata* Moore, 1868					■									
141	*Hysterura multifaria* Swinhoe, 1890											■	■		
142	*Laciniodes plurilinearia* Moore, 1867	■	■	■											
143	*Laciniodes unistirpis* Butler, 1878	■	■												
144	*Lampropteryx otregiata* Metcalf, 1917												■		
145	*Larentia* sp.											■	■		
146	*Lobogonodes multistriata* Butler, 1889	■	■												
147	*Melanthia alaudaria* Freyer, 1846			■	■										
148	*Perizoma bicolor* Warren, 1893	■	■												
149	*Pseudopolynesia* sp.			■	■	■									
150	*Photoscotosia chlorochrota* Hampson, 1902											■	■	■	■
151	*Photoscotosia dejeani* Oberthur, 1893										■	■	■	■	
152	*Photoscotosia indecora* Prout, 1940												■		
153	*Photoscotosia insularis* Bastelberger, 1909							■	■	■	■	■	■		
154	*Photoscotosia metachryseis* Hampson, 1896											■	■	■	■
155	*Physetobasis dentifascia* Hampson, 1895						■	■	■						
156	*Stamnodes danilovi* Erschoff, 1877								■						
157	*Stamnodes pauperaria* Eversmann, 1877									■	■				
Subfamily Sterrhinae (04)															
158	*Organopoda carnearia* Walker, 1861	■													
159	*Scopula calcarata* D.S. Fletcher, 1958				■	■	■								
160	*Scopula* sp.				■	■									
161	*Timandra correspondens* Hampson, 1895			■	■	■	■								

*1—1200–1400 m | 2—1400–1600 m | 3—1600–1800 m | 4—1800–2000 m | 5—2000–2200 m | 6—2200–2400 m | 7—2400–2600 m | 8—2600–2800 m | 9—2800–3000 m | 10—3000–3200 m | 11—3200–3400 m | 12—3400–3600 m | 13—3600–3800 m | 14—3800–4000 m.

warning species (Table 4). Both these categories of indicator species, however, reflect upon the habitat changes, habitat modification, environmental stress, or successional shifts (Bandyopadhyay 2021).

The highest number of indicator species were recorded from Ennominae subfamily (14 spp.), followed by Larentiinae (7 spp.), Sterrhinae (1 sp.), and Geometrinae (1 sp.) (Table 4). In terms of distribution profiles, a significant number of species (5) were confined to transects, ranging 2,200–2,400 m, followed by four species confined to the transects lying at 1,800–2,000 m; in three transects (1,200–1,400 m, 2,400–2,600 m, and 3,600–3,800 m) each have three spp.; in transects at altitudes of 1,600–1,800 m and 2,600–2,800 m two spp. were recorded from each; and the transect 2,800–3,000 m contain only a single indicator species (Table 4). In terms of the distribution of representative indicator species across the families Geometridae exhibiting species distribution across the whole transect area, from 1,200 m at the bottom to 4,000 m, characteristically is marked by the absence of any indicator species between the six transects lying between 1,400–1,600 m, 2,000–2,200 m, 3,000–3,600 m, and 3,800–4,000 m (Table 4).

Several species (Images 1–7) are reported for the first time from Uttarakhand, most of which belong to the subfamily Ennominae. These include- *Chiasmia cymatodes* Wehrli, 1932, *Cleora alienaria* Walker, 1860, *Dalima apicata* Moore, 1868, *Harutalcis vialis* Moore, 1888, and *Micronidia simpliciata* Moore, 1868; while two species- *Agnibesa pictaria brevibasis* Prout, 1938 and *Physetobasis dentifascia* Hampson, 1895, belong to the Larentiinae. Of greater importance are the two species, Euclidiodes meridionalis Wallengren, 1860, and *Hypochrosis amaurospila* Yazaki, 1995 (Ennominae, Images 8 & 9), reported for the first time from the country.

DISCUSSION

Changes in subfamily composition of geometrid moths along elevational transects show different patterns of distribution (Brehm & Fiedler 2003). The maximum diversity encountered in zones I and II (altitude 1,200–2,600 m), reflects the findings of Brehm et al. (2003). Also, the finding that Ennominae accounts for the highest proportions at low elevations (1,200–2,800 m), while Larentiinae dominates at higher elevations (2,800–4,000 m), is consistent with Brehm & Fiedler's (2003) findings in the Ecuadorian Andes.

The declining trend in species diversity, along the altitudinal gradient, could be ascribed to open patches and anthropogenic disturbance, principally in zone III, while the other factors could be declining temperature (21.19 ± 0.26 to 11.69 ± 0.95) and concomitant increase in humidity (63.81 ± 1.12 to 78.02 ± 0.75), with altitude (Table 1). The subfamily Ennominae exhibits a strong positive correlation with ambient temperature (r = 0.61) and a negative correlation with humidity (r = -0.57). In contrast, Larentiinae exhibits a strong negative correlation with temperature (r = -0.78), but a strong positive correlation with humidity (r = 0.74). This contrasts with the findings of Colwell & Lees (2000) and Colwell et al. (2004), which indicate that Ennominae exhibits a positive relationship with both humidity and temperature. With respect to Larentiinae, our findings further support those of Colwell & Lees (2000) and Colwell et al. (2004), namely that species diversity within Larentiinae is positively correlated with humidity.

