



Building evidence for conservation globally

Journal of  
Threatened  
Taxa

Open Access

10.11609/jott.2022.14.11.22039-22206

[www.threatenedtaxa.org](http://www.threatenedtaxa.org)

26 November 2022 (Online & Print)

14 (11): 22039-22206

ISSN 0974-7907 (Online)

ISSN 0974-7893 (Print)





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

Publisher  
**Wildlife Information Liaison Development Society**  
[www.wild.zooreach.org](http://www.wild.zooreach.org)

Host  
**Zoo Outreach Organization**  
[www.zooreach.org](http://www.zooreach.org)

43/2 Varadarajulu Nagar, 5<sup>th</sup> Street West, Ganapathy, Coimbatore, Tamil Nadu 641035, India  
Ph: +91 9385339863 | [www.threatenedtaxa.org](http://www.threatenedtaxa.org)  
Email: [sanjay@threatenedtaxa.org](mailto:sanjay@threatenedtaxa.org)

#### EDITORS

##### Founder & Chief Editor

**Dr. Sanjay Molur**

Wildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO),  
12 Thiruvannamalai Nagar, Saravanampatti, Coimbatore, Tamil Nadu 641035, India

##### Deputy Chief Editor

**Dr. Neelesh Dahanukar**

Noida, Uttar Pradesh, India

##### Managing Editor

**Mr. B. Ravichandran**, WILD/ZOO, Coimbatore, 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 641035, India

**Dr. B.A. Daniel**, ZOO/WILD, Coimbatore, Tamil Nadu 641035, 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, Mavinahalla 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. Ilangoan**, Chennai, 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 2019–2021

##### Fungi

Dr. B. Shivaraju, Bengaluru, Karnataka, India

Dr. R.K. Verma, Tropical Forest Research Institute, Jabalpur, India

Dr. Vatsavaya S. Raju, Kakatiya University, Warangal, Andhra Pradesh, India

Dr. M. Krishnappa, Jnana Sahyadri, Kuvempu University, Shimoga, Karnataka, India

Dr. K.R. Sridhar, Mangalore University, Mangalagangothri, 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 Ontario 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, Kadoorie Farm and Botanic Garden Corporation, Hong Kong S.A.R., China

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. Janarthnam, 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. Navendu Page, Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand, India

Dr. Kannan C.S. Warrior, 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.

Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK

For Focus, Scope, Aims, and Policies, visit [https://threatenedtaxa.org/index.php/JoTT/aims\\_scope](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](https://threatenedtaxa.org/index.php/JoTT/policies_various)

continued on the back inside cover

Cover: Mugger Crocodile basking on the banks of Savitri River at Mahad in Maharashtra, India. © Utkarsha M. Chavan.



## Diversity patterns and seasonality of hawkmoths (Lepidoptera: Sphingidae) from northern Western Ghats of Maharashtra, India

Aditi Sunil Shere-Kharwar<sup>1</sup> , Sujata M. Magdum<sup>2</sup> , G.D. Khedkar<sup>3</sup> & Supriya Singh Gupta<sup>4</sup>

<sup>1,4</sup> HPT Arts & RYK Science College, College Road, Nashik, Maharashtra 422005, India.

<sup>2</sup> KTHM College, Gangapur Road, Nashik, Maharashtra 422002, India.

<sup>3</sup> Paul Hebert Centre for DNA Barcoding and Biodiversity Studies, BAMU, Aurangabad, Maharashtra 431004, India.

<sup>1</sup>adushere@gmail.com, <sup>2</sup>sujata\_magdum@yahoo.com, <sup>3</sup>gdkhedkar@gmail.com, <sup>4</sup>singhguptasupriya@gmail.com (corresponding author)

**Abstract:** As most of the biodiversity studies report the abundance and enlist the species, there is severe data deficiency in understanding the diversity patterns. The present study was designed to carry out periodic diversity assessments to understand the trends in diversity patterns of hawk moths. The study was carried out in the northern Western Ghats in Nashik district. Seven sampling stations were identified and periodic visits to these places were carried out over the span of five years (2011–2015). A total of 463 moths were recorded belonging to 18 species, represented by 10 genera. A new record from Western Ghat, *Theretra sumatrensis* (Joicey & Kaye 1917) is reported for the first time along with its DNA barcode. Six diversity indices (four alpha diversity indices and two beta diversity indices) were employed to understand the diversity dynamics. Whittaker's plot was generated using the rank abundance suggesting high species evenness for all sampling stations. Maximum diversity was observed during Monsoon. Wani was the most diverse sampling station throughout the study period (Shannon's Index =  $2.7132 \pm 0.060$ ; Simpson's Index =  $0.9273 \pm 0.006$ ; Brillouin's Index =  $2.252 \pm 0.089$ ; Fisher's alpha =  $10.9472 \pm 1.685$ ). Beta diversity was assessed with the help of Dice's coefficient and Jaccard's similarity index. Hence, we recommend rigorous periodic diversity assessments to generate adequate information about diversity that expedites conservational strategies' pace.

**Keywords:** DNA barcode, moth diversity, new report, range extension, species abundance, Sphingidae.

**Abbreviations:** CH—Chandwad; IG—Igatpuri; KL—Kalwan; NC—Nashik City; PT—Peint; TM—Triambakeshwar; WN—Wani.

**Editor:** Jatishwor Singh Irungbam, Sphingidae Museum, Pribram, Czech Republic.

**Date of publication:** 26 November 2022 (online & print)

**Citation:** Shere-Kharwar, A.S., S.M. Magdum, G.D. Khedkar & S.S. Gupta (2022). Diversity patterns and seasonality of hawkmoths (Lepidoptera: Sphingidae) from northern Western Ghats of Maharashtra, India. *Journal of Threatened Taxa* 14(11): 22105–22117. <https://doi.org/10.11609/jott.7511.14.11.22105-22117>

**Copyright:** © Shere-Kharwar et al. 2022. 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:** The present work was partially funded by University Grants Commission, Government of India [File No. 41-172/2012 (SR), dated 26/06/2012].

**Competing interests:** The authors declare no competing interests.

**Author details:** DR ADITI SUNIL SHERE KHARWAR is working as assistant professor at Department of Zoology, HPT Arts and RYK College affiliated to Savitribai Phule Pune University. She was principal investigator for the UGC Project that funded the present research. Her area of research is related to molecular taxonomy, diversity, and ecological studies of moth. DR SUJATA MAGDUM is working as assistant professor at Department of Zoology, KTHM College affiliated to Savitribai Phule Pune University. Her research interest includes lepidopteran taxonomy and toxicological studies. DR G.D. KHEDKAR is professor at Department of Zoology, Babasaheb Ambedkar Marathwada University and director, Paul Hebert Centre for DNA Barcoding and Biodiversity Studies, Babasaheb Ambedkar Marathwada University. He expertise in molecular systematics. DR SUPRIYA SINGH GUPTA works as associate professor at Department of Zoology, HPT Arts and RYK College affiliated to Savitribai Phule Pune University. Her area of research includes systematics and toxicology.

**Author contributions:** ASK and SM were involved in project design. Data collection and analysis were performed by ASK, GDK and SM. ASK and SSG were involved in manuscript preparation.

**Acknowledgements:** We are grateful to University Grants Commission, New Delhi for providing funds to carry out molecular analysis. The authors are thankful to Dr Archana Patil for helping in preparing map. We would also like to thank Dr Ian Kitching for confirming the moth identifications. We are forever indebted to Dr Paul D N Hebert for his support and encouragement.



## INTRODUCTION

Insecta, being the most diverse class of Kingdom Animalia, rules the planet with their existence in all habitats. The adaptive features of this group of organisms allowed their natural selection in due course of evolution. Insects have existed since the Silurian period, approximately 420 mya (Misof et al. 2014). Currently, insects account for almost half of the known species on the earth (Chapman 2009). The tropical climate of India provides a conducive environment for a variety of insects. According to Murugan, 80% of insects from India are endemic (Murugan 2006).

Lepidoptera is one of the four super radiations of the class Insecta and includes butterflies and moths. Moths account for 85% of the lepidopteran population, and the remaining 15 % are butterflies and skippers. Moths serve as food for a variety of animals such as birds, bats, and praying mantis (Macgregor et al. 2015). The moth caterpillars are plant feeding, while the adult forms of the moths may be nectar feeding or fruit piercing (Reddy et al. 2005). Thus, forming a major pest clade (Cho et al. 2008). Moreover, their association with the plants makes them an integral part of the ecosystem. As a result, their numbers and availability are a good indicator of ecosystem's health (Thomas 2005).

Diversity studies of sphingid moths from India have been done and reported by many taxonomists (Bell & Scott 1937; Roonwal & Thapa 1963; Subalakmi 2008; Smetacek & Kitching 2012; Chandra et al. 2013, 2014; Kitching et al. 2014; Pathania et al. 2014; Sondhi et al. 2017; Melichar et al. 2018; Iyer & Kitching 2019; Singh et al. 2021). E.C. Cotes and C. Swinhoe conducted preliminary pioneering studies on Sphingid moths (Cotes & Swinhoe 1889). Further substantial work was done by Hampson (Hampson 1892). He reported 121 species of sphingid moths across India. Later, Bell & Scott (1937) documented sphingid from the Indian sub-continent. Almost three decades later, Roonwal & Thapa (1963) enlisted sphingids from peninsular India. Sambath (2011) described documented sphingid fauna from Dalma Wildlife Sanctuary, Jharkhand. Shubhalaxmi et al. (2011) described 45 hawk moths from northern Western Ghats near Mumbai. Sphingid moths from peninsular India were listed by Patil et al. (2013). Chandra et al. (2013) reported sphingid diversity from Veerangana Durgavati Wildlife Sanctuary, Damoh, Madhya Pradesh. The sphingid fauna from Ladakh, Jammu & Kashmir was reported by Smetacek & Kitching (Kitching et al. 2014). Sondhi et al. (2017) described a new species of *Theretra* Hubner from southern Western Ghats. Even though

there are many studies of moth diversity, there has been a meagre number of inventories undertaken to focus primarily on the family Sphingidae. Further, there has been one report of sphingid diversity from the northern Western Ghats (Gurule & Nikam 2013). However, this study did not focus entirely on the diversity and dynamics of sphingid moths.

