Building evidence for conservation globally

Journal of Threatened Taxa

10.11609/jott.2023.15.6.23283-23462
www.threatenedtaxa.org

26 June 2023 (Online & Print)
15(6): 23283–23462
ISSN 0974-7907 (Online)
ISSN 0974-7893 (Print)

Open Access

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

43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, 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), 43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore, Tamil Nadu 641006, India

Deputy Chief Editor
Dr. Neelesh Dahanukar
Noida, Uttar Pradesh, 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
Dr. B.A. Daniel, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India

Editorial Board
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. Martin Fisher
Senior Associate Professor, Battcock Centre for Experimental Astrophysics, Cavendish Laboratory, JJ Thomson Avenue, Cambridge CB3 0HE, UK

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
Mr. P. Ilangovan, Chennai, India
Ms. Sindhura Stothra Bhashyam, Hyderabad, India

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

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

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

Subject Editors 2020–2022

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

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
Mr. Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.

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: Marine invertebrates - made with acrylic paint. © P. Kritika.

Journal of Threatened Taxa | www.threatenedtaxa.org | 26 June 2023 | 15(6): 23359–23372

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

https://doi.org/10.11609/jott.8072.15.6.23359-23372

#8072 | Received 27 June 2022 | Final received 16 May 2023 | Finally accepted 30 May 2023

OPEN ACCESS

COMMUNICATION

Moth diversity of Guindy, Chennai, India and DNA barcoding of selected erebid moths

Sreeramulu Bhuvaragavan [1], Mani Meenakumari [2], Ramanathan Nivetha [3] & Sundaram Janarthanan [4]

[1-4] Department of Zoology, University of Madras, Guindy Campus, Chennai, Tamil Nadu 600025, India.
[1] bhuvaragavan281@gmail.com, [2] tameenakumari@gmail.com, [3] nivetharamanathan94@gmail.com,
[4] janas_09@yahoo.co.in (corresponding author)

Abstract: In this study, diversity of moths has been documented from Chennai, the capital city of Tamil Nadu. During the study, over 100 specimens were collected from which 59 moth species were identified from the commercial hub of Chennai, Guindy. The species identified belonged to 52 genera, 11 families, and 25 subfamilies. Erebidae was a front runner, followed by Crambidae, Geometridae, Sphingidae, and Noctuidae. Furthermore, Eupterotidae, Uraniidae, Nolidae, Lasiocampidae, Pterophoridae, and Thyrididae were the least recorded families. Among 26 erebids, 14 species were subjected for identification through mitochondrial cytochrome oxidase subunit 1 gene to resolve the ambiguity. The sequences resulted were deposited in GenBank and BOLD system where they received accession numbers and process IDs. Further, phylogenetic analysis categorized *Metanastria hyrtaca* Cramer, 1782 in a separate clade.

Keywords: Barcode, biodiversity, conservation, Erebidae, moths.

Editor: Sachin Arjun Gurule, MVP's S.S.S.M. Arts, Science and Commerce College, Saikheda, Nashik, India. **Date of publication:** 26 June 2023 (online & print)

Citation: Bhuvaragavan, S., M. Meenakumari, R. Nivetha & S. Janarthanan (2023). Moth diversity of Guindy, Chennai, India and DNA barcoding of selected erebid moths. *Journal of Threatened Taxa* 15(6): 23359–23372. https://doi.org/10.11609/jott.8072.15.6.23359-23372

Copyright: © Bhuvaragavan et al. 2023. Creative Commons Attribution 4.0 International License. JoTT allows unrestricted use, reproduction, and distribution of this article in any medium by providing adequate credit to the author(s) and the source of publication.

Funding: University Grants Commission; Department of Science and Technology; University of Madras.

Competing interests: The authors declare no competing interests.

Author details: Dr. S. Bhuvaragavan is a guest lecturer of Biology at University of Madras. He has been involved in focused research on invertebrate biology dealing with protein structure and function. His specializations include immunology and physiology. This study was in his interest to understand the distribution of potential insect pest models in Chennai. Ms. R. Nivetha is a senior research scholar from Department of Zoology, University of Madras, Chennai. She pursues research on biopolymers with biomedical applications with special inclination towards glycoproteins. Molecular taxonomy of insects is another area she is interested. Her research interests are protein purification, experimental glycobiology and possess laudable experience in bioinformatics. Ms. M. Meenakumari is a senior researcher from Department of Zoology, University of Madras, Chennai. She works on natural polymers with possible practice in insect pest control. Molecular taxonomy of biology is also her best-loved subject. Her research interests are cloning novel genes for large scale purification of potential natural polymers. Dr. S. Janarthanan is a professor of Zoology at University of Madras, Chennai. His research involves purification and characterization of insect lectins with distinct carbohydrate binding specificities for use as biosensors, bio-pesticidal, anti-microbial and anti-cancer molecules. Furthermore, he is working on molecular biomarkers for classification of insects.

Author contributions: S. Bhuvaragavan: Conceptualization, sample collection, investigation, interpretation, preparation of manuscript draft and funding acquisition. M. Meenakumari: Investigation and data curation. R. Nivetha: Interpretation of results, data curation and preparation of manuscript draft. S. Janarthanan: Project administration, supervision, funding acquisition, review and edit of manuscript.

Acknowledgements: The first author gratefully acknowledges the UGC for the NET-SRF (CSIR-UGC) Fellowship (Certificate Sr. No. 2121530460, Ref. No: 20/12/2015 (ii) EU-V) (2016–2021). The third author acknowledges the support of Dr. Kalaignar M. Karunanidhi Endowment Scholarship (2018-19), University of Madras (No. F.11-Endow/Ph.D Scholarship/2018-19/712 dt 21 May 2019). The authors acknowledge the infrastructure support provided in the department under the DST-FIST programme. We thank Dr. P.R. Shashank (Scientist, ICAR-Indian Agricultural Research Institute, New Delhi) and Dr. Gagan Preet Kour Bali (Punjabi University, Patiala and Eternal University, Baru Sahib) for sharing their valuable insights in identification of moth species. The authors thank Mr. Mari Krishnamurthy for his valuable assistance in sample collection. We acknowledge the usage of COI gene sequences of 38 species retrieved from NCBI. Finally, the authors thank the anonymous reviewers and the subject editor for revising the species identification.

INTRODUCTION

With about 1.2 million species, arthropods continue to be a dominant group in the earth's biodiversity. Their significance in sustaining the health of an ecosystem by furnishing livelihood and nutrition to human communities is far-reaching (Chakravarthy & Sridhara 2016). Nevertheless, insects are contemplated to be a potential group for understanding the effects of habitat attributes and environmental gradients on faunal diversity (Watt et al. 1997; Humphrey et al. 1999; Dey et al. 2017). Lepidoptera, which encompasses butterflies and moths, constitutes one of the three most species-rich insect orders and the largest evolutionary radiation of herbivorous animals comprising around 175,000 described species (Cover & Bogan 2015). However, another 125,000 to 150,000 species are thought to await description (Goldstein 2017). It exhibits close association with vegetation, their depletion and ensuing regeneration and is accordingly regarded as an indicator taxon (Summerville et al. 2004; Dey et al. 2015). Moths, being the most prominent terrestrial invertebrates, represent the majority of the order Lepidoptera consisting 158,570 described species (Zhang 2013). An estimation of about 15000 species of Lepidoptera belonging to 84 families are reported from India (Chandra et al. 2019). They form a critical facet of the terrestrial ecosystem by serving as nocturnal pollinators, herbivores of crops and prey for numerous species (Wagner et al. 2021). Many angiospermous plants that largely depend on animal-assisted pollination are critically associated with moth species (Wahlberg et al. 2013). Erebidae is the most prominent moth family consisting of 24,569 species belonging to 18 subfamilies (Nieukerken et al. 2011). Most of them are phytophagous as larvae and few are nectar suckers as adults (Terra & Ferreira 2020). The economic importance of family Erebidae can be attributed to the fact that it includes a significant number of major and minor pest species, and therefore their distributional knowledge is highly significant for the economy of any country (Bin-Cheng 1994). Furthermore, exploring the changes in the pattern associated with moth distribution and abundance in different local habitats constitutes a significant element of global biodiversity monitoring and conservation (Dennis et al. 2019).

Classification of organisms is a prerequisite for understanding their distribution and diversity in any habitat. Classification of closely related lepidopteran species based on wing patterns and other morphological attributes posses' difficulties and imprecision those are amenable to change as a function of environment and prevalence of several biotypes. Over the last few years, DNA barcodes are known to answer elemental ecological questions that govern community assemblage, processes of macroevolution, species conservation and incorporation of molecular tools along with morphology, which can add value to the existing information on moth diversity (Dey et al. 2019). A cytochrome oxidase subunit 1 (COI) gene identification system is contemplated to be more reliable, economical and a quick fix to the problems involved in species identification (Hebert et al. 2003). Since Hebert et al. (2003), order Lepidoptera has been regarded as a model group for DNA-barcoding studies (Goldstein 2017). Several studies have been carried out to investigate the moth diversity in peninsular India, yet Tamil Nadu has only fewer studies especially minuscule information in Chennai metropolitan, as follows. Reports of 154 species of noctuid moths from the Tamil Nadu part of Western Ghats, 67 species of erebid moths and 105 moth species from Maruthamalai hills are notable among them (Sivasankaran & Ignacimuthu 2014). Close to 135 species have been recorded in Valmiki Nagar, Chennai (Nagarajan et al. 2021). Besides being an ecologically significant group, they are less explored, finding their way into the present biodiversity conservation scenario (Dey et al. 2015). Despite rich lepidopteran diversity existing in India, attempts that are made to generate DNA barcode data of moths in India are very scarce (Dey et al. 2019; Kumar et al. 2019). Urban areas are considered significant drivers of biodiversity change due to expressively transformed landscape changes and rapid anthropogenic actions (Zari 2018). Declines in the diversity and abundance of moth population are reported over the past few years due to explicit factors like loss of habitat, fragmentation, pollution, urbanization and other related anthropogenic practices (Dennis et al. 2019; Hallmann et al. 2020). There is a research gap in knowledge of how the aforementioned explicit factors impact the diversity and abundance of population of moths in an urban environment. Consequently, an attempt was made to generate a preliminary checklist of moth fauna from Guindy, a commercial hub in Chennai and further species authentication of selected erebid moths to resolve ambiguity in identification using mitochondrial COI gene.