Overall, for Geometridae, a positive correlation with temperature (r = 0.35) and a negative correlation with humidity (r = -0.32) were observed. It would thus be safe to conclude that changes in species diversity, along the altitudinal gradient, are influenced principally by the vegetation cover—tree species as host plants for Ennominae, and subsequently, herbaceous species in the case of Larentiinae. This feature is exemplified by a positive correlation (r = 0.59) between Ennominae and tree diversity, and a negative correlation (r = -0.74) between Larentiinae and tree diversity. The latter exhibit increased diversity with decreased forest cover and increased herbaceous diversity, as also indicated by their distribution pattern (Figure 3).

The marked increase in species richness in zone 2 relative to zone 1 could be attributed to the ecotonal effect between forest cover and species diversity. In zone 1 the ecotonal effect is between forest cover and agricultural patches. This ecotone effect on species diversity across zones III and IV is presumably offset by anthropogenic disturbance, primarily tree lopping and grass removal. On the other hand, the marked increase in species abundance in the alpine zone could be attributed to greater host plant diversity.

Various biotic and abiotic factors shape the diversity and distribution of Geometrid moths, governing species assemblages along elevational and vegetational gradients (Webb et al. 2002; Graham et al. 2009). One of the major factors determining the distribution pattern of moths is the availability of larval host plants. This is especially true for highly specialized species, as exemplified by 54 species restricted to one or two transects (Brehm et al. 2013). At the same time, 32 species, mostly belonging

1. ***Agnibesa pictaria brevibasis*** **Prout, 1938**

2. ***Chiasmia cymatodes*** **Wehrli, 1932**

3. ***Cleora alienaria*** **Walker, 1860**

4. ***Dalima apicata*** **Moore, 1868**

5. ***Harutalcis vialis*** **Moore, 1888**

6. ***Micronidia simpliciata*** **Moore, 1868**

7. ***Physetobasis dentifascia*** **Hampson, 1895**

8. ***Euclidiodes meridionalis*** **Wallengren, 1860**

9. ***Hypochrosis amaurospila*** **Yazaki, 1995**

Images 1–9. Moths from Pithoragarh District, Kumaon Himalaya. © Narendra Singh Lotani.

Table 3. Correlation between species richness and altitudinal gradient.

	Subfamilies	Altitudinal transects														Correlation coefficient	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	*r*-value	*p*-value
1	Desmobathrinae	0	0	0	0	1	1	1	0	0	0	0	0	0	0	+0.290	0.320
2	Ennominae	15	25	36	42	44	44	29	19	7	6	11	13	15	10	-0.597	0.024
3	Geometrinae	0	2	9	5	7	4	6	4	0	0	0	0	0	0	-0.545	0.044
4	Larentiinae	8	9	7	11	10	8	7	7	11	15	27	29	21	17	+0.730	0.003
5	Sterrhinae	1	1	1	3	2	1	1	0	0	0	0	0	0	0	-0.684	0.007

***1**—1200–1400 m | **2**—1400–1600 m | **3**—1600–1800 m | **4**—1800–2000 m | **5**—2000–2200 m | **6**—2200–2400 m | **7**—2400–2600 m | **8**—2600–2800 m | **9**—2800–3000 m | **10**—3000–3200 m | **11**—3200–3400 m | **12**—3400–3600 m | **13**—3600–3800 m | **14**—3800–4000 m.

Table 4. Indicator species of the Geometridae family with their indicator value and significant *p*-value.

	Subfamily	Species	Indicator value (%)	p-value	Transect
1	Ennominae	*Biston sionitibetica* Warren, 1941	100	0.0096	2600–2800 m
2	Ennominae	*Corymica spatiosa* Prout, 1925	100	0.0099	1200–1400 m
3	Ennominae	*Euclidiodes meridionalis* Wallengren, 1860	100	0.0096	2600–2800 m
4	Ennominae	*Odontopera kanchia* Moore, 1883	100	0.0098	2400–2600 m
5	Ennominae	*Psyra falcipennis* Yazaki, 1994	100	0.0096	2200–2400 m
6	Geometrinae	*Chlororithra fea* Butler, 1889	100	0.0096	2200–2400 m
7	Larentiinae	*Stamnodes danilovi* Erschoff, 1877	100	0.0096	2400–2600 m
8	Ennominae	*Gelasma inaptaria* Walker, 1863	83.33	0.0098	1800–2000 m
9	Ennominae	*Plagodis inustaria* Moore, 1868	82.35	0.0097	2400–2600 m
10	Ennominae	*Ophthalmitis cordularia* Swinhoe, 1893	73.21	0.0098	1800–2000 m
11	Larentiinae	*Perizoma bicolor* Warren, 1893	73.21	0.0099	1200–1400 m
12	Larentiinae	*Baynia odontata* Prout, 1910	71.66	0.0099	3600–3800 m
13	Larentiinae	*Eustroma chalcoptera* Hampson, 1895	70.23	0.0098	3600–3800 m
14	Ennominae	*Tanaoctenia haliaria* Walker, 1861	69.34	0.0098	1200–1400 m
15	Ennominae	*Cabera quadrifasciaria* Packard, 1873	68.18	0.0099	1600–1800 m
16	Larentiinae	*Melanthia alaudaria* Freyer, 1846	66.67	0.0099	1600–1800 m
17	Ennominae	*Hirasa scripturaria* Walker, 1866	64.71	0.0098	2200–2400 m
18	Sterrhinae	*Scopula* sp.	63.36	0.01	2200–2400 m
19	Ennominae	*Eutoea heteroneurata* Guenee, 1858	61.52	0.0098	2200–2400 m
20	Ennominae	*Lomographa vestaliata* Guenee, 1857	59.23	0.0096	1800–2000 m
21	Larentiinae	*Stamnodes pauperaria* Eversmann, 1877	58.06	0.0099	2800–3000 m
22	Larentiinae	*Hysterura multifaria* Swinhoe, 1889	53.85	0.0096	3600–3800 m
23	Ennominae	*Oxymacaria penumbrata* Warren, 1896	53.33	0.0096	1800–2000 m