The novelty of the present study lay in the exclusivity and thoroughness attained to understand and analyze the hawkmoth moth diversity. Hawkmoths account for a very low number (~1,400 global species) than other giant moth families such as Erebidae and Geometridae (van Nieukerken et al. 2011); thus, get insufficient attention to the inventories. However, sphingids are known to be major pests but also good pollinators (Madden 1944; Eisikowitch & Galil 1971; Nilsson et al. 1985; Danaheer et al. 2019). Hence, their presence creates a unique balance in the ecological niche. Also, these are some of the best flyers amongst the moth community.

## MATERIAL & METHODS

### Study Area

The present study aimed to analyze the diversity of sphingid moths from the northern Western Ghats (Nashik district), Maharashtra, India. Nashik district is located between 18.33–20.53 °N & 73.16–75.16 °E (Image 1). It covers approximately 15,582 km<sup>2</sup> and lies on the western edge of the Deccan plateau. The Sahyadri Mountains lie in the western part of the district, while Wani and Chandwad hill ranges cover the central part of the district. There are no ranges in the eastern part of the district. Forest coverage is approximately 3,400 km<sup>2</sup>. The forests are of mixed type, with Teak and Sissoo being the significant trees. The forests are tropical moist deciduous, tropical dry deciduous and tropical hill forest types. As per Koppen's climate classification, the study area is a tropical wet and tropical dry climate with peak rains in July (McKnight 2017). The Western Ghats divides the district into two parts: The western part lies in the rainfed region, while the eastern part lies in the rain shadow region.

### Collection & Identification

From 2011 to 2015, extensive observation and collection were carried out. The study area was thoroughly studied to finalize the sampling stations (Table 1). After the initial survey, seven sampling stations were finalized. Table 2 describes the details of the sampling stations and the collection events. Light traps

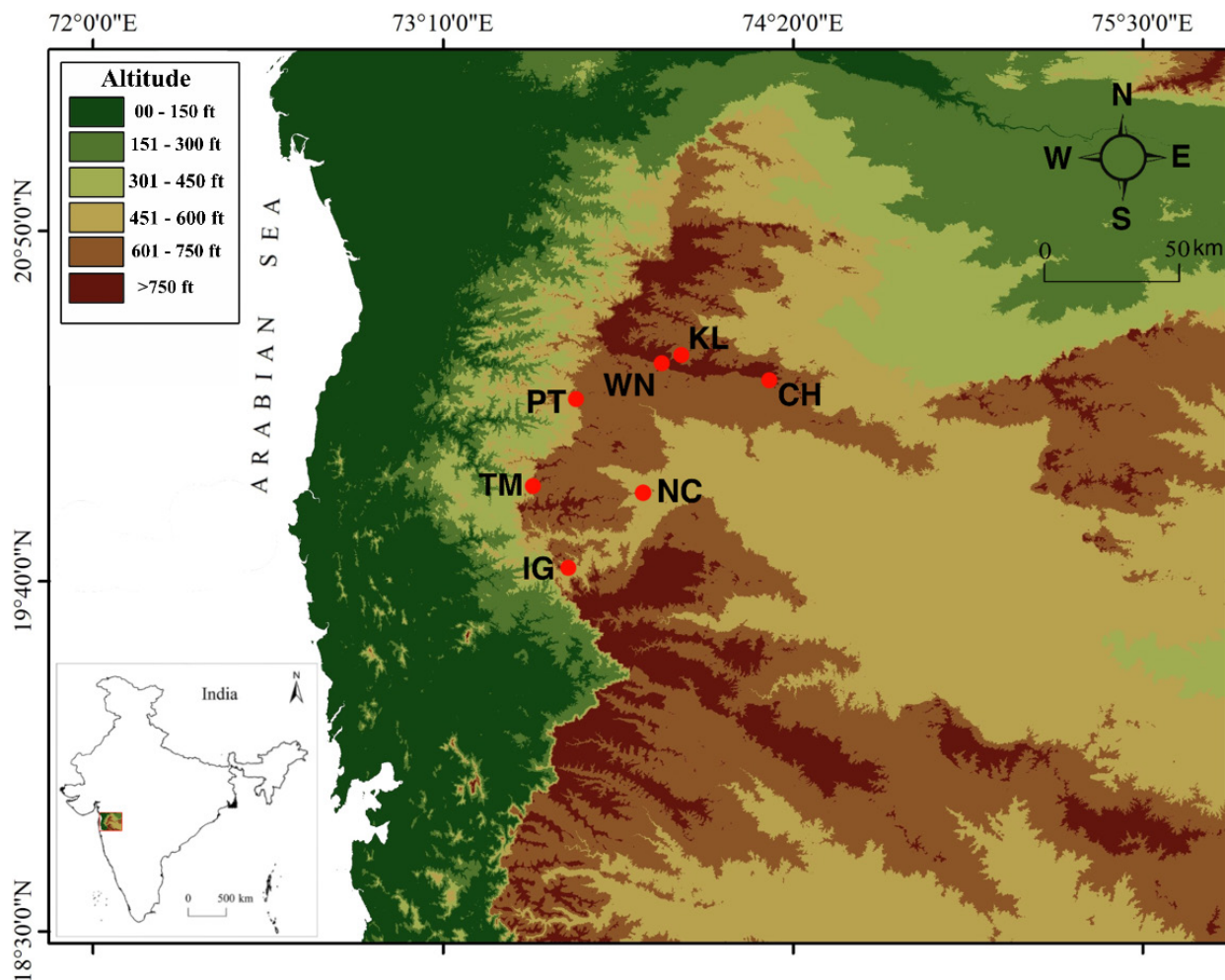


Image 1. Geographical location of the sampling sites.

Table 1. Sampling stations with their co-ordinates.

Name of sampling station	Abbreviation	Latitude	Longitude
Chandwad	CH	20°20'26.42"N	74°15'10.18"E
Igatpuri	IG	19°42'37.21"N	73°34'42.56"E
Kalwan	KL	20°25'12.49"N	73°57'8.99"E
Nashik City	NC	19°57'31.44"N	73°49'47.01"E
Peint	PT	20°15'33.42"N	73°36'40.43"E
Triambakeshwar	TM	19°59'6.19"N	73°28'1.21"E
Wani	WN	20°23'26.49"N	73°54'25.79"E

or a simple spreadsheet operated by fluorescent light (Compton 35 W; Philips tornado 27 W 130–320 V) were used. Collection set up was run from around 1900 h to 0500 h. Inverter batteries were used for operating the lights.

According to Brehm & Axmacher (2006), adaptability

and flexibility in collection methods result in better collection and observations. Therefore, the collection assembly type varied initially, and the best-suited method was followed based on the collection conditions. However, hawkmoths vibrate their wings, causing loss of wing scales in the light trap. Moreover, all the observed specimens were not collected, and documentation of moths was easier by spreadsheet setup. Hence, the spreadsheet method was preferred over light traps. The sampling sites with large capture rates are challenging to handle, which is a common experience shared by many lepidopterists. In such situations, collecting, relaxing, and spreading of specimens is arduous (Abang & Ak Karim 2002; Gurule & Nikam 2013). Therefore, moths were observed, and the species abundance was calculated during the collection visits. Unique moth specimens which could not be identified were collected and brought back to the laboratory to investigate further. A small sample size of moths was collected from



each sampling station. Collected moth specimens were spread on spreading boards and were oven-dried for 3–5 days depending upon the size of the moth. The digital documentation was carried out using Nikon 3200 DSLR. Photographs were edited with the help of the software GIMP.

All the specimens were identified with the help of reference manuscripts (Barlow 1982; Holloway 1987; Haruta 1992, 1994, 1995; Inoue et al. 1997; Kendrick 2002; Srivastava 2002; Gurule & Nikam 2013; Sondhi et al. 2017). Unique samples were processed for molecular identification.

Along with the observation and collection of moths, other metadata was also collected, such as time of collection, altitude, the topography of the collection site, overall vegetation, season, and overall rainfall. These metadata are known to affect the moth availability and helps in understanding the ecological dynamics and intricate patterns of moth abundance (Hardwick 1972; McGeachie 1989; Yela & Holyoak 1997; Mittelbach et al. 2007; Chen et al. 2009).