MATERIALS AND METHODS

Study area

The study was conducted in Guindy, one of the largest Southern neighbourhoods of Chennai, Tamil

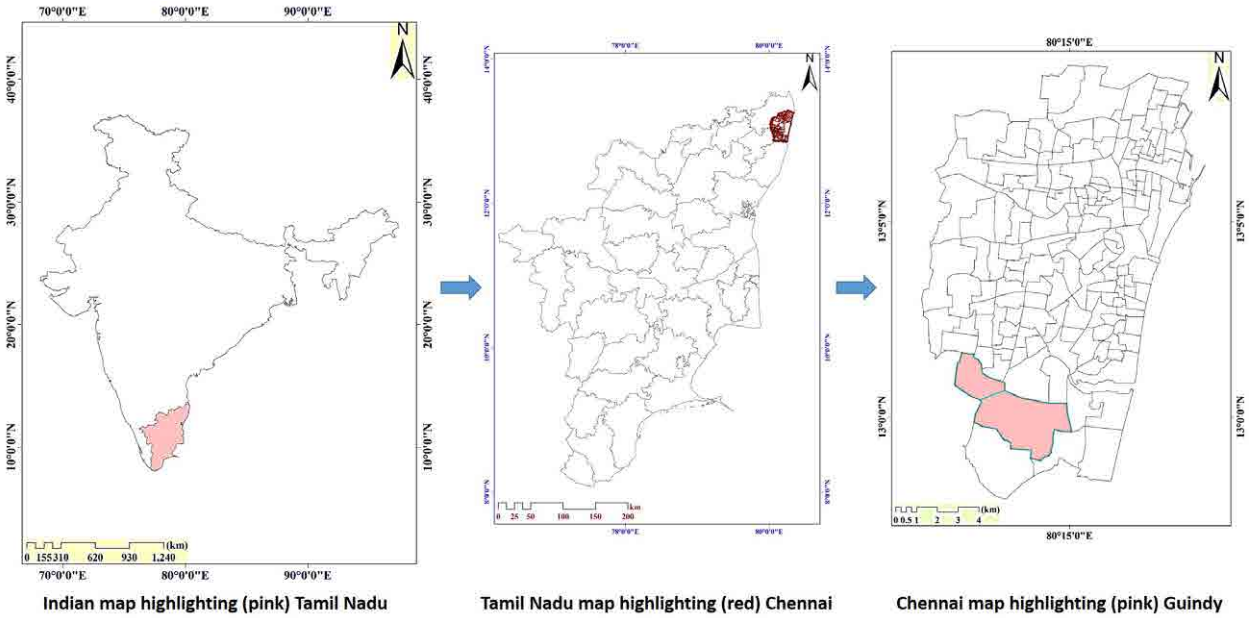

Figure 1. Map depicting the study area (Guindy, Chennai, Tamil Nadu) generated using ArcGIS (v10.8) software.

Nadu (Figure 1). It is located between 13.010236° N latitude and 80.215652° E longitude. Guindy National Park is situated inside the city covering an area of 2.70 km^2 lies between 12.99° N, 80.23° E and 13.00° N, 80.21° E consisting of single habitat type, dry evergreen woodland.

Sample collection and identification

Moth species were collected using traps consisting of light source (Mercury vapour light) during night from places in and around Guindy, Chennai. The collected specimens were identified by their morphological characters using manuals of Bell & Scott (1937) and Hampson (1892, 1895, 1896). They were killed using chloroform, pinned using entomological pins and stretched on spreading board. Later, they were oven-dried at 52°C and were preserved in the insect box. The stretched specimens were photographed using Nikon camera after drying.

Genomic DNA extraction, PCR amplification (COI gene) and sequencing

Species authentication was carried out using the mitochondrial COI gene to resolve ambiguity in identifying 14 selected Erebid individuals. Total genomic DNA from individual species was extracted from the legs using the phenol-chloroform method. DNA extracted were then resuspended in Tris- etheylenediaminetetraacetic acid (EDTA) buffer (TE buffer) and stored at -20°C until further use. The lepidopteran specific COI primers of Hebert et al. (2003) [Forward primer - F: 5′ -ATTCAACCAATCATAAAGATATTGG-3′; Reverse primer - R: 5′- TAAACTTCTGGATGTCCAAAAAATCA-3′] were used to amplify regions of COI from 14 species of moths belonging to the Erebidae family that exhibited uncertainty in their identification using taxonomic keys. PCR amplification was carried out in a total volume of 10 µl consisting of Ampliqon-Taq DNA Polymerase 2x Master Mix RED, lepidopteran specific COI primers of Hebert et al. (2003), template DNA and sterile water (MyGene Series, Peltier Gradient Thermal Cycler). The reaction mixture was initially denatured for 5 min at 94°C followed by 35 cycles of denaturation at 94°C for 1 min, annealing of 56°C for 1 min, extension of 72°C for 1 min and a final extension cycle of 72°C for 7 min. It was then stored at 4°C. A control reaction was prepared without template DNA. A 1.2% agarose gel stained with ethidium bromide was used to examine the amplified gene product. It was then gel purified and sequenced using the Sanger dideoxynucleotide sequencing protocol (AgriGenome Labs, Kochi). Sequences were then analysed with the National Centre for Biotechnology Information (NCBI) Blast Server and submitted in NCBI GenBank and Barcode of Life Data (BOLD) system to obtain corresponding accession numbers and process IDs.

Phylogenetic analysis

A phylogenetic tree was constructed using MEGA X: Molecular Evolutionary Genetics Analysis across

computing platforms to study the evolutionary relationship among various species identified (Kumar et al. 2018). The Neighbour-Joining method was used to infer the evolutionary history, and the Kimura 2-parameter method was used to compute evolutionary distances (Kimura 1980). Bootstrap analysis was also performed using MEGA X (10000 replicates). The available (database) mitochondrial COI gene sequences of morphologically-identified species (38) (among the 45 species) were retrieved from NCBI for constructing phylogenetic tree along with COI gene-based identified species (14) in this study. Multiple sequence alignment was carried out before the construction of the phylogenetic tree using CLUSTALW multiple alignment available as accessory application in BioEdit software. All the sequences were then subjected to evolutionary analysis by phylogenetic tree construction using neighbour-joining method mentioned above.

RESULTS

Distribution profile of moth fauna from Guindy, Chennai

59 species were identified, and a checklist was constructed along with their scientific name, common name, family and subfamily (Table 1, Image 1–7). The 59 species identified belonged to 52 genera and 11 families such as Erebidae, Crambidae, Geometridae, Sphingidae, Noctuidae, Eupterotidae, Lasiocampidae, Nolidae, Pterophoridae, Thyrididae and Uraniidae (Figure 2). As a result of the comparative distribution, family Erebidae was higher in numbers with a total of 26 species (21 genera and 25 species), followed by the families such as Crambidae with 10 species (9 genera and 10 species), Geometridae with 8 species (7 genera and 6 species), Sphingidae with 5 species (5 genera and 5 species) and Noctuidae with 4 species (4 genera and 3 species); while families viz. Eupterotidae, Lasiocampidae, Nolidae, Pterophoridae, Thyriridae and Uraniidae accounted for single species each. The Family Erebidae was observed to be a species-rich group in Guindy, Chennai.

Mitochondrial COI gene amplification

The lepidopteran specific COI primers of Hebert et al. (2003) did amplify COI gene from all the 14 erebid species. The product was then gel purified, sequenced, and analysed. To resolve ambiguity in identification of Erebid moths, the DNA barcoding was adopted and the sequence results identified 14 different species of Erebidae which includes *Achaea janata* (Linnaeus, 1758), *Achaea mercatoria* (Fabricius, 1775), *Amata passalis* (Fabricius, 1781), *Asota caricae* (Fabricius, 1775), *Creatonotos gangis* (Linnaeus, 1763), *Erebus caprimulgus* (Fabricius, 1781), *Erebus macrops* (Linnaeus, 1768), *Eudocima materna* (Linnaeus, 1767), *Eudocima phalonia* (Linnaeus, 1763), *Hypocala deflorata* (Fabricius, 1794), *Olepa schleini* (Witt et al. 2005), *Perina nuda* (Fabricius, 1787), *Sphingomorpha chlorea* (Cramer, 1777) and *Utetheisa pulchelloides* (Hampson, 1907). The representative amplified COI gene is presented in Figure 3. The nucleotide sequences of mitochondrial COI gene from all the 14 species were deposited in GenBank and BOLD system where they received individual accession numbers and process IDs, respectively (Table 2).

Phylogenetic analysis

MEGA X: Molecular Evolutionary Genetics Analysis was used to construct a phylogenetic tree to infer the evolutionary relationship among various identified species of moths. The percentage of replicate trees in which the associated taxa clustered together in the bootstrap test (10000 replicates) was shown next to the branches. The Neighbourhood joining method was used instead of maximum parsimony or maximum likelihood approaches because of its accuracy, rapidity and optimum assumptions (Hong et al. 2021). The results of the phylogenetic analysis are shown in Figure 4, with *Apis mellifera* being the outgroup. *Metanastria hyrtaca* (Cramer, 1782) formed a separate clade, and all other species were clustered in another clade.

DISCUSSION

Species identification is a prerequisite in estimating biodiversity in an area and perceiving knowledge on species ecology. Thus, explicit identification is obligatory to gain insights into any species' diversity and distribution profile in any place under study. Morphological identification and taxonomic keys are important methods used extensively (Sviridov & Leuschner 1986). Notably, among the various moths collected in this study, moths belonging to Erebidae family dominated others. Presumably, their polyphagous nature could be the impetus for their wide distribution, making them fit to survive in any resource condition (Zahiri et al. 2012). A similar domination pattern of erebid moths was also observed in the Northern part of the Western Ghats (Shubhalaxmi et al. 2011; Gurule & Nikam 2013). These are then accompanied by species belonging to the family Crambidae, the second most prominent family,

Table 1. Checklist of moth fauna from Guindy, a commercial hub in Chennai.