to Ennominae (23 species), exhibiting relatively wider distribution (more than 5 transects, which equals a significant distance of 1 km altitudinally), could be defined as 'polyphagous' and 'generalists.'

The relative greater species richness as well as abundance of moths, predominantly belonging to the subfamily Larentiinae, in the alpine (zone V), compared to immediate sub-alpine zones III and IV, could be ascribed to the fact that species occupying higher elevations have a larger range of tolerances (Brehm et al. 2007), and possess physiological characteristics to comply with the cooler temperatures and affiliation with the host plants that have colonized the upper areas (Brehm et al. 2013). It could be presumed that the Larentiinae moths are better suited to cooler environments than the members of other subfamilies, especially Sterrhinae and Geometrinae (Brehm et al. 2013). The physiological properties, which allow moths of this subfamily to be unusually tolerant of unfavourable conditions, however, remain unknown (Brehm & Fiedler 2003). Furthermore, Larentiinae moths, owing to their relatively weaker body structure compared with other subfamilies, are weak flyers, which might benefit them in predator-free environments (Brehm & Fiedler 2003). Moderate host-plant specificity, as exhibited primarily by Ennominae, coupled with adaptability to cooler temperatures, as exhibited by Larentiinae, broadly describes patterns in species distribution across the altitudinal gradient (Brehm et al. 2013).

The indicator species were confined to a single transect, i.e., within an altitudinal breadth of just 200 m, which makes them not just highly specialized species (in terms of distribution), but more importantly, their niche specificity, relegated to biotic (mostly) and abiotic factors, would necessitate their greater monitoring. Any degradation of the habitat would invariably result in population decline and the loss of these species.

REFERENCES

Ashton, L.A., E.H. Odell, C.J. Burwell, S.C. Maunsell, A. Nakamura, W.J.F. McDonald & R.L. Kitching (2016). Altitudinal patterns of moth diversity in tropical and subtropical Australian rainforests. *Austral Ecology* 41(2): 197–208. https://doi.org/10.1111/aec.12309

Ashton, L.A., R.L. Kitching, S. Maunsell, D. Bito & D. Putland (2011). Macrolepidopteran assemblages along an altitudinal gradient in subtropical rainforest—Exploring indicators of climate change. *Memoirs of the Queensland Museum* 55(2): 375–389.

Axmacher, J.C., G. Holtmann, L. Scheuermann, G. Brehm, K. Müller-Hohenstein & K. Fiedler (2004). Diversity of geometrid moths (Lepidoptera, Geometridae) along an Afrotropical elevational rainforest transect. *Diversity and Distributions* 10(4): 293–302. https://doi.org/10.1111/j.1366-9516.2004.00110.x

Bandyopadhyay, U. (2021). Diversity and distribution pattern of moths (Lepidoptera: Heterocera) with spatial emphasis on family Noctuidae in Askote Wildlife Sanctuary, Uttarakhand. *Doctoral dissertation*, Saurashtra University, Rajkot, India**.**

Beck, J. & I.J. Kitching (2009). Drivers of moth species richness on tropical altitudinal gradients: A cross-regional comparison. *Global Ecology and Biogeography* 18(3): 361–371. https://doi.org/10.1111/j.1466-8238.2009.00447.x

Beck, J. & V.K. Chey (2008). Explaining the elevational diversity pattern of geometrid moths from Borneo: A test of five hypotheses. *Journal of Biogeography* 35(8): 1452–1464. https://doi.org/10.1111/j.1365-2699.2008.01886.x

Bray, J.R. & J.T. Curtis (1957). An ordination of the upland forest communities of southern Wisconsin. *Ecological Monographs* 27(4): 325–349. https://doi.org/10.2307/1942268

Brehm, G. & K. Fiedler (2003). Faunal composition of geometrid moths changes with altitude in an Andean montane rainforest. *Journal of Biogeography* 30 (2): 431–440. https://doi.org/10.1046/j.1365-2699.2003.00830.x

Brehm, G. & K. Fiedler (2005). Diversity and community structure of geometrid moths of disturbed habitat in a montane area in the Ecuadorian Andes. *Journal of Research on the Lepidoptera* 38: 1–14. https://doi.org/10.5962/p.266542