### Molecular Identification

Total genomic DNA was isolated using the modified phenol chloroform extraction method (Sperling et al. 1994). The isolated DNA was amplified using readily available markers LCO 1490–HCO 2198. A total reaction mixture of 25 µl was prepared, comprising of 12.5 µl trehalose, 2.5 µl 10X reaction buffer, 1 µl of MgCl<sub>2</sub>, 2 µl of dNTP, 1 µl each of forward and reverse primer, 1.88 µl of water and 3 µl of DNA template. The thermal cycle included initial heating for DNA denaturation at 94°C for 2 minutes. The next five cycles were at 94°C for 30 seconds followed by 45°C for 1 minute and 30 seconds and final extension at 72°C for 1 minute. The next 35 cycles were for 94°C for 1 minute 30 seconds, 51°C for 1 minute and 30 seconds, and extension at 72°C for 1 minute. PCR product was cycle sequenced and sequencing was carried out in ABI 3130 sequencer. The sequencer files were aligned and edited using Bioedit and were converted to FASTA format. The FASTA files were uploaded on BOLD (Barcode of life Data systems, <https://boldsystems.org>) (Ratnasingham & Hebert 2007).



Figure 1. Recorded geographical expanse of *Theretra sumatrensis*. (© [https://mol.org/species/Theretra\\_sumatrensis](https://mol.org/species/Theretra_sumatrensis))

## Diversity analysis

Four alpha diversity indices were employed: Shannon's, Simpson's, Brillouin's, and Fisher's alpha. Beta diversity was assessed with the help of two indices: Dice's Coefficient and Jaccard's similarity index. These diversity indices were calculated using cumulative abundance data, and all the calculations were performed using the software PAST ver. 4.03.

## RESULTS

A total of 463 hawkmoths were recorded over five years (2011–2015). These moths were identified into 18 species represented by three subfamilies and ten genera (Image 2). The most diverse subfamily was Macroglossinae, represented by 12 species, and *Theretra* Hübner, 1819, was the most diverse genus comprising of seven species. Table 3 depicts the systematic position, distribution, and status of all the moths recorded.

*T. sumatrensis* (Joicey & Kaye 1917), the Southern Spotted Hunter Hawkmoth, was a unique record from this region and has not been previously reported. As described by Joicey & Kaye, 1917, *Theretra sumatrensis* has dull greyish-brown forewing. Black marks are present at the base. The post medial line is faint and marked on veins as dashes. Diffused darker clouds are present across the middle of the forewing. The hindwing is black with paler margins. There is the presence of a distally pointed yellowish patch at the anal angle. Sondhi et al. 2017 have compared the habitus of other species of the genus *Theretra* and have confirmed the similarity between *T. boisduvalii* and *T. sumatrensis*. However, the two can be differentiated by the pattern of colouration where *T. boisduvalii* is more greenish in colour with uniform suffusion while the latter is paler and brownish in colour.

The species identification was confirmed by DNA barcoding, and there is no published article describing its presence in the entire Western Ghats. This species has been reported only from the Himalayan region (Sondhi et al. 2017). Ballesteros-Mejia et al. (2017) have created global distribution maps for sphingid moths. Figure 1 shows the distribution of *T. sumatrensis* according to Ballesteros-Mejia et al. 2017 ([https://mol.org/species/Theretra\\_sumatrensis](https://mol.org/species/Theretra_sumatrensis)). Thus, we further extend the range of *T. sumatrensis* to the Western Ghats, the specimens recorded at Wani and Kalwan from Nashik District, Maharashtra, India. Table 4 describes

**Table 2. Overview of inventory visits and moth recorded.**

Sampling station	Symbol	Inventory visits made between 2011–2015			Number of moths recorded
		Summer	Monsoon	Winter	
Chandwad	CH	5	14	5	59
Igatpuri	IG	5	11	5	60
Kalwan	KL	5	11	5	43
Nashik City	NC	5	6	5	21
Peint	PT	5	6	5	15
Triambakeshwar	TM	5	9	5	24
Wani	WN	5	14	5	241
Grand Total					463

the details of sequences mined from BOLD and GenBank to generate the neighbour-joining tree based on the  $K_2P$  model using mitochondrial COI gene. The NJ tree based on  $K_2P$  model indicated approximate species relationship within genus *Theretra* (Figure 2).

Although the geographical expanse of the present study was small, it exhibited great diversity (Image 1). The seven sampling stations showed varied diversity patterns. The most diverse sampling community was WN, where all the 18 species of moths were recorded, followed by IG and CH, having seven species. Figure 3 describes the relative species abundance at all sampling stations over five years (2011–2015). Figure 4 represents Whittaker's plot for abundance. It is clear from Figure 4A that the species richness and evenness for sampling stations vary drastically. KL, TM, and PT show precisely the same richness, while TM and PT have the same evenness. KL has the least evenness amongst all the sampling stations. On the other hand, WN has maximum richness and evenness in the entire study. Further, Whittaker's plot is originally used to describe species richness and evenness. In contrast, we have also utilized it to compare our observations annually (Figure 4B). This figure helps clarify that collection over five years showed nearly the same trend confirming that there was no bias or error and the collection events were carried out randomly. We want to support this further because the rigorous collection and increased number of samples helped eliminate the errors. Figure 5 illustrates variations in the four alpha diversity indices (Shannon's, Simpson's, Brillouin's, and Fisher's alpha) at all the sampling stations over five years (2011–2015). Figures 6 & 7 are heatmaps elucidating the beta diversity amongst the seven sampling stations.

**Table 3. Taxonomic position, distribution, and status of hawkmoths from northern Western Ghats.**

Family	Sub-family	Species	Distribution	Status
Sphingidae	Macroglossinae	<i>Daphnis nerii</i> (Linnaeus, 1758)	CH, WN	U
		<i>Hippotion celerio</i> (Linnaeus, 1758)	CH, IG, KL, WN	C
		<i>Hippotion rosetta</i> (Swinhoe, 1892)	CH, IG, KL, NC, PT, TM, WN	C
		<i>Hyles livornica</i> (Esper, 1780)	IG, KL, WN	C
		<i>Nephele hespera</i> (Fabricius, 1775)	IG, KL, NC, WN	C
		<i>Theretra alecto</i> (Linnaeus, 1758)	CH, IG, PT, TM, WN	C
		<i>Theretra castanea</i> (Moore, 1872)	WN	R
		<i>Theretra clotho</i> (Drury, 1773)	WN	R
		<i>Theretra gnoma</i> (Fabricius, 1775)	WN	U
		<i>Theretra nessus</i> (Drury, 1773)	WN	U
		<i>Theretra oldenlandiae</i> (Fabricius, 1775)	WN	R
		<i>Theretra sumatrensis</i> (Joicey & Kaye, 1917)	KL, WN	U
	Smerinthinae	<i>Marumba dyas</i> (Walker, 1856)	WN	U
		<i>Polyptychus dentatus</i> (Cramer, 1777)	WN	U
	Sphinginae	<i>Acherontia lachesis</i> (Fabricius, 1775)	WN	U
		<i>Acherontia styx</i> (Westwood, 1847)	IG, WN	U
		<i>Agrius convolvuli</i> (Linnaeus, 1758)	CH, IG, KL, NC, PT, TM, WN	C
		<i>Psilogramma vates</i> (Butler, 1875)	CH, WN	C

## DISCUSSION

India shares 8.1% of global diversity on only 2.4% of the global land area resulting in diversity richness (Balasubramanian 2017). There are 12 mega biodiverse countries in the entire world, and India is one of them. The present study area lies in the Western Ghats, which have been declared World Heritage Site as it harbours humungous diversity. Continuous inventories have proved to generate valuable information and increased taxonomic knowledge (Janzen et al. 2009). Hence, we strongly support and recommend continuous periodical assessments to understand the diversity and its dynamics. The incorporation of molecular tools has also encouraged young taxonomists to indulge more. Moreover, diversity studies are necessary to understand the species distribution and unfold the ecological dynamics. It is frequently observed that diversity studies are reported with the species diversities, which may or may not be combined with the diversity analysis. However, there exist complex dynamics between the species and its environmental and ecological surroundings. Understanding this can help to predict diversity for unassessed areas and develop better

conservation strategies. Thus, understanding diversity becomes indispensable.