	Family	Subfamily	Species (Common name)	Author & year
1	Crambidae	Pyraustinae	*Maruca vitrata* (Bean pod borer)	Fabricius, 1787
2	Crambidae	Pyraustinae	*Omphisa anastomosalis* (Sweetpotato vineborer)	Guenée, 1854
3	Crambidae	Pyraustinae	*Spoladea recurvalis* (Beet Webworm Moth)	Fabricius, 1775
4	Crambidae	Spilomelinae	*Botyodes asialis*	Guenée, 1854
5	Crambidae	Spilomelinae	*Cnaphalocrocis medinalis* (Rice leaf roller)	Guenée, 1854
6	Crambidae	Spilomelinae	*Cnaphalocrocis poeyalis* (Lesser rice- leafroller)	Boisduval, 1833
7	Crambidae	Spilomelinae	*Diaphania indica* (Cucumber Moth)	Saunders, 1851
8	Crambidae	Spilomelinae	*Haritalodes derogata* (Cotton leaf roller)	Fabricius, 1775
9	Crambidae	Spilomelinae	*Isocentris filalis*	Guenée, 1854
10	Crambidae	Spilomelinae	*Palpita vitrealis* (Jasmine Moth)	Rossi, 1794
11	Erebidae	Aganainae	*Asota caricae* (Tropical Tiger Moth)	Fabricius, 1775
12	Erebidae	Arctiinae	*Amata passalis* (Sandalwood defoliator)	Fabricius, 1781
13	Erebidae	Arctiinae	*Creatonotos gangis* (Baphomet Moth)	Linnaeus, 1763
14	Erebidae	Arctiinae	*Olepa schleini*	Witt et al. 2005
15	Erebidae	Arctiinae	*Utetheisa pulchelloides* (Heliotrope Moth)	Hampson, 1907
16	Erebidae	Calpinae	*Eudocima materna* (Dot-underwing Moth)	Linnaeus, 1767
17	Erebidae	Calpinae	*Eudocima phalonia* (Common fruit-piercing Moth)	Linnaeus, 1763
18	Erebidae	Catocalinae	*Achaea janata* (Castor semi-looper)	Linnaeus, 1758
19	Erebidae	Erebinae	*Achaea mercatoria*	Fabricius, 1775
20	Erebidae	Erebinae	*Dysgonia stuposa*	Fabricius, 1794
21	Erebidae	Erebinae	*Erebus caprimulgus*	Fabricius, 1781
22	Erebidae	Erebinae	*Erebus macrops* (Common Owl Moth)	Linnaeus, 1768
23	Erebidae	Erebinae	*Lacera noctilio*	Fabricius, 1794
24	Erebidae	Erebinae	*Ophiusa tirhaca* (Green Drab)	Cramer, 1777
25	Erebidae	Erebinae	*Pericyma cruegeri* (Poinciana looper)	Butler, 1886
26	Erebidae	Erebinae	*Sphingomorpha chlorea* (Sundowner Moth)	Cramer, 1777
27	Erebidae	Hypeninae	*Hypena obacerralis*	Walker, 1859
28	Erebidae	Hypocalinae	*Hypocala deflorata*	Fabricius, 1794
29	Erebidae	Lymantriinae	*Artaxa digramma*	Boisduval, 1844
30	Erebidae	Lymantriinae	*Euproctis scintillans* (Lymantriid Moth)	Walker, 1856
31	Erebidae	Lymantriinae	*Euproctis similis* (Yellow-tail Moth)	Fuessly, 1775
32	Erebidae	Lymantriinae	*Laelia exclamationis*	Kollar, 1848
33	Erebidae	Lymantriinae	*Laelia litura* (Tussock Moth)	Walker, 1855
34	Erebidae	Lymantriinae	*Olene mendosa* (Brown Tussock Moth)	Hübner, 1823
35	Erebidae	Lymantriinae	*Perina nuda* (Clearwing Tussock Moth)	Fabricius, 1787
36	Erebidae	Scoliopteryginae	*Anomis* spp.	Hübner, 1821
37	Eupterotidae	Eupterotinae	*Eupterote bifasciata* (Giant Lappet Moth)	Kishida, 1994
38	Geometridae	Ennominae	*Iridopsis larvaria* (Bent-lined Gray)	Guenée, 1858
39	Geometridae	Ennominae	*Chiasmia eleonora*	Cramer, 1780
40	Geometridae	Ennominae	*Chiasmia* spp.	Cramer, 1780
41	Geometridae	Ennominae	*Macaria multilineata* (Many-lined Angle)	Packard, 1873
42	Geometridae	Ennominae	*Cleora* spp.	Curtis, 1825
43	Geometridae	Geometrinae	*Thalassodes veraria*	Guenée, 1858
44	Geometridae	Geometrinae	*Nemoria bistriaria* (Red-fringed Emerald)	Hübner, 1818

	Family	Subfamily	Species (Common name)	Author & year
45	Geometridae	Sterrhinae	*Idaea sylvestraria* (Dotted Border Wave)	Hübner, 1799
46	Lasiocampidae	Pinarinae	*Metanastria hyrtaca* (Hairy caterpillar)	Cramer, 1782
47	Noctuidae	Hadeninae	*Chasmina candida*	Walker, 1865
48	Noctuidae	Heliothinae	*Helicoverpa armigera* (Cotton Bollworm)	Hübner, 1808
49	Noctuidae	Noctuinae	*Spodoptera litura* (Tobacco Cutworm)	Fabricius, 1775
50	Noctuidae	Noctuinae	*Mythimna* spp.	Ferdinand Ochsenheimer, 1816
51	Nolidae	Nolinae	*Nola analis*	Wileman & West, 1928
52	Pterophoridae	Pterophorinae	*Geina periscelidactyla* (Grape Plume Moth)	Fitch, 1855
53	Sphingidae	Macroglossinae	*Hippotion boerhaviae* (Hippotion Sphinx Moth)	Fabricius, 1775
54	Sphingidae	Macroglossinae	*Nephele hespera* (Crepuscular Hawkmoth)	Fabricius, 1775
55	Sphingidae	Sphinginae	*Acherontia lachesis* (Greater death's head Hawkmoth)	Fabricius, 1798
56	Sphingidae	Sphinginae	*Agrius convolvuli* (Convolvulus Hawkmoth)	Linnaeus, 1758
57	Sphingidae	Sphinginae	*Psilogramma increta* (Plain grey Hawkmoth)	Walker, 1864
58	Thyrididae	Striglinae	*Striglina scitaria* (Daincha leaf webber)	Walker, 1862
59	Uraniidae	Microniinae	*Micronia aculeata* (Asian Spotted Swallowtail Moth)	Guenée, 1857

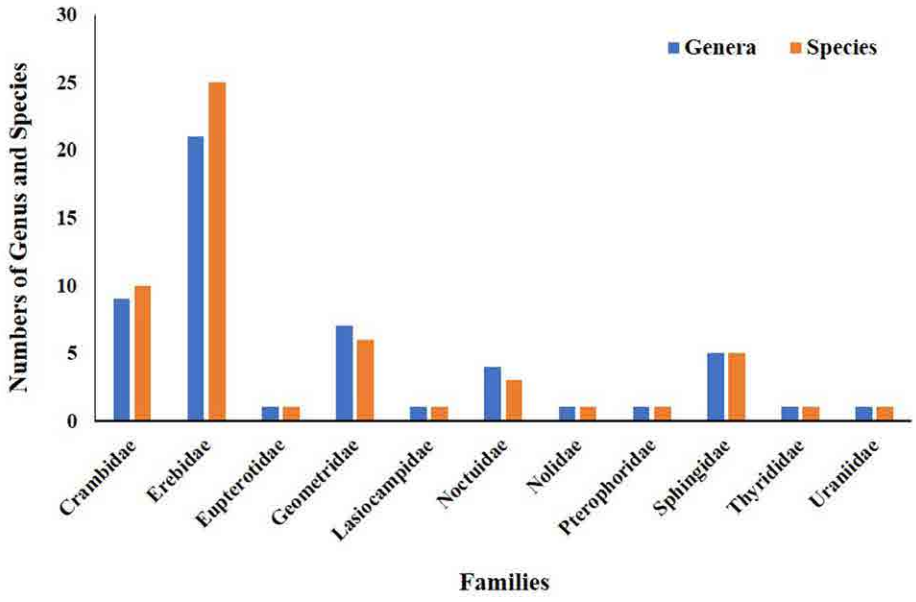

Figure 2. The species richness of moth fauna in relation to their families from Guindy, Chennai.

which is attributed to the phytophagous, detritivorous, coprophagous, parasitic habits of their larvae and ability to feed on roots, stems or grasses (Nayak & Ghosh 2020). This is followed by the distribution of Geometridae, the next abundant moth family. Comparatively, the least documented families were Eupterotidae, Uraniidae, Nolidae, Lasiocampidae, Pterophoridae and Thyrididae. Twenty-six species belonging to 18 genera of family Pterophoridae were identified and examined from the Shiwalik hills of North-West India (Pooni et al. 2019). In an attempt to document the moth fauna of Goa, *Collinsa decoratalis* (Warren, 1986), a thyridid moth, was reported as a new record from the Western Ghats. In addition to this, the uraniid moth *Pseudhyria rubra* (Hampson, 1891) was also reported for the first time from Goa (Gurule & Brookes 2021). Estimated diversity and distribution of moths in Nanda Devi Biosphere Reserve, Shendurney and Ponmudi in Agastyamalai Biosphere Reserve, Tawang district (Arunachal Pradesh) recorded that the most abundant family was Geometridae

(Chandra & Sambath 2013; Dey et al. 2015; Sondhi et al. 2018). Geometrid moths were found in abundance at tea plantations of North-East India (Sinu et al. 2013). However, Erebidae was the most profusely distributed family in Vagamon hills (Western Ghats), Dehradun and Devalsari, North East Jharkhand, Midnapore town (West Bengal) and Banaras Hindu University, Varanasi (Sondhi & Sondhi 2016; Singh et al. 2017; Nayak & Ghosh 2020; Nayak & Sasmal 2020).