Brehm, G., J. Homeier & K. Fiedler (2003). Beta diversity of geometrid moths (Lepidoptera, Geometridae) in an Andean montane rainforest. *Diversity and Distributions* 9(5): 351–366. https://doi.org/10.1046/j.1472-4642.2003.00023.x

Brehm, G., P. Strutzenberger & K. Fiedler (2013). Phylogenetic diversity of geometrid moths decreases with elevation in the tropical Andes. *Ecography* 36(11): 1247–1253. https://doi.org/10.1111/j.1600-0587.2013.00030.x

Brehm, G., R.K. Colwell & J. Kluge (2007). The role of environment and mid-domain effect on moth species along a tropical elevational gradient. *Global Ecology and Biogeography* 16(2): 205–219. https://doi.org/10.1111/j.1466-8238.2006.00281.x

Choi, S.W. (2006). Patterns of species description and species richness of geometrid moths (Lepidoptera, Geometridae) on the Korean peninsula. *Zoological Science* 23(2): 155–160. https://doi.org/10.2108/zsj.23.155

Colwell, F., R. Matsumoto & D. Reed (2004). A review of the gas hydrates, geology, and biology of the Nankai Trough. *Chemical Geography* 205(3–5): 391–404. https://doi.org/10.1016/j.chemgeo.2003.12.034

Colwell, R.K. & D.C. Lees (2000). The mid-domain effect: geometric constraints on the geography of species richness. *Trends in Ecology and Evolution* 15(2): 70–76. https://doi.org/10.1016/S0169-5347(99)01767-X

Dey, P., V.P. Uniyal & K. Sanyal (2015). Moth assemblages (Lepidoptera: Heterocera) as a potential conservational tool for biodiversity monitoring- Study in western Himalayan protected areas. *Indian Forester* 141(9): 985–992.

Doran, N.E., J. Balmer, M. Driessen, R. Bashford, S. Grove, A.M. Richardson & D. Ziegeler (2003). Moving with the times: Baseline data to gauge future shifts in vegetation and invertebrate altitudinal assemblages due to environmental change. *Organisms Diversity & Evolution* 3(2): 127–149. https://doi.org/10.1078/1439-6092-00069

Dufrêne, M. & P. Legendre (1997). Species assemblages and indicator species: the need for a flexible asymmetrical approach. *Ecological Monographs* 67(3): 345–366. https://doi.org/10.1890/0012-9615(1997)067[0345:SAAIST]2.0.CO;2

Enkhtur, K., B. Boldgiv & M. Pfeiffer (2020). Diversity and distribution patterns of geometrid moths (Geometridae, Lepidoptera) in Mongolia. *Diversity* 12(5): 186. https://doi.org/10.3390/d12050186

Enkhtur, K., M. Pfeifer, A. Lkhagva & B. Boldgiv (2017). Response of moths (Lepidoptera: Heterocera) to livestock grazing in Mongolian rangelands. *Ecological Indicators* 72: 667–674. https://doi.org/10.1016/j.ecolind.2016.08.047

Fiedler, K. & E. Beck (2008). Investigating gradients in ecosystem analysis, pp. 49–54. In: Beck, E., J. Bendix, I. Kottke, F. Makeschin & R. Mosandl (eds.). *Gradients in a Tropical Mountain Ecosystem of Ecuador*. Springer Verlag (Ecological Studies 198), Berlin, 6. https://doi.org/10.1007/978-3-540-73526-7_6

Fiedler, K., G. Brehm, N. Hilt, D. Subenbach & C.L. Hauser (2008). Variation of diversity patterns across moth families along a tropical altitudinal gradient, pp. 167–179. In: Beck, E., J. Bendix, I. Kottke, F. Makeschin & R. Mosandl (eds.). *Gradients in a Tropical Mountain Ecosystem of Ecuador.* Springer Verlag (Ecological Studies 198), Berlin, https://doi.org/10.1007/978-3-540-73526-7

Fischer, A., M. Blaschke & C. Bassler (2011). Altitudinal gradients in biodiversity research: The state of the art and future perspectives under climate change aspects. *Forest Ecology, Landscape Research and Conservation* 11: 5–17.

Foster, P. (2010). Changes in mist immersion, pp. 57–66. In: Bruijnzeel, L.A., F.N. Scatena & L. S. Hamilton, (eds.). *Tropical Montane Cloud Forests: Science for Conservation and Management.* Cambridge University Press, Cambridge, U.K, https://doi.org/10.1017/CBO9780511778384.006

Graham, C.H., J.L. Parra, C. Rahbek & J.A. McGuire (2009). Phylogenetic structure in tropical hummingbird communities. *Proceedings of the*

National Academy of Sciences 106 (2): 19673–19678. https://doi.org/10.1073/pnas.0901649106

Haruta, T. (Ed.) (2000). *Moths of Nepal, Part 6.* Tinea 16(Suppl. 1): 1–163. https://www.pemberleybooks.com/product/moths-of-nepal.-6/4361/?utm_source=chatgpt.com

Hill, G.M., A.Y. Kawahara, J.C. Daniels, C.C. Bateman & B.R. Scheffers (2021). Climate change effects on animal ecology: Butterflies and moths as a case study. *Biological Reviews* 96(5): 2113–2126. https://doi.org/10.1111/brv.12746

Holloway, J.D. (1985a). Moths as indicator organisms for categorizing rain forest and monitoring changes and regenerating processes, pp. 235–242. In: Chadwick, A.C. & S.L. Sutton (eds.). *Tropical Rainforest: The Leeds Symposium*. Philosophical and Literary Society, London, UK.