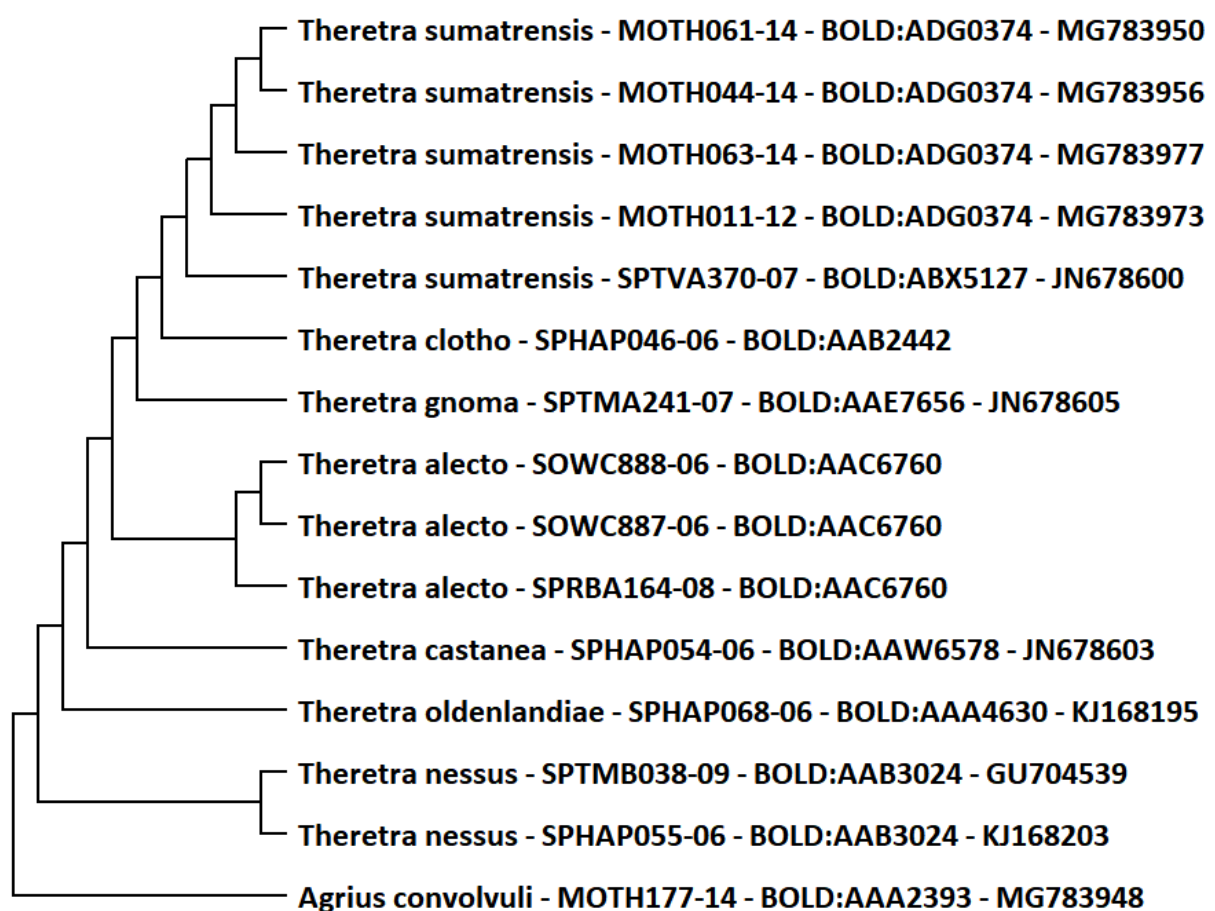
When diversity indices are applied, interpreting species distribution becomes easier. The present study calculated alpha and beta diversity indices for each sampling station to understand the species distribution. Four indices were used to assess alpha diversity (Shannon's, Simpson's, Brillouin's, and Fisher's alpha) and two to study beta diversity (Dice's Coefficient and Jaccard's similarity index). According to Barrantes & Sandoval (2009), using multiple indices helps eliminate drawbacks of the individual index. Further, the indices chosen in the present study focus on varied aspects of diversity. Shannon's Index describes species diversity. Maximum species diversity was observed for WN ( $2.7132 \pm 0.060$ ) and minimum diversity for TM ( $0.9683 \pm 0.185$ ) Figure 5A. When Shannon's index is calculated, a weighted geometric mean of the proportional abundances is employed. Thus, it reflects the logarithm of actual diversity observed and is used frequently.

Simpson's index uses the weighted arithmetic mean or proportional abundances and describes species richness and evenness. Thus, a high Simpson's index



**Table 4.** Sequences used to generate Neighbour Joining Tree based on K2P model for species from genus *Theretra*.

Species	Sequence ID	BIN	Genbank Accession	Source
<i>Theretra sumatrensis</i>	MOTH011-12	BOLD:ADG0374	MG783973	Present Study
	MOTH044-14	BOLD:ADG0374	MG783956	Present Study
	MOTH061-14	BOLD:ADG0374	MG783950	Present Study
	MOTH063-14	BOLD:ADG0374	MG783977	Present Study
	SPTVA370-07	BOLD:ABX5127	JN678600	Wilson et al. 2011
<i>Theretra clotho</i>	SPHAP046-06	BOLD:AAB2442	-	<a href="https://boldsystems.org">https://boldsystems.org</a>
<i>Theretra gnoma</i>	SPTMA241-07	BOLD:AAE7656	JN678605	Wilson et al. 2011
<i>Theretra alecto</i>	SPRBA164-08	BOLD:AAC6760	-	<a href="https://boldsystems.org">https://boldsystems.org</a>
	SOWC887-06	BOLD:AAC6760	-	<a href="https://boldsystems.org">https://boldsystems.org</a>
	SOWC888-06	BOLD:AAC6760	-	<a href="https://boldsystems.org">https://boldsystems.org</a>
<i>Theretra castanea</i>	SPHAP054-06	BOLD:AAW6578	JN678603	Wilson et al. 2011
<i>Theretra oldenlandiae</i>	SPHAP068-06	BOLD:AAA4630	KJ168195	Rougerie et al. 2014
<i>Theretra nessus</i>	SPTMB038-09	BOLD:AAB3024	GU704539	<a href="https://www.ncbi.nlm.nih.gov/nuccore/GU704539">https://www.ncbi.nlm.nih.gov/nuccore/GU704539</a>
	SPHAP055-06	BOLD:AAB3024	KJ168203	Rougerie et al. 2014
<i>Agrius convolvuli</i> (out group)	MOTH177-14	BOLD:AAA2393	MG783948	Shere 2018

**Figure 2.** NJ tree based on K2P model of genus *Theretra* using mitochondrial COI gene sequence.

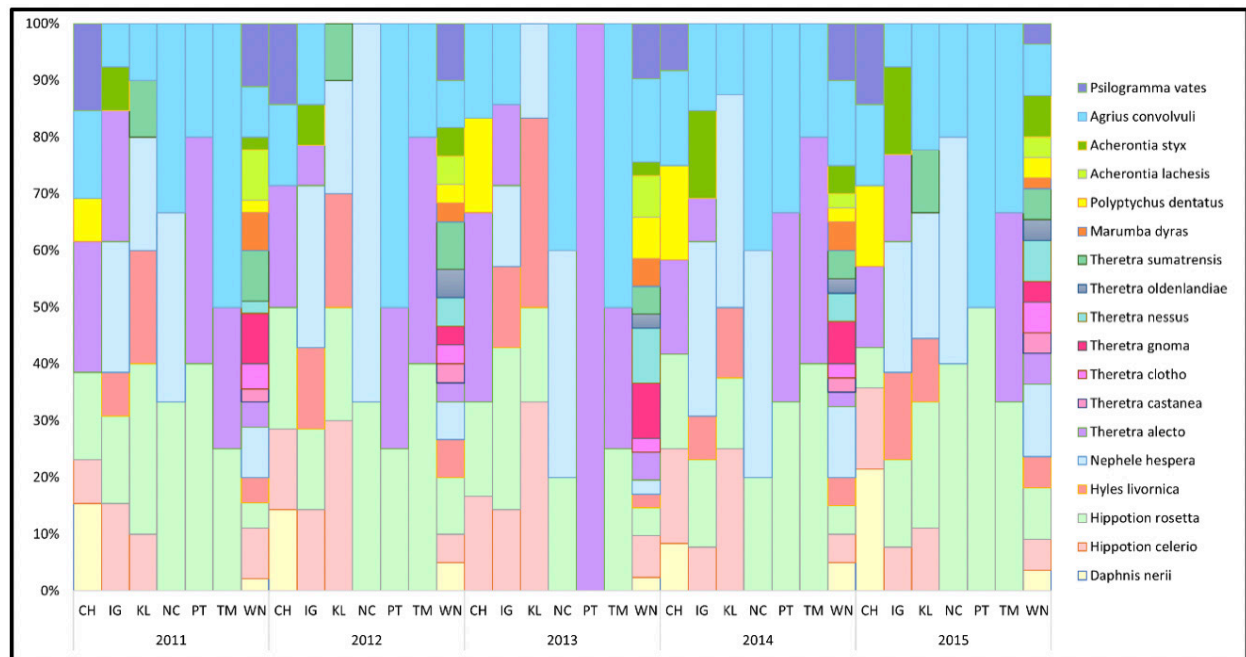


Figure 3. Relative species abundance at all sampling station over five years (2011–2015).

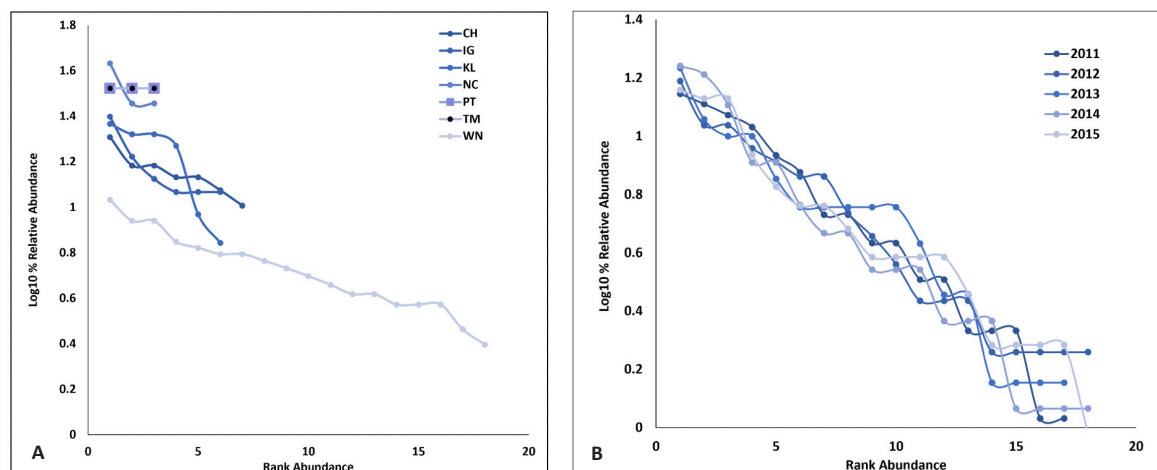


Figure 4. Whittaker's plot: A—Sampling station-wise | B—Sampling year-wise.

suggests higher species richness and evenness. The maximum value for Simpson's index was calculated for WN ( $0.9273 \pm 0.006$ ) and minimum for TM ( $0.5978 \pm 0.086$ ) (Figure 5B). this suggests that the species richness at WN is definitely high and there is an evenness to the species distribution too.