Family Erebidae is copiously found in a diverse habitat, which includes predominantly polyphagous species and pests. The discovery of the species *Asota paliura* (Swinhoe 1893) belonging to the family Erebidae from India was also reported (Rajan & Shamsudeen 2020). A tentative list of Erebidae from the Tamil Nadu part of Western Ghats is documented as well (Sivasankaran & Ignacimuthu 2014). In addition, based on the survey made in Tamil Nadu at different localities, the genus *Othreis* (Synonym *Eudocima*) (Linnaeus, 1763) was one among the two genera of predominant fruit piercers, which is by far the most harmful and a severe pest on citrus, guava, pomegranate, grapes, fig, sapota, mango, papaya, and tomato in India (Ramkumar et al. 2010). An endemic Indian moth, *Gurna indica* (Moore, 1879) of the Erebidae family, was rediscovered after 125 years (Kalawate et al. 2019). An attempt has been made to document the species of Erebid moths from Aligarh, Uttar Pradesh, India (Farooqui et al. 2020). In addition, the discovery of *Asota paliura* (Swinhoe, 1893) (Lepidoptera: Erebidae) represents a new record from India (Rajan & Shamsudeen 2020). Similarly, *Pericyma cruegeri* (Butler, 1886) was also reported for the first time in India (Singh & Ranjan 2016). New additions of eight species to the known Indian fauna of the family Erebidae was also accounted (Kirti et al. 2017). Recently, moth diversity and preliminary checklist of moths from different regions of Rajasthan including Sariska Tiger Reserve were reported (Dar et al. 2021a,b; Jamal 2021). Additionally, there is also first report of Oleander Hawkmoth, *Daphnis nerii* (Linnaeus, 1758) from India (Dar et al. 2022).

DNA barcoding is a proven tool used for expeditious and unambiguous identification of species, thus circumventing the problems associated with morphology-based identification of species (Hebert & Gregory 2005). PCR amplification of short fragments within the barcoding region of the COI gene has been comprehensively used to identify different species. Sustainable identification relies mainly upon the construction of a system that utilizes DNA sequences as taxon barcodes. The mitochondrial COI gene was

Table 2. GenBank accession numbers and BOLD process IDs for erebid species authenticated using mitochondrial COI gene.

	Species	GenBank accession number	BOLD Process ID
1	*Achaea Janata*	MW421768	DBEM007-21
2	*Achaea mercatoria*	MW425700	DBEM008-21
3	*Amata passalis*	MW425697	DBEM002-21
4	*Asota caricae*	MW425696	DBEM001-21
5	*Creatonotos gangis*	MW425695	DBEM014-21
6	*Erebus caprimulgus*	MW435024	DBEM009-21
7	*Erebus macrops*	MW425705	DBEM010-21
8	*Eudocima materna*	MW425702	DBEM005-21
9	*Eudocima phalonia*	MW425701	DBEM006-21
10	*Hypocala deflorata*	MW407951	DBEM012-21
11	*Olepa schleini*	MW425704	DBEM003-21
12	*Perina nuda*	MW425699	DBEM013-21
13	*Sphingomorpha chlorea*	MW425703	DBEM011-21
14	*Utetheisa pulchelloides*	MW425698	DBEM004-21

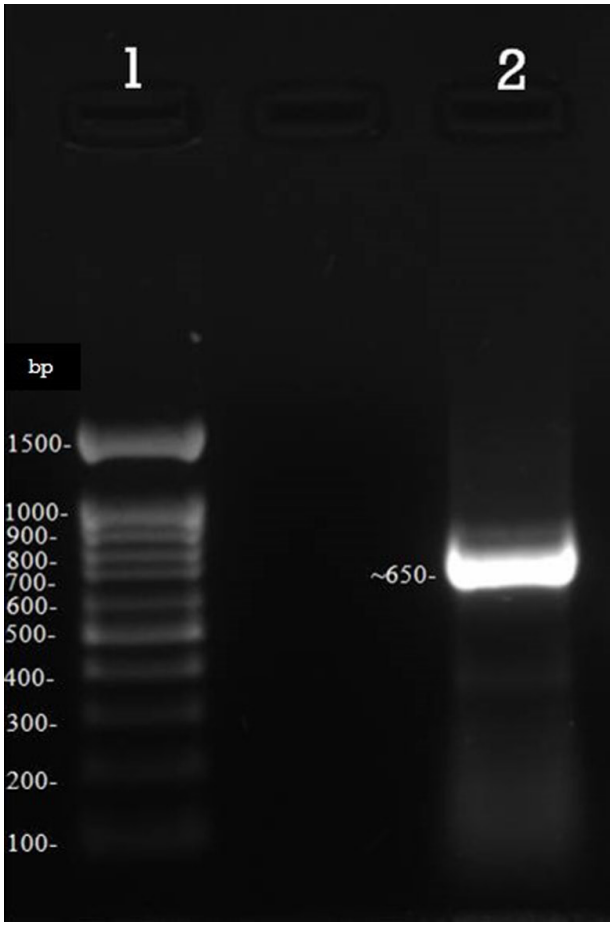

Figure 3. Electrophoresis of representative mtCOI gene: Lane 1—DNA ladder | Lane 2—Amplified product.

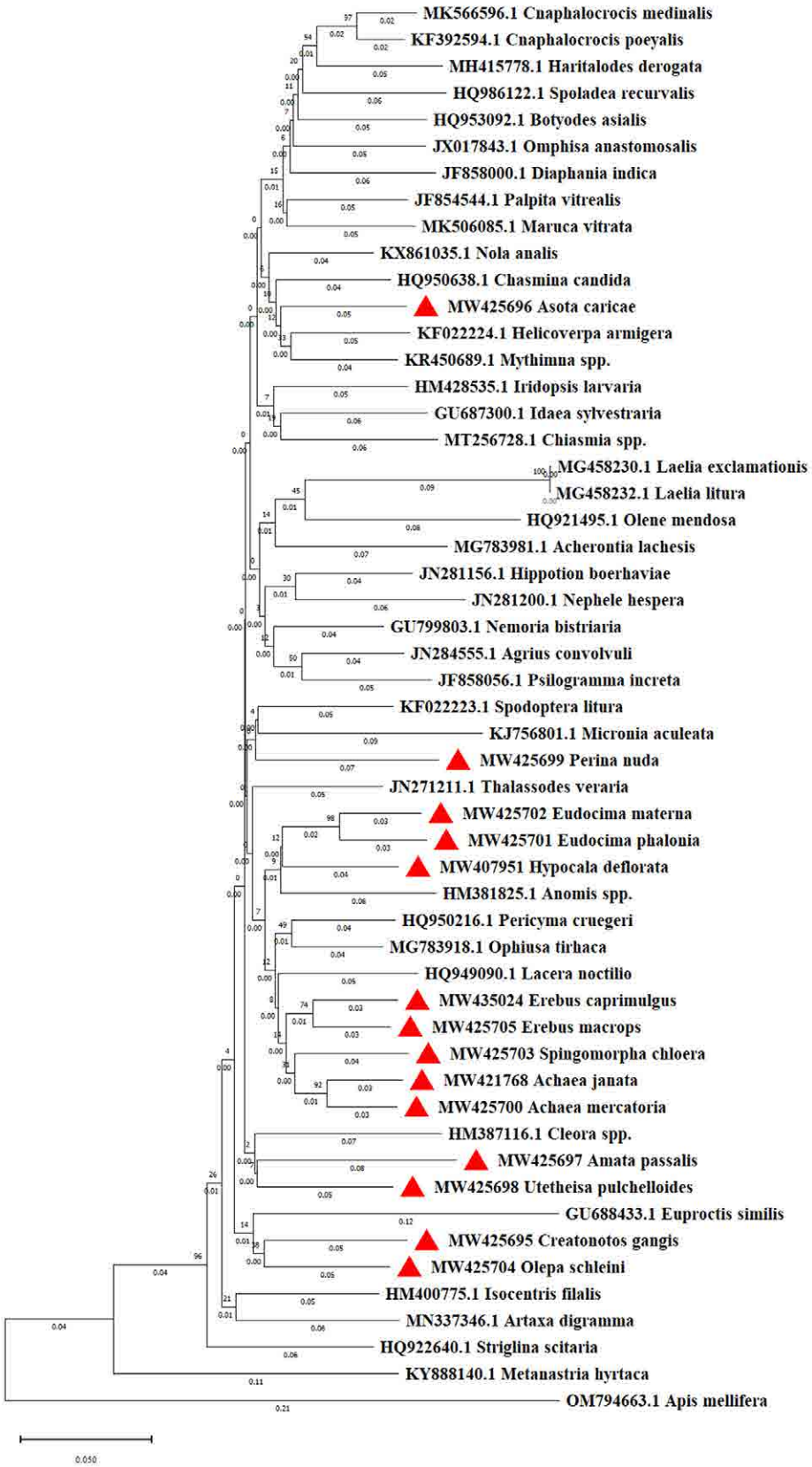

Figure 4. Phylogenetic tree based on mitochondrial COI gene sequences (MEGA X). The available (database) mitochondrial COI gene sequences of morphologically-identified species (38) (among the 45 species) were retrieved from NCBI for constructing phylogenetic tree along with COI gene-based identified species (14) (denoted in triangle) in this study.

established to serve a crucial role in the global bio-identification system for animals (Hebert et al. 2003). DNA barcoding is considered a definitive method for identifying insects (Jalali et al. 2015). COI DNA barcodes were used to distinguish among species of three lepidopteran families in north-western Costa Rica (Hajibabaei et al. 2006). A DNA Barcoding reference library of about of 113 species of geometrid moths from Western Himalaya was constructed which can effectively provide information on geographical distribution and basis for their conservation (Dey et al. 2019). Another study in Namdapha National Park, East Himalaya, produced a DNA barcode sequence of 44 Geometridae moths (Kumar et al. 2018). Further, a study concluded that a two-step barcoding analysis pipeline could swiftly characterize insects' biodiversity and explicate species boundaries for taxonomic complexes (Jin et al. 2018). Thus, the DNA barcoding tool can be used to discriminate constructively among various species in the lepidopteran family (Hajibabaei et al. 2006). To resolve ambiguity in some erebids, we used mitochondrial COI gene for identification of species. This assisted in the precise identification of the 14 erebid species. Phylogenetic studies can provide clues on the evolutionary relatedness among various groups of organisms.