Holloway, J.D. (1985b). The moths of Borneo: Part 14. Family Noctuidae: Euteliinae, Stictopterinae, Plusiinae, Pantheinae. *Malayan Nature Journal* 38(2–3): 157–317. https://doi.org/10.5281/zenodo.6195532

Holloway, J.D. (1987). Macrolepidoptera diversity in the Indo-Australian tropics: Geographic, biotopic, and taxonomic variations. *Biological Journal of the Linnean Society* 30(4): 325–341. https://doi.org/10.1111/j.1095-8312.1987.tb00305.x

Holloway, J.D. (1993). The moths of Borneo (Part 11), Family Geometridae: Subfamilies Ennominae. *Malayan Nature Journal* 47(1): 1–309.

Holloway, J.D. (1996). The moths of Borneo (Part 9), Family Geometridae: Subfamilies Oenochrominae, Desmobathrinae, Geometrinae. *Malayan Nature Journal* 49(2–3): 147–326.

Holloway, J.D. (1997). The moths of Borneo (Part 10), Family Geometridae: Subfamilies Sterrhinae, Larentiinae, Addenda to other subfamilies. *Malayan Nature Journal* 51(1): 1–242. https://doi.org/10.1007/978-3-540-73526-7_15

Jacobson, M.Z. (2005). *Fundamentals of Atmospheric Modelling*. Cambridge University Press, Cambridge, UK. https://doi.org/10.1017/CBO9780511812870

Kessler, M., S.K. Herzog & J. Fjeldsa (2001). Species richness and endemism of plant and bird communities along two gradients of elevation, humidity, and land use in the Bolivian Andes. *Diversity and Distributions* 7(2): 61–77. https://doi.org/10.1046/j.1472-4642.2001.00097.x

Kitching, R.L. & L.A. Ashton (2014). Predictor sets and biodiversity assessments: the evolution and application of an idea. *Pacific Conservation Biology* 19(4): 418–426. https://doi.org/10.1071/PC130418

Kitching, R.L., D. Putland, L.A. Ashton, M.J. Laidlaw, S.L. Boulter, H. Christensen & C.L. Lambkin (2011). Detecting biodiversity changes along climatic gradients: The IBISCA Queensland Project. *Memoirs of the Queensland Museum* 55(2): 235–250. https://doi.org/10.17082/j.2204-1478.55.2011.2011-02

Kristensen, N.P., M.J. Scoble & O. Karsholt (2007). Lepidoptera phylogeny and systematics: the state of inventorying moth and butterfly diversity. *Zootaxa* 1668(1): 699–747. https://doi.org/10.11646/zootaxa.1668.1.30

Krogmann, L., J. Holstein, J. Eymann, J. Degreef, C. Hauser, J.C. Monje & D.V. Spiegel (2010). Preserving and specimen handling: Insects and other invertebrates, pp. 463–481. In: Eymann, J., J. Degreef, C. Häuser, J.C. Monje, Y. Samyn & D.V. Spiegel (eds.). *Manual on Field Recording Techniques and Protocols for All-Taxa Biodiversity Inventories* 2. Abc Taxa.be, Belgian Development Corporation, 18. https://doi.org/10.5281/zenodo.4628402

Lomolino, M.V. (2001). Elevation gradients of species density: Historical and prospective views. *Global Ecology and Biogeography* 10(1): 3–13. https://doi.org/10.1046/j.1466-822X.2001.00229.x

Lomov, B., D.A. Keith, D.R. Britton & D.F. Hochuli (2006). Are butterflies and moths useful indicators for restoration monitoring? A pilot study in Sydney's Cumberland Plain Woodland. *Ecological Management and Restoration* 7(2): 204–210. https://doi.org/10.1111/j.1442-8903.2006.00310.x

McGeoch, M.A., B.J. van Rensburg & A. Botes (2002). The verification and application of bioindicators: a case study of dung beetles in a savanna ecosystem. *Journal of Applied Ecology* 39(4): 661–672. https://doi.org/10.1046/j.1365-2664.2002.00743.x

Nakamura, A., C.J. Burwell, L.A. Ashton, M.J. Laidlaw, M. Katabuchi & R.L. Kitching (2016). Identifying indicator species of elevation: Comparing the utility of woody plants, ants, and moths for long-term monitoring. *Australian Ecology* 41(2): 179–188. https://doi.org/10.1111/aec.12319

Pearson, K. (1895). Notes on regression and inheritance in the case of two parents. *Proceedings of the Royal Society of London* 58: 240–242.