The following index calculated was Brillouin's index. According to Magurran, this diversity index serves better when there is no surety for the randomness of the sample (Magurran 1988). Thus, to eliminate any biases raised unknowingly, we employed this index.

The maximum value for this index was calculated again for WN ( $2.252 \pm 0.089$ ) and minimum for again Triambakeshwar TM ( $0.6056 \pm 0.136$ ) (Figure 5C).

Lastly, Fisher's alpha was the fourth alpha diversity index employed. Fisher's alpha has a good discriminating capability in cases where sample sizes vary a lot. As the sample size for all the sampling stations varied (Table 2), this index was used. Maximum value for this index was calculated for WN ( $10.9472 \pm 1.685$ ) and minimum for TM ( $3.5152 \pm 1.108$ ) (Figure 5D). Thus, all the four alpha diversity indices confirm that maximum alpha diversity



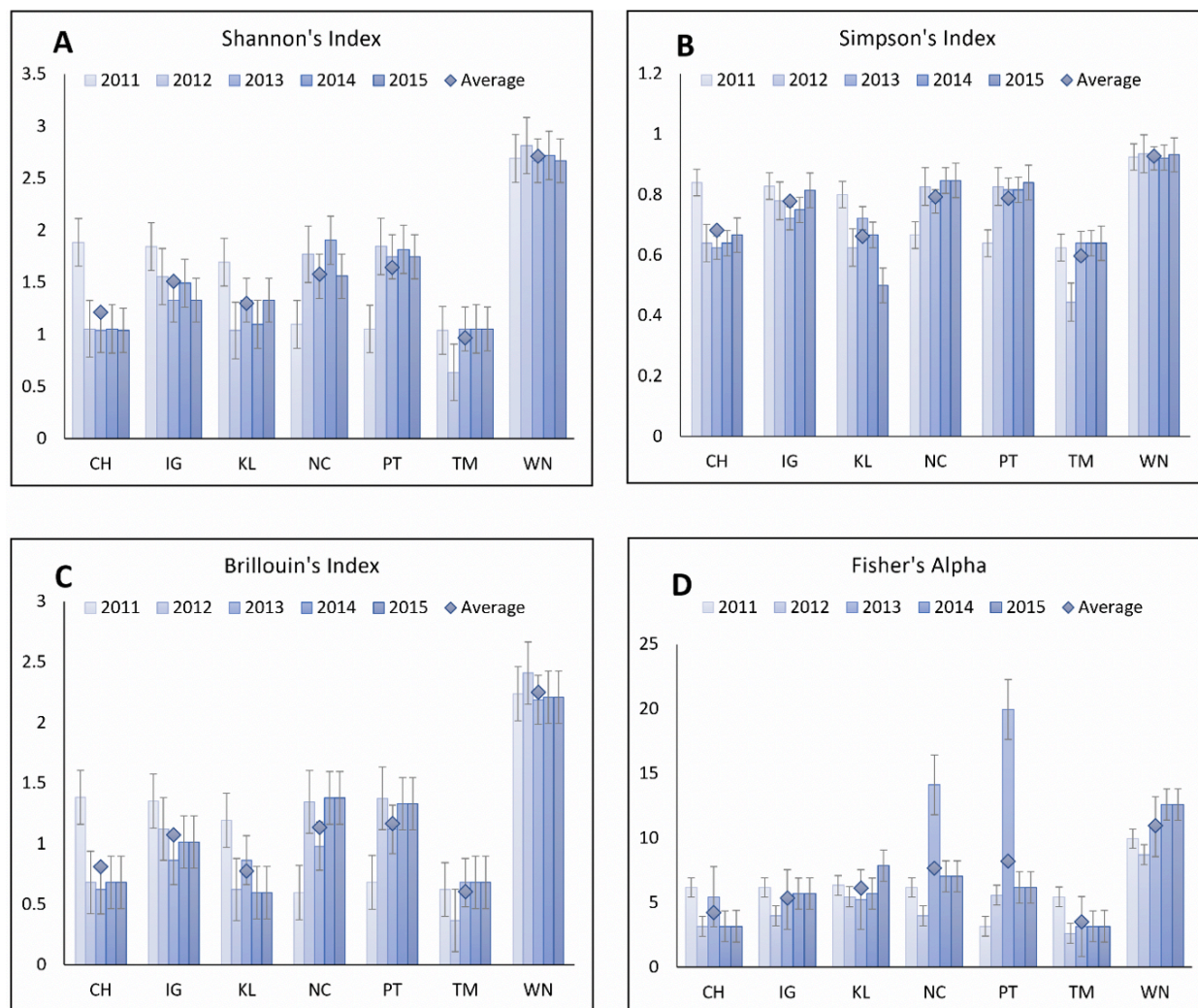


Figure 5. Alpha diversity indices calculated for seven sampling stations over five years (2011–2015).

was observed at WN and minimum at TM.

Dice's coefficient and Jaccard's Similarity index were used to assess beta diversity indices. Beta diversity is used to compare the similarity between two sampling points. The value for beta diversity always lies between 0 and 1, and the level of similarity increases with an increase in value. The sampling points where the value is 0 indicate no common species between those sampling points. On the other hand, when the value is 1, all the species were shared by both sampling points. The maximum value was calculated for TM and PT (1) as both the sampling stations shared all the species. Further, minimum values for Dice's coefficient and Jaccard's similarity index were between WN & TM, PT & NC (Dice's coefficient = 0.2857; Jaccard's Similarity Index = 1.666) (Figure 6, 7). It is also clear from the figure that there was no difference in the pattern; only the values of the indices varied slightly.

In the present study, the seasonality of moths was

also observed. It is quite conspicuous from Figure 8 that moth abundance is maximum during monsoon. During summers, almost the majority of species are not found except *Nephele hespera* (Fabricius, 1775), *Agrius convolvuli* (Linnaeus, 1758), and *Psilogramma vates* (Butler, 1875). However, all these individuals were observed at almost the summer's end and the monsoon's beginning. In winters, moth abundance was observed but not as much as during the monsoon. The probable reason for high moth abundance during monsoon could be the conducive environment created at the time. The temperatures decrease with an increase in relative humidity, which favours moths.

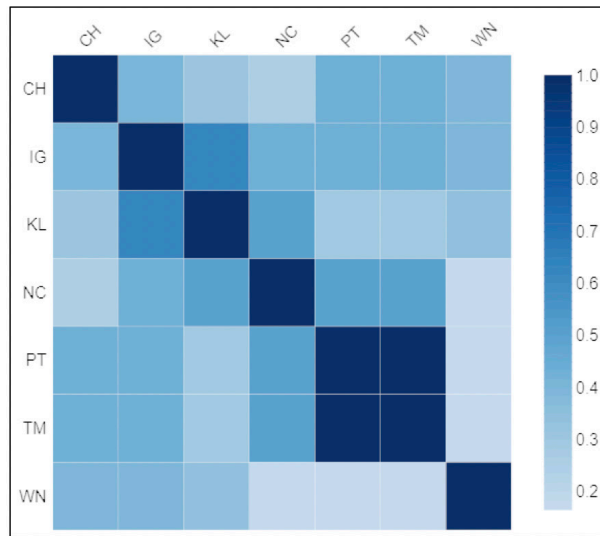


Figure 6. Heatmap for Jaccard's similarity index.

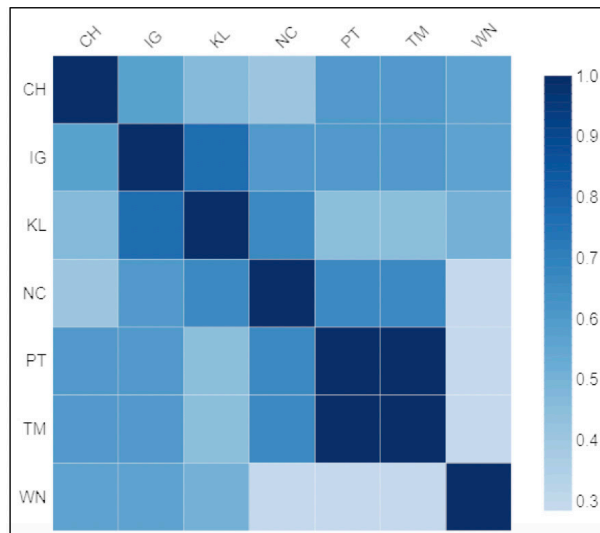


Figure 7. Heatmap for Dice's coefficient.