The collection site of this study also covers the area in the University of Madras. Many urban universities like Banaras Hindu University have developed many strategies to monitor, manage and conserve biodiversity (Nayak & Ghosh 2020). In addition, universities have an eccentric potentiality to embrace a biophilic design inside the campus which aids in reconfiguring urban residents to the biosphere and serve as an excellent source for biodiversity-based research in urban (Liu et al. 2021). Further, the study can be extended to cover many urban areas to comprehend the effect of urbanization on the distribution profile of moths.

The distribution profile of a species depends significantly on the biogeographical region in which they occur (Gaston 1994). Artificial light pollution due to the imprudent use of artificial light was reported to cause temporal and spatial disorientation, biorhythms desynchronization, and desensitization of visual systems, affecting the moth physiology and behaviour (Nayak & Ghosh 2020). In addition, LED lights have been found to lower the risk of urban areas becoming ecological traps (White et al. 2016). Spatial habitat heterogeneity is essential to sustain the gamma diversity of macro-moth species (de Miranda et al. 2019). Urban green areas were indicated in a finding to support a wide array of moths (Paul 2021). A maiden comprehensive annotated checklist of moths of Delhi with 234 species that were not previously reported were added (Komal et al. 2021). Consequently, the number of described species may or may not constitute the definite number of species occurring in an area. Nevertheless, this documentation can provide particulars on their distribution and their conservation status.

REFERENCES

Bell, T.R.D. & F.B. Scott (1937). *The Fauna of British India, including Ceylon and Burma, Moths–Vol. 5, Sphingidae.* Taylor and Francis, London, 537 pp.

Bin-Cheng, Z. (1994). *Index of economically important Lepidoptera*. CAB International, Wallingford, United Kingdom.

Chakravarthy, A.K. & S. Sridhara (2016). *Economic and Ecological Significance of Arthropods in Diversified Ecosystems: Sustaining Regulatory Mechanisms.* Springer, Singapore, 22 pp.

Chandra, K. & S. Sambath (2013). Moth diversity of Tawang District, Arunachal Pradesh. *Journal of Threatened Taxa* 5(1): 3565–3570. https://doi.org/10.11609/JoTT.o2718.966

Chandra, K., V. Kumar, N. Singh, A. Raha & A.K. Sanyal (2019). Assemblages of Lepidoptera in Indian himalaya through long term monitoring plots. *Kolkata: Zoological Survey of India* 1–457.

Cover, M.R. & M.T. Bogan (2015). Minor insect orders, pp. 1059–1072. In: Thorp, J.H. & D.C. Rogers (eds.). *Ecology and General Biology, Thorp and Covich's Freshwater Invertebrates*. Academic Press/ Elsevier, Amsterdam.

Dar, A.A., K. Jamal & M.S. Shah (2022). First report of Oleander Hawkmoth, *Daphnis nerii* (Lepidoptera: Sphingidae) feeding on *Alstonia scholaris* (Apocynaceae) from India. *Transactions of the American Entomological Society* 148(1): 59–63. https://doi.org/10.3157/061.148.0105

Dar, A.A., K. Jamal, A. Alhazmi, M. El-Sharnouby, M. Salah & S. Sayed (2021a). Moth diversity, species composition, and distributional pattern in Aravalli Hill Range of Rajasthan, India. *Saudi Journal of Biological Sciences* 28(9): 4884–4890. https://doi.org/10.1016/j.sjbs.2021.06.018

Dar, A.A., K. Jamal & M. Salah (2021b). Preliminary checklist of moth fauna (Lepidoptera: Heterocera) of Rajasthan, India. *Journal of Entomological Research* 45(3): 549–554.

de Miranda, M.D., H.M. Pereira, M.F. Corley & T. Merckx (2019). Beta diversity patterns reveal positive effects of farmland abandonment on moth communities. *Scientific Reports* 9(1): 1–9. https://doi.org/10.1038/s41598-018-38200-3

Dennis, E.B., T.M. Brereton, B.J. Morgan, R. Fox, C.R. Shortall, T. Prescott & S. Foster (2019). Trends and indicators for quantifying moth abundance and occupancy in Scotland. *Journal of Insect Conservation* 23(2): 369–380. https://doi.org/10.1007/s10841-019-00135-z

Dey, P., A. Hausmann & V.P. Uniyal (2019). Towards creating a DNA barcode reference library of geometrid moths from Western Himalaya, India. *Spixiana* 42: 47–59.

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

Dey, P., V.P. Uniyal & K. Chandra (2017). A prefatory estimation of diversity and distribution of moths in Nanda Devi Biosphere Reserve, Western Himalaya, India. *National Academy Science Letters* 40(3): 199–203. https://doi.org/10.1007/s40009-016-0534-1

Farooqui, S.A., H. Parwez & R. Joshi (2020). A preliminary study and new distributional records of family Erebidae (Leach, 1815) (Lepidoptera: Noctuoidea) from Aligarh,

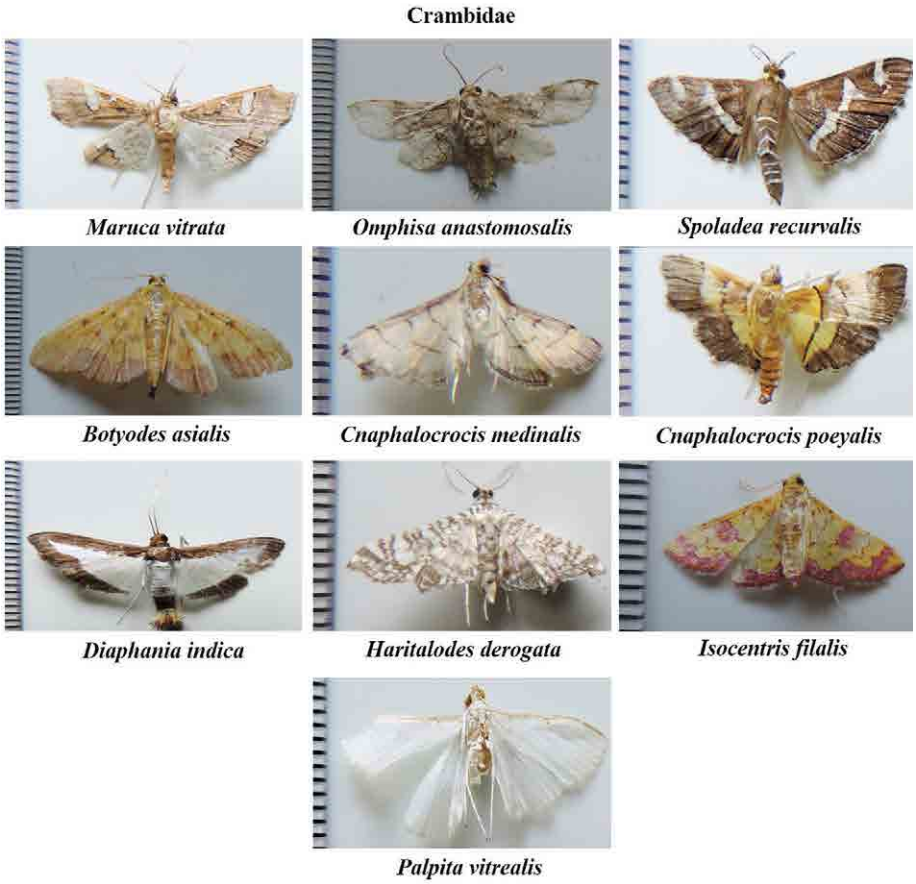

Image 1. Moths of Guindy: Crambidae.

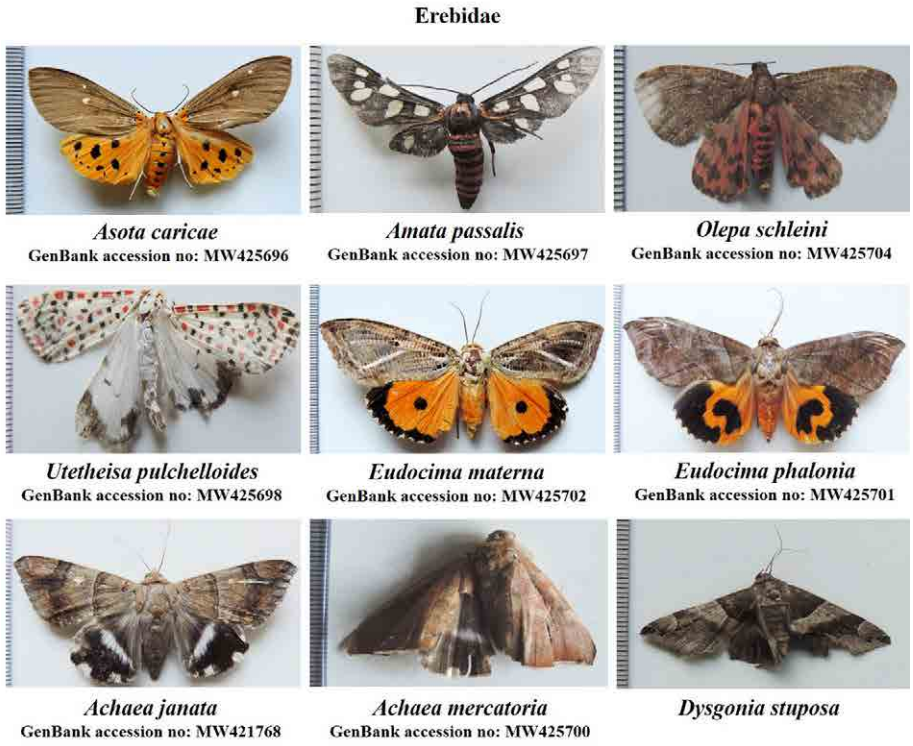

Image 2. Moths of Guindy: Erebidae.