Rahbek, C. (2005). The role of spatial scale and the perception of large-scale species richness patterns. *Ecology Letters* 8(2): 224–239. https://doi.org/10.1111/j.1461-0248.2004.00701.x

Ratnasingham, S. & P.D.N. Hebert (2007). BOLD: the Barcode of Life Data System (www.barcodinglife.org). *Molecular Ecology Notes* 7(3): 355–364. https://doi.org/10.1111/j.1471-8286.2007.01678.x

Rehm, E.M. (2014). Rates of upslope shifts for tropical species depend on life history and dispersal mode. *Proceedings of the National Academy of Sciences USA* 111(17): E1676. https://doi.org/10.1073/pnas.1403417111

Ricketts, T.H., G.C. Daily, P. R. Ehrlich & J.P. Fay (2001). Countryside biogeography of moths in a fragmented landscape: Biodiversity in native and agricultural habitats. *Conservation Biology* 15(2): 378–388. https://doi.org/10.1046/j.1523-1739.2001.015002378.x

Sanyal, A.K., P. Dey, V.P. Uniyal, K. Chandra & A. Raha (2017). Geometridae Stephens, 1829 from different altitudes in western Himalayan Protected areas of Uttarakhand, India (Lepidoptera: Geometridae). *SHILAP Revista de Lepidopterología* 45(177): 143–163. https://doi.org/10.57065/shilap.978

Schulze, C.H., K.E. Linsenmair & K. Fiedler (2001). Understorey versus canopy: Patterns of vertical stratification and diversity among Lepidoptera in a Bornean rainforest. *Plant Ecology* 153(1–2): 133–152. https://doi.org/10.1023/A:1017589711553

Scoble, M.J. & A. Hausmann (2007). Online list of valid and available names of the Geometridae of the world. Geometroidea Archive. https://geometroidea.smns-bw.org/archive/48. Accessed on 18.v.2023

Scoble, M.J. (1992). *The Lepidoptera—Form, Function and Diversity.* Oxford University Press, Oxford, UK, xi + 404 pp.

Stevens, G.C. (1992). The elevational gradient in altitudinal range: An extension of Rapoport's latitudinal rule to altitude. *American Naturalist* 140(6): 893–911. https://doi.org/10.1086/285447

Strong, C.L., S.L. Boulter, M.J. Laidlaw, S.C. Maunsell, D. Putland & R.L. Kitching (2011). The physical environment of an altitudinal gradient in the rainforest of Lamington National Park, southeast Queensland. *Memoirs of the Queensland Museum* 55(2): 251–270.

Summerville, K.S. & T.O. Crist (2003). Determinants of lepidopteran community composition and species diversity in eastern deciduous forests: Roles of season, eco-region, and patch size. *Oikos* 100(1): 134–148. https://doi.org/10.1034/j.1600-0706.2003.11992.x

Toko, P.S., B. Koane, K. Molem, S.E. Miller & V. Novotny (2023). Ecological trends in moth communities (Geometridae, Lepidoptera) along a complete rainforest elevation gradient in Papua New Guinea. *Insect Conservation and Diversity* 16(5): 649–657. https://doi.org/10.1111/icad.12663

Webb, C.O., D.D. Ackerly, M.A. McPeek & M.J. Donoghue (2002). Phylogenies and community ecology. *Annual Review of Ecology, Evolution, and Systematics* 33: 475–505. https://doi.org/10.1146/annurev.ecolsys.33.010802.150448

Mr. Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.
Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK
Dr. George Mathew, Kerala Forest Research Institute, Peechi, India
Dr. John Noyes, Natural History Museum, London, UK
Dr. Albert G. Orr, Griffith University, Nathan, Australia
Dr. Sameer Padhye, Katholieke Universiteit Leuven, Belgium
Dr. Nancy van der Poorten, Toronto, Canada
Dr. Kareen Schnabel, NIWA, Wellington, New Zealand
Dr. R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India
Dr. Manju Siliwal, WILD, Coimbatore, Tamil Nadu, India
Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India
Dr. P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India
Dr. R. Varatharajan, Manipur University, Imphal, Manipur, India
Dr. Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain
Dr. James Young, Hong Kong Lepidopterists' Society, Hong Kong
Dr. R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India
Dr. M. Nithyanandan, Environmental Department, La Ala Al Kuwait Real Estate. Co. K.S.C., Kuwait
Dr. Himender Bharti, Punjabi University, Punjab, India
Mr. Purnendu Roy, London, UK
Mr. Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan
Dr. Sanjay Sondhi, TITLI TRUST, Kalpavriksh, Dehradun, India
Dr. Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam
Dr. Nitin Kulkarni, Tropical Research Institute, Jabalpur, India
Dr. Robin Wen Jiang Ngiam, National Parks Board, Singapore
Dr. Lional Monod, Natural History Museum of Geneva, Genève, Switzerland.
Dr. Asheesh Shivam, Nehru Gram Bharti University, Allahabad, India
Dr. Rosana Moreira da Rocha, Universidade Federal do Paraná, Curitiba, Brasil
Dr. Kurt R. Arnold, North Dakota State University, Saxony, Germany
Dr. James M. Carpenter, American Museum of Natural History, New York, USA
Dr. David M. Claborn, Missouri State University, Springfield, USA
Dr. Kareen Schnabel, Marine Biologist, Wellington, New Zealand
Dr. Amazonas Chagas Júnior, Universidade Federal de Mato Grosso, Cuiabá, Brasil
Mr. Monsoon Jyoti Gogoi, Assam University, Silchar, Assam, India
Dr. Heo Chong Chin, Universiti Teknologi MARA (UiTM), Selangor, Malaysia
Dr. R.J. Shiel, University of Adelaide, SA 5005, Australia
Dr. Siddharth Kulkarni, The George Washington University, Washington, USA
Dr. Priyadarsanan Dharma Rajan, ATREE, Bengaluru, India
Dr. Phil Alderslade, CSIRO Marine And Atmospheric Research, Hobart, Australia
Dr. John E.N. Veron, Coral Reef Research, Townsville, Australia
Dr. Daniel Whitmore, State Museum of Natural History Stuttgart, Rosenstein, Germany.
Dr. Yu-Feng Hsu, National Taiwan Normal University, Taipei City, Taiwan
Dr. Keith V. Wolfe, Antioch, California, USA
Dr. Siddharth Kulkarni, The Hormiga Lab, The George Washington University, Washington, D.C., USA
Dr. Tomas Ditrich, Faculty of Education, University of South Bohemia in Ceske Budejovice, Czech Republic
Dr. Mihaly Foldvari, Natural History Museum, University of Oslo, Norway
Dr. V.P. Uniyal, Wildlife Institute of India, Dehradun, Uttarakhand 248001, India
Dr. John T.D. Caleb, Zoological Survey of India, Kolkata, West Bengal, India
Dr. Priyadarsanan Dharma Rajan, Ashoka Trust for Research in Ecology and the Environment (ATREE), Royal Enclave, Bangalore, Karnataka, India