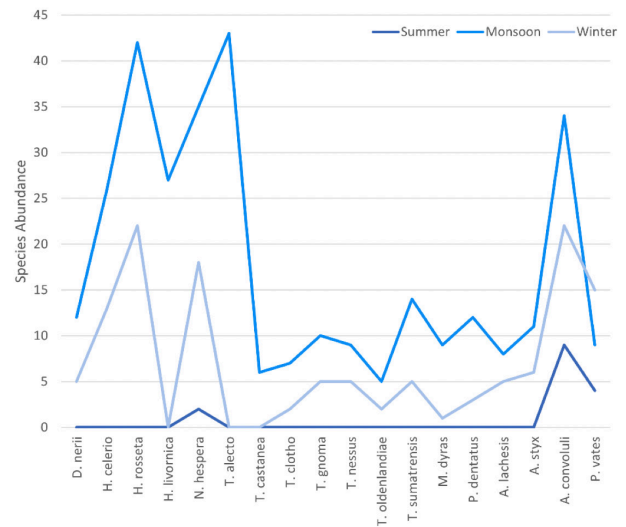


Figure 8. Seasonality in moth distribution.

natural history information of the moths and reinforce the need for further research on ecological and taxonomic consequences of differences in the seasonal activity. Complete knowledge of the distribution patterns of the individual species helps expound the reasons for species' availability in a peculiar area. When such results are combined with other ecological parameters, a comprehensive database is created. Such complex knowledge further helps in devising conservational strategies. Comprehensive knowledge and stepwise incorporations of the natural history information would lead to a deeper understanding of the complex dynamics of any ecological niche. Moreover, we cannot conserve what we do not know. Thus, we suggest extensive taxonomic studies involving periodic assessments and statistical analysis to monitor the diversity patterns, which would help devise customized conservational strategies for different localities.

## CONCLUSION

Alpha diversity indices strongly support that high hawkmoth diversity is observed in the northern Western Ghats. However, there is variation in the moth availability at different sampling stations, reinforcing the knowledge that these organisms are sensitive to changes and can be used as flagships. It was conspicuous that the moth availability showed seasonal variations, and maximum diversity was observed during monsoon.

We strongly recommend monitoring the moth diversity throughout the year for a prolonged duration. These data inputs would elaborate the knowledge of

## REFERENCES

- Abang, F. & C. Karim (2000). The larger moths (Lepidoptera: Heterocera) of the Crocker Range National Park, Sabah: a preliminary checklist. A scientific journey through Borneo: the Crocker Range National Park, Sabah: natural ecosystem and species components. *ASEAN Academic Press, London* 147–56. <http://www.arbec.com.my/pdf/art18julysep02.pdf>
- Balasubramanian, A. (2017). *Biodiversity profile of India*. Report Submitted to Centre for Advanced Studies in Earth Science University of Mysore, Mysore, 11 pp.
- Ballesteros-Mejia, L., I.J. Kitching, W. Jetz & J. Beck (2017). Putting insects on the map: Near-global variation in sphingid moth richness along spatial and environmental gradients. *Ecography* 40(6): 698–708. <https://doi.org/10.1111/ecog.02438>



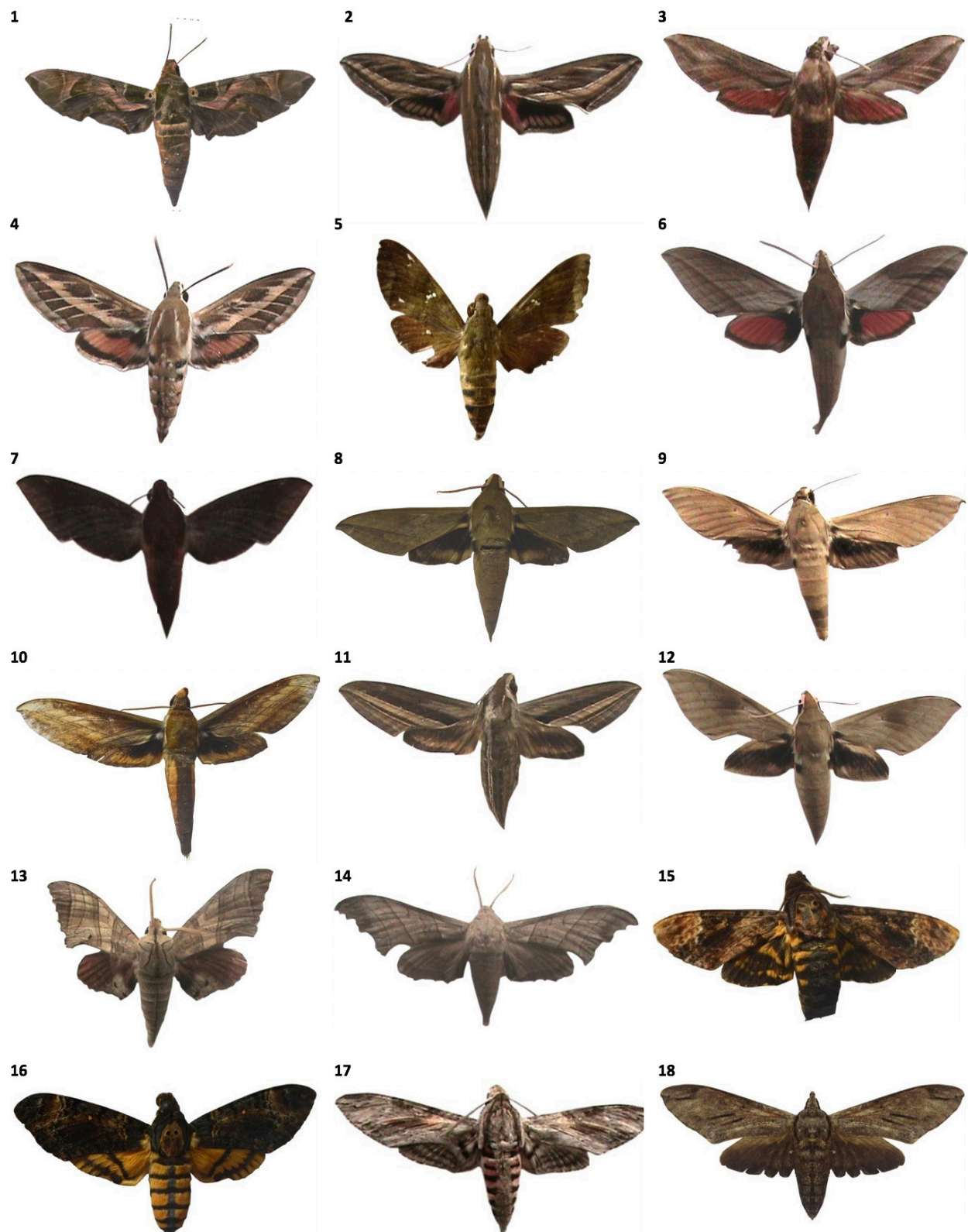


Image 2. 1—*Daphnis nerii* | 2—*Hippotion celerio* | 3—*Hippotion rosseta* | 4—*Hyles livornica* | 5—*Nephele hespera* | 6—*Theretra alecto* | 7—*Theretra castanea* | 8—*Theretra clotho* | 9—*Theretra gnoma* | 10—*Theretra nessus* | 11—*Theretra oldenlandiae* | 12—*Theretra sumatrensis* | 13—*Marumba dyas* | 14—*Polyptychus dentatus* | 15—*Acherontia Lachesis* | 16—*Acherontia styx* | 17—*Agrius convolvuli* | 18—*Psilogramma vates*.