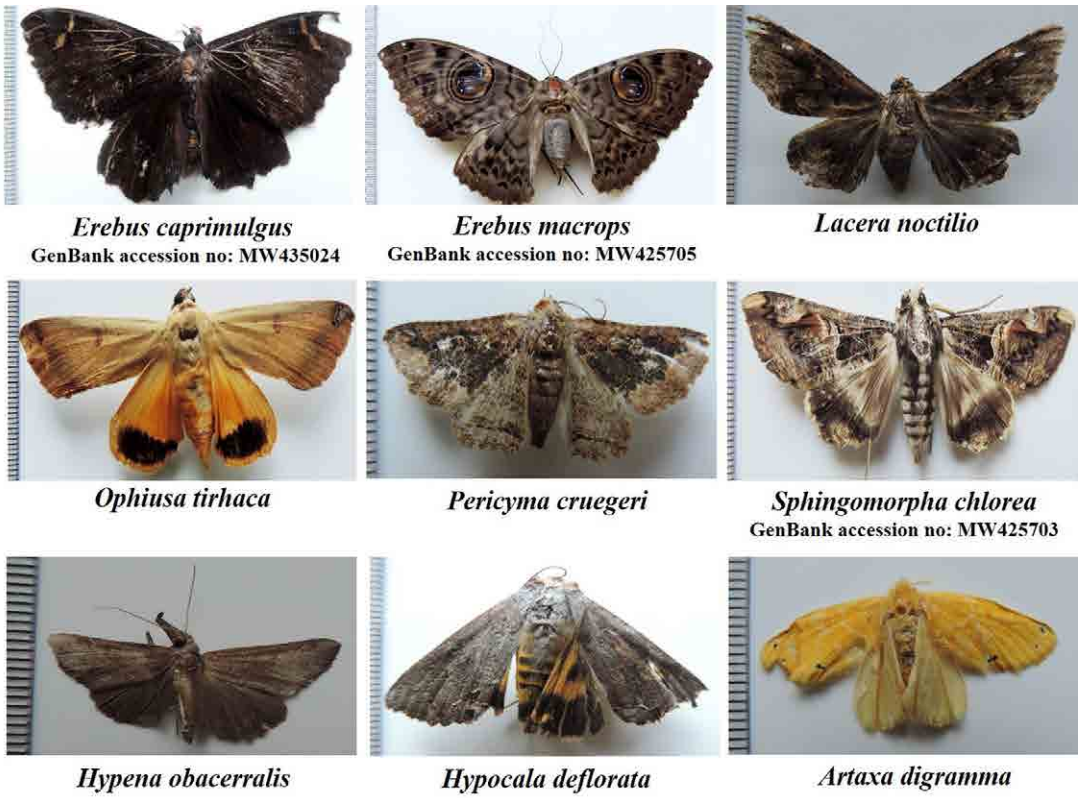

Image 3. Moths of Guindy: Erebidae.

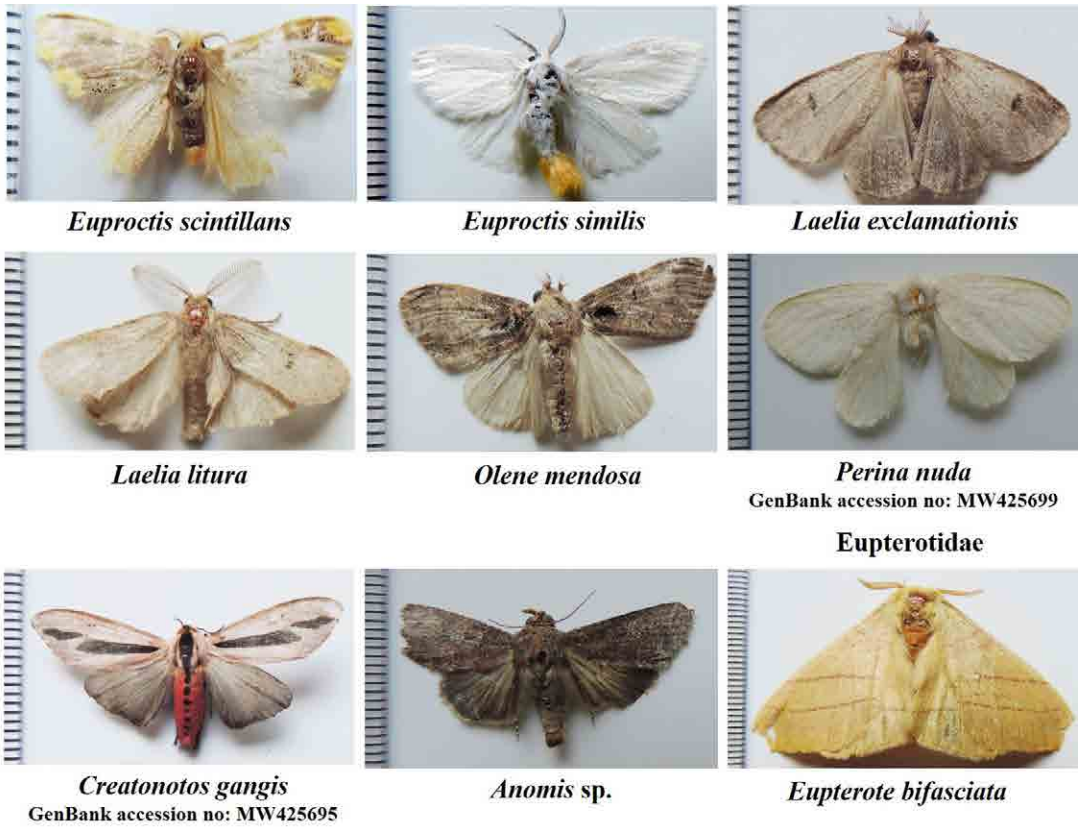

Image 4. Moths of Guindy: Erebidae and Eupterotidae.

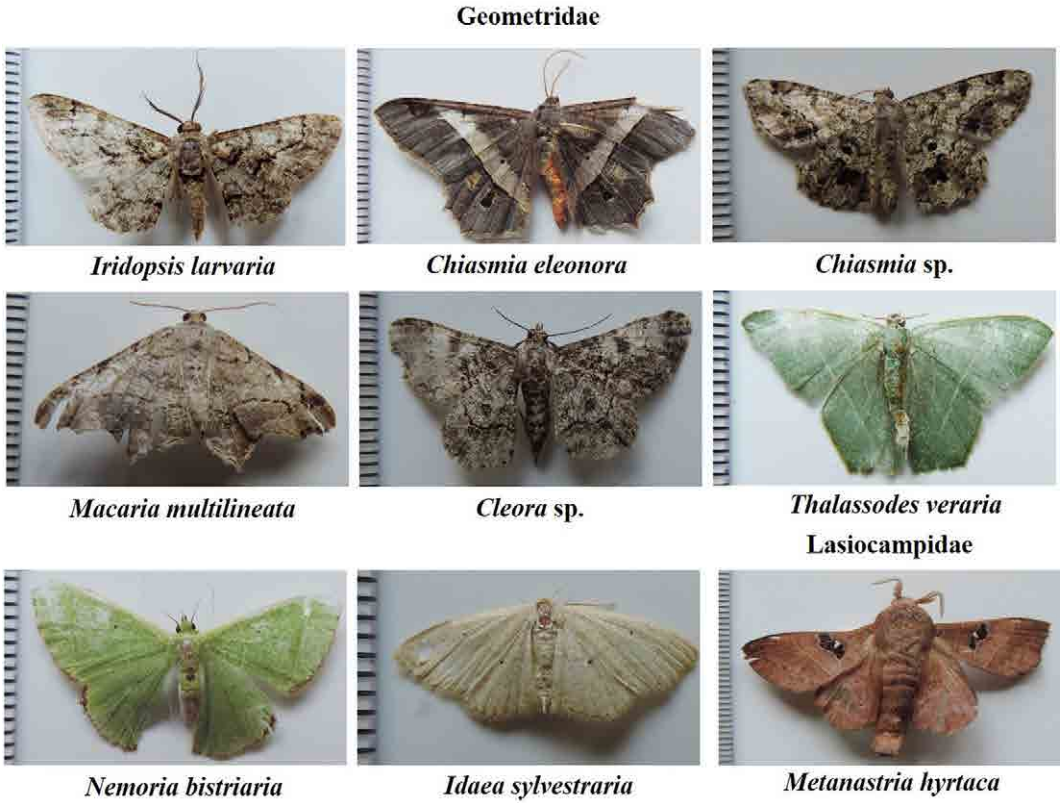

Image 5. Moths of Guindy: Geometridae and Lasiocampidae.