Fishes

Dr. Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México
Dr. Heok Hee Ng, National University of Singapore, Science Drive, Singapore
Dr. Rajeev Raghavan, St. Albert's College, Kochi, Kerala, India
Dr. Robert D. Sluka, Chiltern Gateway Project, A Rocha UK, Southall, Middlesex, UK
Dr. E. Vivekanandan, Central Marine Fisheries Research Institute, Chennai, India
Dr. Davor Zanella, University of Zagreb, Zagreb, Croatia
Dr. A. Biju Kumar, University of Kerala, Thiruvananthapuram, Kerala, India
Dr. Akhilesh K.V., ICAR-Central Marine Fisheries Research Institute, Mumbai Research Centre, Mumbai, Maharashtra, India
Dr. J.A. Johnson, Wildlife Institute of India, Dehradun, Uttarakhand, India
Dr. R. Ravinesh, Gujarat Institute of Desert Ecology, Gujarat, India

Amphibians

Dr. Sushil K. Dutta, Indian Institute of Science, Bengaluru, Karnataka, India
Dr. Annemarie Ohler, Muséum national d'Histoire naturelle, Paris, France

Reptiles

Dr. Gernot Vogel, Heidelberg, Germany
Dr. Raju Vyas, Vadodara, Gujarat, India
Dr. Pritpal S. Soorae, Environment Agency, Abu Dubai, UAE.
Prof. Dr. Wayne J. Fuller, Near East University, Mersin, Turkey
Prof. Chandrashekher U. Rivonker, Goa University, Taleigao Plateau, Goa. India
Dr. S.R. Ganesh, Kalinga Foundation, Agumbe, India.
Dr. Himansu Sekhar Das, Terrestrial & Marine Biodiversity, Abu Dhabi, UAE

Birds

Dr. Hem Sagar Baral, Charles Sturt University, NSW Australia
Mr. H. Byju, Coimbatore, Tamil Nadu, India
Dr. Chris Bowden, Royal Society for the Protection of Birds, Sandy, UK
Dr. Priya Davidar, Pondicherry University, Kalapet, Puducherry, India
Dr. J.W. Duckworth, IUCN SSC, Bath, UK
Dr. Rajah Jayapal, SACON, Coimbatore, Tamil Nadu, India
Dr. Rajiv S. Kalsi, M.L.N. College, Yamuna Nagar, Haryana, India
Dr. V. Santharam, Rishi Valley Education Centre, Chittoor Dt., Andhra Pradesh, India
Dr. S. Balachandran, Bombay Natural History Society, Mumbai, India
Mr. J. Praveen, Bengaluru, India
Dr. C. Srinivasulu, Osmania University, Hyderabad, India
Dr. K.S. Gopi Sundar, International Crane Foundation, Baraboo, USA
Dr. Gombobaatar Sundev, Professor of Ornithology, Ulaanbaatar, Mongolia
Prof. Reuven Yosef, International Birding & Research Centre, Eilat, Israel
Dr. Taej Mundkur, Wetlands International, Wageningen, The Netherlands
Dr. Carol Inskipp, Bishop Auckland Co., Durham, UK
Dr. Tim Inskipp, Bishop Auckland Co., Durham, UK
Dr. V. Gokula, National College, Tiruchirappalli, Tamil Nadu, India
Dr. Arkady Lelej, Russian Academy of Sciences, Vladivostok, Russia
Dr. Simon Dowell, Science Director, Chester Zoo, UK
Dr. Mário Gabriel Santiago dos Santos, Universidade de Trás-os-Montes e Alto Douro, Quinta de Prados, Vila Real, Portugal
Dr. Grant Connette, Smithsonian Institution, Royal, VA, USA
Dr. P.A. Azeez, Coimbatore, Tamil Nadu, India