- Barlow, H.S. (1982). *An introduction to the Moths of South-East Asia*. Malayan Nature Society, Malaysia, 305 pp.
- Barrantes, G. & L. Sandoval (2009). Conceptual and statistical problems associated with the use of diversity indices in ecology. *International Journal of Tropical Biology* 57(3): 451–460. <https://doi.org/10.15517/rbt.v57i3.5467>
- Bell, T.R. & L.F.B. Scott (1937). *The Fauna of British India, including Ceylon and Burma. Moths, Vol. 5, Sphingidae*. Taylor & Francis, United Kingdom, 537 pp.
- Brehm, G. & J. Axmacher (2006). A comparison of manual and automatic moth sampling methods (Lepidoptera: Arctiidae, Geometridae) in a rain forest in Costa Rica. *Entomological Society of America* 35(3): 757–764. <https://doi.org/10.1603/0046-225X-35.3.757>
- Chandra, K., J. Kumar, S. Sambath & B. Mitra (2014). A catalogue of the hawk-moths of India (Lepidoptera: Sphingidae). *Bionotes* 16(2): 37–47.
- Chandra, K., R. Pandey, R. Bhandari & S. Sambath (2013). Diversity of hawk moths (Lepidoptera: Sphingidae) in Veerangana Durgavati Wildlife Sanctuary, Damoh, Madhya Pradesh. *Biological Forum* 5(1): 73–77.
- Chapman, A.D. (2009). *Numbers of Living Species in Australia and the World* (2<sup>nd</sup> ed.) A Report for the Australian Biological Resources Study September 2009. Australian Biodiversity Information Services, Toowoomba. Downloaded on 27 July 2017. <http://www.environment.gov.au/node/13866>
- Chen, I.C., H.J. Shiu, S. Benedick, J.D. Holloway, V.K. Chey, H.S. Barlow, J.K. Hill & C.D. Thomas (2009). Elevation increases in moth assemblages over 42 years on a tropical mountain. *Proceedings of the National Academy of Sciences of the United States of America* 106(5): 1479–1483. <https://doi.org/10.1073/pnas.0809320106>
- Cho, S., A. Mitchell, C. Mitter, J. Regier, M. Matthews & R. Robertson (2008). Molecular phylogenetics of heliothine moths (Lepidoptera: Noctuidae: Heliothinae), with comments on the evolution of host range and pest status. *Systematic Entomology* 33(4): 581–594. <https://doi.org/10.1111/j.1365-3113.2008.00427.x>
- Cotes, E.C. & C.C. Swinhoe (1889). *A Catalogue of Moths of India. Part I–VI: Sphinges, Bombyces, Noctues, Pseudo-Deltoids and Deltoids, Geometrites, Pyrales, Crambites, Tortrices and Addenda*. Orders of trustees of Indian Museum, Calcutta, India, 40 pp.
- Danaher, M.W., C. Ward, L.W. Zettler & C.V. Covell (2019). Pollinia Removal and Suspected Pollination of the Endangered Ghost Orchid, *Dendrophylax lindenii* (Orchidaceae) by Various Hawk Moths (Lepidoptera: Sphingidae): Another Mystery Dispelled. *Florida Entomologist* 102(4): 671–683. <https://doi.org/10.1653/024.102.0401>
- Eisikowitch, D. & J. Galil (1971). Effect of Wind on the Pollination of *Pancreatium maritimum* L. (Amaryllidaceae) by Hawkmoths (Lepidoptera: Sphingidae). *Journal of Animal Ecology* 40(3): 673–678. <https://doi.org/10.2307/3444>
- 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>
- Hampson, G.F. (1892). *The Fauna of British India including Ceylon and Burma, Moths volume 1*. Taylor and Francis, London, United Kingdom, 527 pp.
- Hardwick, D.F. (1972). The influence of temperature and moon phase on the activity of the Noctuid moths. *The Canadian Entomologist* 104(11): 1767–1770.
- Haruta, T. (1992). Sphingidae, pp. 83–92. In: Haruta, T. (ed.). *Moths of Nepal, Part 1. Tinea Vol. 13 (Supplement 2)*. The Japanese Heterocerists' Society, Tokyo. i–xvii, 1–122 pp., 1–32 pls.
- Haruta, T. (1994). Sphingidae, pp. 154–158. In: Haruta, T. (ed.). *Moths of Nepal, Part 3. Tinea Vol. 14 (Supplement 1)*. The Japanese Heterocerists' Society, Tokyo. i–xvii, 1171 pp., 65–96 pls.
- Haruta, T. (1995). Sphingidae, pp. 89. In: Haruta, T. (ed.). *Moths of Nepal, Part 4. Tinea Vol. 14 (Supplement 2)*. The Japanese Heterocerists' Society, Tokyo, i–xviii, 206 pp., 97–128 pls.
- Holloway, J.D. (1987). *The Moths of Borneo: Part 3; Laciocampidae, Eupterotidae, Bombycidae, Brahmaedidae, Saturniidae, Shingidae*. Malayan Nature Society, Kuala Lumpur (Southdene), Malaysia, 199 pp.
- Inoue, H., R.D. Kennett & I.J. Kitching (1997). *Moths of Thailand. Vol. 2 (Sphingidae)*. Brothers of St. Gabriel in Thailand, Bangkok, 149 pp.
- Iyer, G. & I.J. Kitching (2019). A preliminary study of the hawkmoth diversity (Lepidoptera: Sphingidae) of Kanyakumari District, Tamil Nadu, India. *Journal of Threatened Taxa* 11(5): 13592–13604. <https://doi.org/10.11609/JOTT.4694.11.5.13592-13604>
- Janzen, D.H., W. Hallwachs, P. Blandin, J.M. Burns, J.M. Cadiou, I. Chacon, T. Dapkey, A.R. Deans, M.E. Epstein, B. Espinoza, J.G. Franclemont, W.A. Haber, M. Hajibabaei, J.P.W. Hall, P.D.N. Hebert, I.D. Gauld, D.J. Harvey, A. Hausmann, I.J. Kitching & J.J. Wilson (2009). Integration of DNA barcoding into an ongoing inventory of complex tropical biodiversity. *Molecular Ecology Resources* 9(1): 1–26. <https://doi.org/10.1111/j.1755-0998.2009.02628.x>
- Joicey, J.J. & W.J. Kaye (1917). XXXIV.—New species and forms of Sphingidae. *Annals and Magazine of Natural History* 20(118): 305–309.
- Kendrick, R.C. (2002). Moths (Insecta: Lepidoptera) of Hong Kong. PhD Thesis. University of Hong Kong, Xavi+660pp.
- Kitching, I.J., R.C. Kendrick & P. Smetacek (2014). A list of Hawkmoth Species (Lepidoptera: Sphingidae) of India, Nepal, Bhutan and Sri Lanka Including their Common Names. Downloaded on 1 June 2021. [http://flutters.org/home/docs/Hawkmoths\\_of\\_India\\_et\\_al.pdf](http://flutters.org/home/docs/Hawkmoths_of_India_et_al.pdf)
- Macgregor, C.J., M.J.O. Pocock, R. Fox & D.M. Evans (2015). Pollination by nocturnal Lepidoptera, and the effects of light pollution: A review. *Ecological Entomology* 40(3): 187–198. <https://doi.org/10.1111/een.12174>
- Madden, A.H. (1944). The external morphology of the adult Tobacco Hornworm (Lepidoptera, Sphingidae). *Annals of the Entomological Society of America* 37(2): 145–160. <https://doi.org/10.1093/aesa/37.2.145>
- Magurran, A.E. (1988). Choosing and interpreting diversity measures, pp. 61–80. In: Magurran, A.E. *Ecological Diversity and Its Measurement*. Princeton University Press, New Jersey, United States of America, 179 pp. [https://doi.org/10.1007/978-94-015-7358-0\\_4](https://doi.org/10.1007/978-94-015-7358-0_4)
- McGeachie, W.J. (1989). The effects of moonlight illuminance, temperature and wind speed on light-trap catches of moths. *Bulletin of Entomological Research* 79(2): 185–192. <https://doi.org/10.1017/S0007485300018162>
- McKnight, T.L. & D. Hess (2017). Climate and climate change: climate classification, 206–226. In: McKnight, T.L. & D. Hess (12<sup>th</sup> ed.) *Physical geography: a landscape appreciation* Pearson Education, Inc. United States of America, 688 pp.
- Melichar, T., J. Haxaire, M. Řezáč & H.B. Manjunatha (2018). A field guide to hawkmoths (Lepidoptera: Sphingidae) of the State of Karnataka India. *Ekologické Centrum Orlov* 1–110.
- Misof, B., S. Liu, K. Meusemann, R.S. Peters, T. Flouri, R.G. Beutel, O. Niehuis & M. Petersen (2014). Phylogenomics resolves the timing and pattern of insect evolution. *Science* 346(6210): 763–768. <https://doi.org/10.1126/science.1257570>
- Mittelbach, G.G., D.W. Schemske, H.V. Cornell, A.P. Allen, J.M. Brown, M.B. Bush, S.P. Harrison, A.H. Hurlbert, N. Knowlton, H.A. Lessios, C.M. McCain, A.R. McCune, L.A. McDade, M.A. McPeck, T.J. Near, T.D. Price, R.E. Ricklefs, K. Roy, D.F. Sax & M. Turelli (2007). Evolution and the latitudinal diversity gradient: speciation, extinction and biogeography. *Ecology Letters* 10(4): 315–331. <https://doi.org/10.1111/j.1461-0248.2007.01020.x>
- Murugan, K. (2006). Biodiversity of insects. *Current Science* 91(12): 1602–1603.
- Nilsson, L.A., L. Jonsson, L. Rason & E. Randrianjohany (1985). Monophily and pollination mechanisms in *Angraecum arachnites* Schltr. (Orchidaceae) in a guild of long-tongued hawkmoths (Sphingidae) in Madagascar. *Biological Journal of the Linnean Society* 26(1): 1–19. <https://doi.org/10.1111/j.1095-8312.1985.tb01549.x>
- Pathania, P., S. Sharma & A. Gill (2014). Hawk moths (Lepidoptera: Sphingidae) from North-West Himalaya along with collection housed