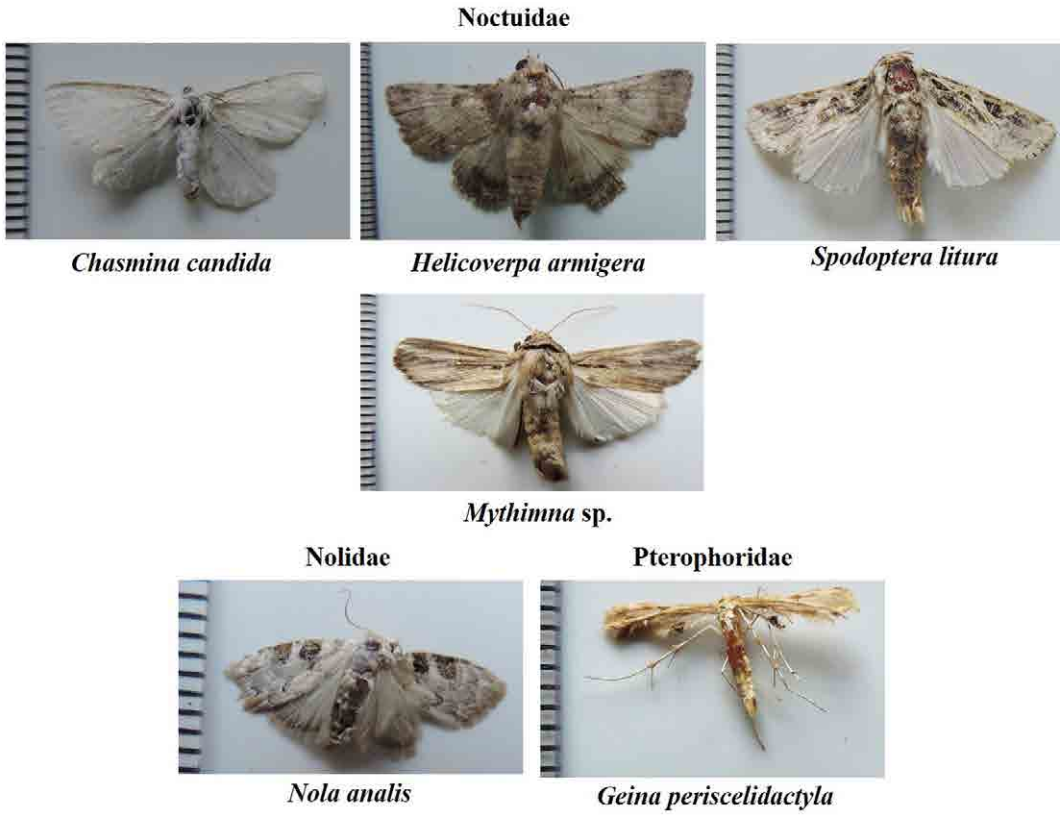

Image 6. Moths of Guindy: Noctuidae, Nolidae and Pterophoridae.

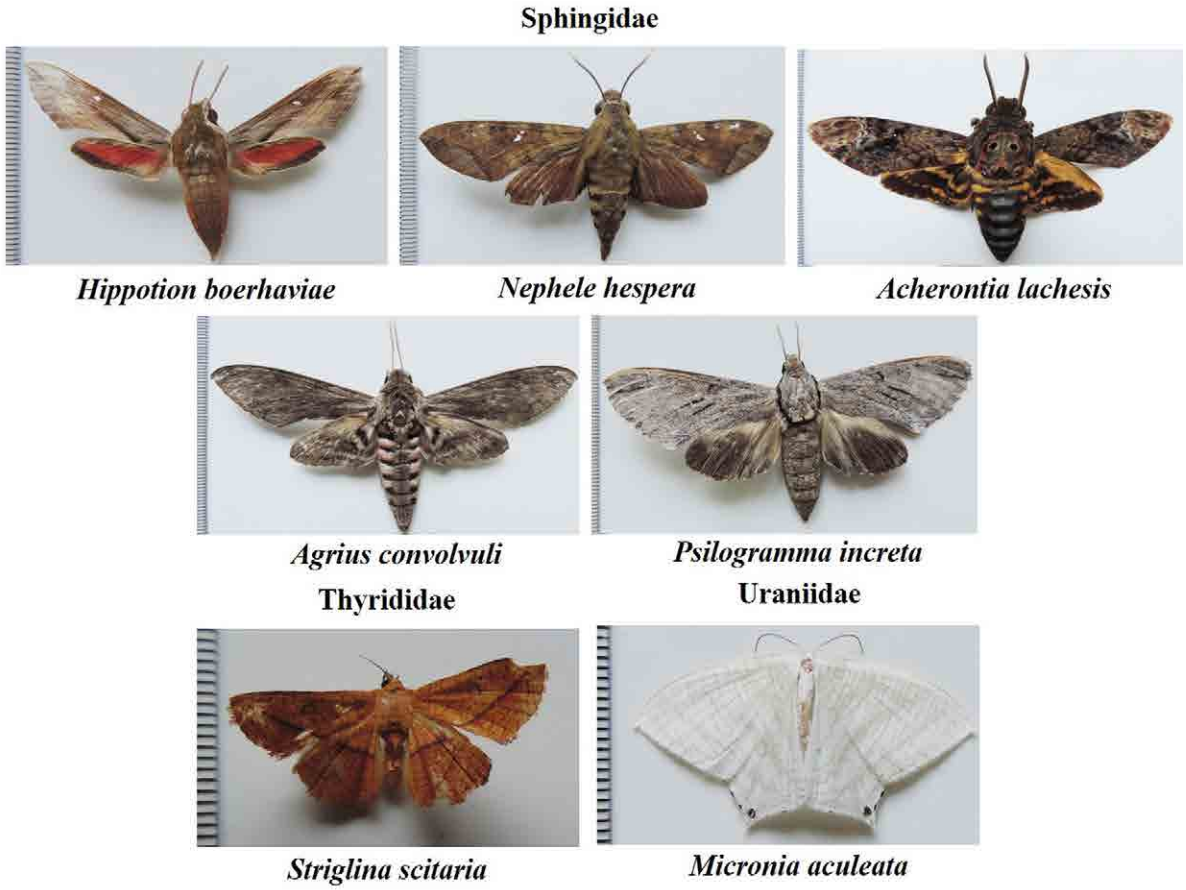

Image 7. Moths of Guindy: Sphingidae, Thyrididae, Uraniidae.

Uttar Pradesh, India. *Notulae Scientia Biologicae* 12(4): 794–806. https://doi.org/10.15835/nsb12410830

Gaston, K.J. (1994). Measuring geographic range sizes. *Ecography* 17: 198–205. https://www.jstor.org/stable/2097247

Goldstein, P.Z. (2017). Diversity and significance of Lepidoptera: a phylogenetic perspective, pp. 463–495. In: Foottit, R.G. & P.H. Adler (eds.). *Insect Biodiversity: Science and Society.* Oxford: Wiley-Blackwell, United Kingdom.

Gurule, S.A. & R.D. Brookes (2021). A preliminary study of moths (Insecta: Lepidoptera) of Goa University Campus, Goa. *Records of the Zoological Survey of India* 121(1): 101–116. https://doi.org/10.26515/rzsi/v121/i1/2021/152996

Gurule, S.A. & S.M. Nikam (2013). The moths (Lepidoptera: Heterocera) of northern Maharashtra: a preliminary checklist. *Journal of Threatened Taxa* 5(12): 4693–4713. https://doi.org/10.11609/JoTT.o2555.4693-713

Hajibabaei, M., D.H. Janzen, J.M. Burns, W. Hallwachs & P.D. Hebert (2006). DNA barcodes distinguish species of tropical Lepidoptera. *Proceedings of the National Academy of Sciences* 103(4): 968–971. https://doi.org/10.1073/pnas.0510466103

Hallmann, C.A., T. Zeegers, R. van Klink, R. Vermeulen, P. van Wielink, H. Spijkers & E. Jongejans (2020). Declining abundance of beetles, moths and caddisflies in the Netherlands. *Insect Conservation and Diversity* 13(2): 127–139. https://doi.org/10.1111/icad.12377

Hampson, G.F. (1892). Moths. In: *Fauna of Britsh India including Ceylon and Burma,* Vol. 1, Taylor and Francis, London, 527 pp.

Hampson, G.F. (1895). Moths. In: *The Fauna of British India, including Ceylon and Burma*, Vol. 3, Taylor and Francis, London.

Hampson, G.F. (1896). Moths. In: *The Fauna of British India, including Ceylon and Burma*, Vol. 4, Taylor and Francis, London, xxviii+449 pp.

Hebert, P.D. & T.K. Gregory (2005). The promise of DNA barcoding for taxonomy. *Systematic Biology* 54(5): 852–859. https://doi.org/10.1080/10635150500354886

Hebert, P.D., A. Cywinska, S.L. Ball & J.R. DeWaard (2003). Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London. Series B* 270(1512): 313–321. https://doi.org/10.1098/rspb.2002.2218

Hong, Y., M. Guo & J. Wang (2021). ENJ algorithm can construct triple phylogenetic trees. *Molecular Therapy-Nucleic Acids* 23: 286–293. https://doi.org/10.1016/j.omtn.2020.11.004

Humphrey, J.W., C. Hawes, A.J. Peace, R. Ferris-Kaan & M.R. Jukes (1999). Relationships between insect diversity and habitat characteristics in plantation forests. *Forest Ecology and Management* 113(1): 11–21. https://doi.org/10.1016/S0378-1127(98)00413-7

Jalali, S.K., R. Ojha & T. Venkatesan (2015). DNA barcoding for identification of agriculturally important insects, pp. 13–23. In: Chakravarthy, A. (eds.). *New Horizons in Insect Science: Towards Sustainable Pest Management.* Springer, New Delhi. https://doi.org/10.1007/978-81-322-2089-3_2

Jamal, K. (2021). Moth (Insecta: Lepidoptera) fauna of Sariska Tiger Reserve, Rajasthan, India. *Notulae Scientia Biologicae* 13(2): 10906–10906. https://doi.org/10.15835/nsb13210906

Jin, Q., X.M. Hu, H.L. Han, F. Chen, W.J. Cai, Q.Q. Ruan & A.B. Zhang (2018). A two–step DNA barcoding approach for delimiting moth species: moths of Dongling Mountain (Beijing, China) as a case study. *Scientific Reports* 8(1): 1–12. https://doi.org /10.1038/s41598-018-32123-9

Kalawate, A.S., N. Upadhyay & B. Mukhopadhyay (2019).