Mammals

Dr. Giovanni Amori, CNR - Institute of Ecosystem Studies, Rome, Italy
Dr. Anwaruddin Chowdhury, Guwahati, India
Dr. David Mallon, Zoological Society of London, UK
Dr. Shomita Mukherjee, SACON, Coimbatore, Tamil Nadu, India
Dr. Angie Appel, Wild Cat Network, Germany
Dr. P.O. Nameer, Kerala Agricultural University, Thrissur, Kerala, India
Dr. Ian Redmond, UNEP Convention on Migratory Species, Lansdown, UK
Dr. Heidi S. Riddle, Riddle's Elephant and Wildlife Sanctuary, Arkansas, USA
Dr. Karin Schwartz, George Mason University, Fairfax, Virginia.
Dr. Lala A.K. Singh, Bhubaneswar, Orissa, India
Dr. Mewa Singh, Mysore University, Mysore, India
Dr. Paul Racey, University of Exeter, Devon, UK
Dr. Honnavalli N. Kumara, SACON, Anaikatty P.O., Coimbatore, Tamil Nadu, India
Dr. Nishith Dharaiya, HNG University, Patan, Gujarat, India
Dr. Spartaco Gippoliti, Socio Onorario Società Italiana per la Storia della Fauna "Giuseppe Altobello", Rome, Italy
Dr. Justus Joshua, Green Future Foundation, Tiruchirapalli, Tamil Nadu, India
Dr. H. Raghuram, Sri S. Ramasamy Naidu Memorial College, Virudhunagar, Tamil Nadu, India
Dr. Paul Bates, Harison Institute, Kent, UK
Dr. Jim Sanderson, Small Wild Cat Conservation Foundation, Hartford, USA
Dr. Dan Challender, University of Kent, Canterbury, UK
Dr. David Mallon, Manchester Metropolitan University, Derbyshire, UK
Dr. Brian L. Cypher, California State University-Stanislaus, Bakersfield, CA
Dr. S.S. Talmale, Zoological Survey of India, Pune, Maharashtra, India
Prof. Karan Bahadur Shah, Budhanilakantha Municipality, Kathmandu, Nepal
Dr. Susan Cheyne, Borneo Nature Foundation International, Palangkaraja, Indonesia
Dr. Hemanta Kafley, Wildlife Sciences, Tarleton State University, Texas, USA

Other Disciplines

Dr. Aniruddha Belsare, Columbia MO 65203, USA (Veterinary)
Dr. Mandar S. Paingankar, University of Pune, Pune, Maharashtra, India (Molecular)
Dr. Jack Tordoff, Critical Ecosystem Partnership Fund, Arlington, USA (Communities)
Dr. Ulrike Streicher, University of Oregon, Eugene, USA (Veterinary)
Dr. Hari Balasubramanian, EcoAdvisors, Nova Scotia, Canada (Communities)
Dr. Rayanna Hellem Santos Bezerra, Universidade Federal de Sergipe, São Cristóvão, Brazil
Dr. Jamie R. Wood, Landcare Research, Canterbury, New Zealand
Dr. Wendy Collinson-Jonker, Endangered Wildlife Trust, Gauteng, South Africa
Dr. Rajeshkumar G. Jani, Anand Agricultural University, Anand, Gujarat, India
Dr. O.N. Tiwari, Senior Scientist, ICAR-Indian Agricultural Research Institute (IARI), New Delhi, India
Dr. L.D. Singla, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, India
Dr. Rupika S. Rajakaruna, University of Peradeniya, Peradeniya, Sri Lanka
Dr. Bahar Baviskar, Wild-CER, Nagpur, Maharashtra 440013, India

Reviewers 2021–2023
Due to pausity of space, the list of reviewers for 2021–2023 is available online.

Journal of Threatened Taxa is indexed/abstracted in Bibliography of Systematic Mycology, Biological Abstracts, BIOSIS Previews, CAB Abstracts, EBSCO, Google Scholar, Index Copernicus, Index Fungorum, JournalSeek, National Academy of Agricultural Sciences, NewJour, OCLC WorldCat, SCOPUS, Stanford University Libraries, Virtual Library of Biology, Zoological Records.

NAAS rating (India) 5.64

The opinions expressed by the authors do not reflect the views of the Journal of Threatened Taxa, Wildlife Information Liaison Development Society, Zoo Outreach Organization, or any of the partners. The journal, the publisher, the host, and the partners are not responsible for the accuracy of the political boundaries shown in the maps by the authors.

Print copies of the Journal are available at cost. Write to:
The Managing Editor, JoTT,
c/o Wildlife Information Liaison Development Society,
3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org & ravi@zooreach.org

Journal of Threatened Taxa
www.threatenedtaxa.org

ISSN 0974-7907 (Online) | ISSN 0974-7893 (Print)

March 2026 | Vol. 18 | No. 3 | Pages: 28455–28606
Date of Publication: 26 March 2026 (Online & Print)
DOI: 10.11609/jott.2026.18.3.28455-28606

Articles

Communications

Short Communications

Notes

Publisher & Host
WILD
zooreach
Zoo Outreach Organisation
Threatened Taxa