- in National PAU Insect museum, Punjab Agricultural University. *Biological Forum* 6(1): 120–127. <http://search.proquest.com/openview/63b8d69e0c96d9c4236a3435dbbc4ccc/1?pq-origsite=gscholar>
- Patil, R.R., K. Ghorepade & M. Chandaragi (2013). Notes on Hawk Moths (Lepidoptera—Sphingidae) in the Karwar-Dharwar transect, peninsular India: a tribute to TRD Bell (1863–1948). *Colemania* 33: 1–16. <http://indiabiodiversity.org/biodiv/content/documents/623.pdf>
- Ratnasingham, S. & P.D.N. Hebert (2007). Barcoding, BOLD: The Barcode of Life Data System ([www.barcodinglife.org](http://www.barcodinglife.org)). *Molecular Ecology Notes* 7: 355–364. <https://doi.org/10.1111/j.1471-8286.2006.01678.x>
- Reddy, G.V.P., Z.T. Cruz, J. Bamba & R. Muniappan (2005). Host adaptation of the fruit piercing moth, *Eudocima fullonia*. *Physiological Entomology* 30(4): 398–401.
- Roonwal, M.L. & R.S. Thapa (1963). Lepidoptera (contd.) Suborder Heteroneura— (Contd.), Superfamily Sphingoidea (Family Sphingidae), pp. 455–463. In Systematic Catalogue of the main identified entomological collection at the Forest Research Institute, Dehra Dun. Parts 22–38. Orders Neuroptera, Mecoptera, Trichoptera and Lepidoptera. *Indian Forester* 121(4): 189–540.
- Rougerie, R., I.J. Kitching, J. Haxaire, S.E. Miller, A. Hausmann & P.D. Hebert (2014). Australian Sphingidae—DNA barcodes challenge current species boundaries and distributions. *PloS one* 9(7): e101108.
- Sambath, S. (2011). Studies on the Sphingid fauna (Lepidoptera: Heterocera:Sphingidae) of Dalma Wildlife Sanctuary, Jharkhand. *Records of the Zoological Survey of India* 111(1): 25–30.
- Shere, A.A. (2018). Taxonomical study of family Sphingidae and Noctuidae (Lepidoptera: Heterocera) using DNA barcoding from Nashik district. PhD Thesis. Savitribai Phule Pune University, University of Hong Kong, viii+173pp.
- 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., J. Ahmad & K. Chandra (2021). An updated checklist of Sphingidae (Lepidoptera) from Great Nicobar Island with a new species record from India. *Records of the Zoological Survey of India* 121(3): 375–381. <https://doi.org/10.26515/rzsi/v121/i3/2021/157648>
- Smetacek, P. & I.J. Kitching (2012). The hawkmoths of Ladakh, Jammu & Kashmir, India (Lepidoptera: Sphingidae). *Nachrichten des Entomologischen Vereins Apollo (NF)* 32: 113–115.
- Sondhi, Y., I.J. Kitching, D.N. Basu & K. Kunte (2017). A new species of *Theretra* Hübner (Lepidoptera: Sphingidae) from the southern Western Ghats, India. *Zootaxa* 4323(2): 185–196. <https://doi.org/10.11646/zootaxa.4323.2.2>
- Sperling, F.A.H., G.S. Anderson & D.A. Hickey (1994). A DNA-Based Approach to the Identification of Insect Species Used for Postmortem Interval Estimation. *Journal of Forensic Science* 39(2): 418–427.
- Srivastava, A. (2002). *Taxonomy of moths in India*. International Book Distributors, Dehradun, India, 334 pp.
- Subalakmi, V. (2008). New record of hawkmoth *Sataspes tangalica* L. Hauxwellii (Lepidoptera: Sphingidae) from Sanjay Gandhi National Park, Mumbai, India. *Journal of Bombay Natural History Society* 105(2): 226–227.
- Thomas, J.A. (2005). Monitoring change in the abundance and distribution of insects using butterflies and other indicator groups. *Philosophical Transactions of the Royal Society B: Biological Sciences* 360(1454): 339–357. <https://doi.org/10.1098/rstb.2004.1585>
- van Nieukerken, E.J., L. Kaila, I.J. Kitching, N.P. Kristensen, D.C. Lees, J. Minet, C. Mitter, M. Mutanen, J.C. Regier, T.J. Simonsen, N. Wahlberg, S.H. Yen, R. Zahiri, D. Adamski, J. Baixeras, D. Bartsch, B.Å. Bengtsson, J.W. Brown & A. Zwick (2011). Order Lepidoptera Linnaeus, 1758. In: Zhang, Z.-Q. (Ed.) *Animal biodiversity: An outline of higher-level classification and survey of taxonomic richness*. *Zootaxa* 3148(1): 212. <https://doi.org/10.11646/zootaxa.3148.1.41>
- Wilson, J.J., R. Rougerie, J. Schonfeld, D.H. Janzen, W. Hallwachs, M. Hajibabaei, I.J. Kitching, J. Haxaire & P.D. Hebert (2011). When species matches are unavailable are DNA barcodes correctly assigned to higher taxa? An assessment using sphingid moths. *BMC Ecology* 11(1): 1–14.
- Yela, J.L. & M. Holyoak (1997). Effects of moonlight and other meteorological factors on light and bait trap catches of Noctuid Moths (Lepidoptera: Noctuidae). *Environmental Entomology* 26(6): 1283–1290. <https://doi.org/10.1093/ee/26.6.1283>





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. Lionel 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 Dhabi, UAE.  
Prof. Dr. Wayne J. Fuller, Near East University, Mersin, Turkey  
Prof. Chandrashekhar 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, SAGON, 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 Sunde, 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. M. Zafar-ul Islam, Prince Saud Al Faisal Wildlife Research Center, Taif, Saudi Arabia

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, SAGON, 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, SAGON, Anaikatty P.O., Coimbatore, Tamil Nadu, India  
Dr. Nishith Dharaia, 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, Tiruchirappalli, 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 2019–2021

Due to pausity of space, the list of reviewers for 2018–2020 is available online.

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, 5<sup>th</sup> Street West, Ganapathy, Coimbatore,  
Tamil Nadu 641035, India  
ravi@threatenedtaxa.org

**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





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](http://www.threatenedtaxa.org). All articles published in JoTT are registered under [Creative Commons Attribution 4.0 International License](https://creativecommons.org/licenses/by/4.0/) unless otherwise mentioned. JoTT 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)

November 2022 | Vol. 14 | No. 11 | Pages: 22039-22206

Date of Publication: 26 November 2022 (Online & Print)

DOI: 10.11609/jott.2022.14.11.22039-22206

[www.threatenedtaxa.org](http://www.threatenedtaxa.org)

## Communications

**New records of pteridophytes in Mount Matutum Protected Landscape, South Central Mindanao, Philippines with notes on its economic value and conservation status**

– Christine Dawn Galope-Obemio, Inocencio E. Buot Jr. & Maria Celeste Banaticla-Hilario, Pp. 22039–22057

**Some threatened woody plant species recorded from forests over limestone of the Philippines**

– Inocencio E. Buot Jr., Marne G. Origenes, Ren Divien R. Obeña, Elaine Loreen C. Villanueva & Marjorie D. delos Angeles, Pp. 22058–22079

**Status of mangrove forest in Timaco Mangrove Swamp, Cotabato City, Philippines**

– Cherie Cano-Mangaoang, Zandra Caderon Amino & Baingan Brahmin Mastur, Pp. 22080–22085

**A comparative analysis of the past and present occurrences of some species of *Paphiopedilum* (Orchidaceae) in northeastern India using MaxEnt and GeoCAT**

– Debonina Dutta & Aparajita De, Pp. 22086–22097

**Foraging activity and breeding system of *Avicennia officinalis* L. (Avicenniaceae) in Kerala, India**

– K. Vinaya & C.F. Binoy, Pp. 22098–22104

**Diversity patterns and seasonality of hawkmoths (Lepidoptera: Sphingidae) from northern Western Ghats of Maharashtra, India**

– Aditi Sunil Shere-Kharwar, Sujata M. Magdum, G.D. Khedkar & Supriya Singh Gupta, Pp. 22105–22117

**Population trends of Mugger Crocodile and human-crocodile interactions along the Savitri River at Mahad, Maharashtra, India**

– Utkarsha Manish Chavan & Manoj Ramakant Borkar, Pp. 22118–22132

**Paresis as a limiting factor in the reproductive efficiency of a nesting colony of *Lepidochelys olivacea* (Eschscholtz, 1829) in La Escobilla beach, Oaxaca, Mexico**

– Alejandra Buenrostro-Silva, Jesús García-Grajales, Petra Sánchez-Nava & María de Lourdes Ruiz-Gómez, Pp. 22133–22138

**Notes on the nesting and foraging behaviours of the Common Coot *Fulica atra* in the wetlands of Viluppuram District, Tamil Nadu, India**

– M. Pandian, Pp. 22139–22147

**Population abundance and threats to Black-headed Ibis *Threskiornis melanocephalus* and Red-naped Ibis *Pseudibis papillosa* at study sites in Jhajjar district, Haryana, India**

– Anjali & Sarita Rana, Pp. 22148–22155

**Crop raiding and livestock predation by wildlife in Khaptad National Park, Nepal**

– Ashish Bashyal, Shyam Sharma, Narayan Koirala, Nischal Shrestha, Nischit Aryal, Bhupendra Prasad Yadav & Sandeep Shrestha, Pp. 22156–22163

## Review

**An annotated checklist of odonates of Amboli-Chaukul-Parpoli region showing new records for the Maharashtra State, India with updated state checklist**

– Dattaprasad Sawant, Hemant Ogale & Rakesh Mahadev Deulkar, Pp. 22164–22178

## Short Communications

**The new addition of Blue Pimpernel of Primulaceae to the state flora of Assam, India**

– Sushmita Kalita, Barnali Das & Namita Nath, Pp. 22179–22183

**A new species of genus *Neocerura* Matsumura, 1929 (Notodontidae: Lepidoptera) from India**

– Amritpal Singh Kaleka & Rishi Kumar, Pp. 22184–22189

**Rediscovery of an interesting preying mantis *Deiphobella laticeps* (Mantodea: Rivetiniidae) from Maharashtra, India**

– Gauri Sathaye, Sachin Ranade & Hemant V. Ghate, Pp. 22190–22194

**Camera trapping records confirm the presence of the elusive Spotted Linsang *Prionodon pardicolor* (Mammalia: Carnivora: Prionodontidae) in Murlen National Park (Mizoram, India)**

– Amit Kumar Bal & Anthony J. Giordano, Pp. 22195–22200

## Notes

**First sighting record of the Orange-breasted Green-Pigeon *Treron bicinctus* (Aves: Columbiformes: Columbidae) from Chittaranjan, West Bengal, India**

– Shahbaz Ahmed Khan, Nazneen Zehra & Jamal Ahmad Khan, Pp. 22201–22202

## Book Reviews

**Decoding a group of winged migrants!**

– Review by Priyanka Iyer, Pp. 22203–22204

**First steps of citizen science programs in India**

– Review by Aishwarya S. Kumar & Lakshmi Nair, Pp. 22205–22206

Publisher & Host