Rediscovery of an endemic Indian moth *Gurna indica* (Moore, 1879) (Lepidoptera: Erebidae: Arctiinae) after 125 years. *Journal of Threatened Taxa* 11(6): 13808–13810. https://doi.org/10.11609/jott.4649.11.6.13808-13810

Kimura, M. (1980). A simple method for estimating evolutionary rates of base substitutions through comparative studies of nucleotide sequences. *Journal of Molecular Evolution* 16: 111–120. https://doi.org/10.1007/BF01731581

Kirti, J.S., N. Singh & H. Singh (2017). Eight new records of family Erebidae (Lepidoptera: Noctuoidea) from India. *Journal of Threatened Taxa* 9(7): 10480–10486. https://doi.org/10.11609/jott.3690.9.7.10480-10486

Komal, J., P.R. Shashank, S. Sondhi, S. Madan, Y. Sondhi, N.M. Meshram & S.S. Anooj (2021). Moths (Insecta: Lepidoptera) of Delhi, India: An illustrated checklist based on museum specimens and surveys. *Biodiversity Data Journal* 9: e73997. https://doi.org/10.3897/BDJ.9.e73997

Kumar, S., G. Stecher, M. Li, C. Knyaz & K. Tamura (2018). MEGA X: molecular evolutionary genetics analysis across computing platforms. *Molecular Biology and Evolution* 35(6): 1547. https://doi.org /10.1093/molbev/msy096

Kumar, V., S. Kundu, R. Chakraborty, A. Sanyal, A. Raha, O. Sanyal & K. Chandra (2019). DNA barcoding of Geometridae moths (Insecta: Lepidoptera): a preliminary effort from Namdapha National Park, Eastern Himalaya. *Mitochondrial DNA Part B* 4(1): 309–315. https://doi.org/10.1080/23802359.2018.1544037

Liu, J., Y. Zhao, X. Si, G. Feng, F. Slik & J. Zhang (2021). University campuses as valuable resources for urban biodiversity research and conservation. *Urban Forestry & Urban Greening* 64: 127255.

Nagarajan, V.M., R. Srinivasan & M. Narayanaswamy (2021). Diversity of moths from the urban set–up of Valmiki Nagar, Chennai, India. *Journal of Threatened Taxa* 13(14): 20174–20189. https://doi.org/10.11609/jott.7515.13.14.20174-20189

Nayak, A. & S. Ghosh (2020). Moth diversity (Lepidoptera: Heterocera) of Banaras Hindu University, Varanasi, India: a preliminary checklist. *Notulae Scientia Biologicae* 12(3): 592–607. https://doi.org/10.15835/nsb12310749

Nayak, A. & S. Sasmal (2020). Monsoon moths (Lepidoptera: Heterocera) of Midnapore town, West Bengal, India: a preliminary checklist with a note on their diversity. *Environmental and Experimental Biology* 18: 271–282. https://doi.org/10.22364/eeb.18.26

Nieukerken, E.J., L. Kaila, I.J. Kitching, N.P. Kristensen, D.C. Lees, J. Minet & A. Zwick (2011). Order Lepidoptera Linnaeus, 1758. In: Zhang, Z.Q. (eds.). *Animal Biodiversity: An Outline of Higher-Level Classification and Survey of Taxonomic Richness*. *Zootaxa* 3148(1): 212–221.

Paul, M. (2021). Impact of urbanization on moth (Insecta: Lepidoptera: Heterocera) diversity across different urban landscapes of Delhi, India. *Acta Ecologica Sinica* 41(3): 204–209. https://doi.org/10.1016/j.chnaes.2021.01.008

Pooni, H.S., P.C. Pathania & A. Katewa (2019). Plume moths of family Pterophoridae (Microlepidoptera) from Shiwaliks of North-West India. *Records of the Zoological Survey of India* 119(3): 256–262. https://doi.org/10.26515/rzsi/v119/i3/2019/143334

Rajan, R. & R.S.M. Shamsudeen (2020). First record of the species *Asota paliura* (Swinhoe, 1893) (Lepidoptera: Erebidae: Aganinae) from India. *Asian Journal of Conservation Biology* 9(2): 359–361.

Ramkumar, J., M. Swamiappan, S. Raguraman & A. Sadasakthi (2010). Species diversity and seasonal abundance of fruit piercing moth complex in Tamil Nadu. *Journal of Biopesticides* 3(Special Issue): 11–15.

Shubhalaxmi, V., R.C. Kendrick, A. Vaidya, N. Kalagi & A. Bhagwat (2011). Inventory of moth fauna (Lepidoptera: Heterocera) of the northern western ghats, Maharashtra, India. *Journal of the Bombay Natural History Society* 108(3): 183–205.

Singh, N. & R. Ranjan (2016). Additions to the moth fauna of Dalma Wildlife Sanctuary, Jharkhand (India). *Records of the Zoological Survey of India* 116(4): 323–336. https://doi.org/10.26515/rzsi.v116i4.142109

Singh, N., J. Ahmad & R. Joshi (2017). Diversity of moths (Lepidoptera) with new faunistic records from North East Jharkhand, India. *Records of the Zoological Survey of India* 117(4): 326–340. https://doi.org/10.26515/rzsi/v117/i4/2017/121289

Sinu, P.A., P. Mandal, D. Banerjee, S. Mallick, T. Talukdar & S.K. Pathak (2013). Moth pests collected in light traps of tea plantations in North East India: species composition, seasonality and effect of habitat type. *Current Science* 104(5): 646–651.

Sivasankaran, K. & S. Ignacimuthu (2014). A report of Erebidae (Lepidoptera: Noctuoidea) from the Tamil Nadu part of the western ghats, India. *Journal of the Bombay Natural History Society* 111(3): 193–209. https://doi.org/10.17087/jbnhs/2014/v111i3/82380

Sondhi, Y. & S. Sondhi (2016). A partial checklist of moths (Lepidoptera) of Dehradun, Mussoorie and Devalsari in Garhwal, Uttarakhand, India. *Journal of Threatened Taxa* 8(5): 8756–8776. https://doi.org/10.11609/jott.2814.8.5.8756-8776

Sondhi, Y., S. Sondhi, S.R. Pathour & K. Kunte (2018). Moth diversity (Lepidoptera: Heterocera) of Shendurney and Ponmudi in Agastyamalai Biosphere Reserve, Kerala, India, with notes on new records. *Tropical Lepidoptera Research* 28(2): 66–69. https://doi.org/10.5281/zenodo.2027709

Summerville, K.S., L.M. Ritter & T.O. Crist (2004). Forest moth taxa as indicators of lepidopteran richness and habitat disturbance: a preliminary assessment. *Biological Conservation* 116(1): 9–18. https://doi.org/10.1016/S0006-3207(03)00168-X

Sviridov, A.V. & D. Leuschner (1986). Optimization of taxonomic keys by means of probabilistic modelling. *Biometrical Journal* 28(5): 609–616. https://doi.org/10.1002/bimj.4710280511

Terra, W.R. & C. Ferreira (2020). Evolutionary trends of digestion and absorption in the major insect orders. *Arthropod Structure & Development* 56: 100931. https://doi.org/10.1016/j.asd.2020.100931

Wagner, D.L., R. Fox, D.M. Salcido & L.A. Dyer (2021). A window to the world of global insect declines: Moth biodiversity trends are complex and heterogeneous. *Proceedings of the National Academy of Sciences* 118(2): e2002549117. https://doi.org/10.1073/pnas.2002549117

Wahlberg, N., C.W. Wheat & C. Peña (2013). Timing and patterns in the taxonomic diversification of Lepidoptera (butterflies and moths). *PLoS ONE* 8(11): e80875. https://doi.org/10.1371/journal.pone.0080875

Watt, A.D., D.A. Barbour & C. McBeath (1997). The invertebrate fauna associated with birch in spruce forests. *Scottish Natural Heritage Research, Survey and Monitoring Report* No. 82, Edinburgh.

White, P.J., K. Glover, J. Stewart & A. Rice (2016). The technical and performance characteristics of a low-cost, simply constructed, black light moth trap. *Journal of Insect Science* 16(1): 25. https://doi.org/10.1093/jisesa/iew011

Zahiri, R., J.D. Holloway, I.J. Kitching, J.D. Lafontaine, M. Mutanen & N. Wahlberg (2012). Molecular phylogenetics of Erebidae (Lepidoptera, Noctuoidea). *Systematic Entomology* 37(1): 102–124. https://doi.org/10.1111/j.1365-3113.2011.00607.x

Zari, M.P. (2018). *Regenerative Urban Design and Ecosystem Biomimicry*. Routledge, United Kingdom, 260 pp. https://doi.org/10.4324/9781315114330

Zhang, Z.Q. (2013). Phylum Arthropoda. In: Zhang, Z.Q. (Ed.) Animal Biodiversity: An Outline of Higher Level Classification and Survey of Taxonomic Richness. *Zootaxa* 3703: 17–26. https://doi.org/10.11646/zootaxa.3703.1.6

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
Dr. 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. Neelesh Dahanukar, IISER, Pune, Maharashtra, India
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, Chennai Snake Park, Chennai, Tamil Nadu, 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, The American College, Madurai, 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 2020–2022
Due to pausity of space, the list of reviewers for 2018–2020 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,
43/2 Varadarajulu Nagar, 5th Street West, Ganapathy, Coimbatore,
Tamil Nadu 641006, India
ravi@threatenedtaxa.org

Journal of Threatened Taxa

www.threatenedtaxa.org

OPEN ACCESS

The Journal of Threatened Taxa (JoTT) is dedicated to building evidence for conservation globally by publishing peer-reviewed articles online every month at a reasonably rapid rate at www.threatenedtaxa.org. All articles published in JoTT are registered under Creative Commons Attribution 4.0 International License unless otherwise mentioned. JoTT allows allows unrestricted use, reproduction, and distribution of articles in any medium by providing adequate credit to the author(s) and the source of publication.

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

June 2023 | Vol. 15 | No. 6 | Pages: 23283–23462
Date of Publication: 26 June 2023 (Online & Print)
DOI: 10.11609/jott.2023.15.6.23283-23462

Publisher & Host

WILD ZOOREACH
Threatened Taxa