



40 **zoo**reach
Zoo Outreach Organisation
Years

Open Access



Building evidence for conservation globally
**Journal of
Threatened
Taxa**

10.11609/jott.2026.18.2.28263-28454
www.threatenedtaxa.org

26 February 2026 (Online & Print)
18(2): 28263-28454
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

Host
Zoo Outreach Organization
www.zooreach.org

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

EDITORS

Founder & Chief Editor

Dr. Sanjay Molur

Wildlife Information Liaison Development (WILD) Society & Zoo Outreach Organization (ZOO),
Coimbatore, Tamil Nadu 641006, India

Assistant Editor

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

Managing Editor

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

Associate Editors

Dr. Mandar Paingankar, Government Science College Gadchiroli, Maharashtra 442605, India

Dr. Ulrike Streicher, Wildlife Veterinarian, Eugene, Oregon, USA

Ms. Priyanka Iyer, ZOO/WILD, Coimbatore, Tamil Nadu 641006, India

Board of Editors

Dr. Russel Mittermeier

Executive Vice Chair, Conservation International, Arlington, Virginia 22202, USA

Prof. Mewa Singh Ph.D., FASC, FNA, FNASC, FNAPsy

Ramanna Fellow and Life-Long Distinguished Professor, Biopsychology Laboratory, and
Institute of Excellence, University of Mysore, Mysuru, Karnataka 570006, India; Honorary
Professor, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore; and Adjunct
Professor, National Institute of Advanced Studies, Bangalore

Stephen D. Nash

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

Dr. Fred Pluthero

Toronto, Canada

Dr. Priya Davidar

Sigur Nature Trust, Chadapatti, Mavinhalla PO, Nilgiris, Tamil Nadu 643223, India

Dr. John Fellowes

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

Prof. Dr. Mirco Solé

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

Dr. Rajeev Raghavan

Professor of Taxonomy, Kerala University of Fisheries & Ocean Studies, Kochi, Kerala, India

English Editors

Mrs. Mira Bhojwani, Pune, India

Dr. Fred Pluthero, Toronto, Canada

Copy Editors

Ms. Usha Madgunaki, Zooreach, Coimbatore, India

Ms. Trisa Bhattacharjee, Zooreach, Coimbatore, India

Ms. Paloma Noronha, Daman & Diu, India

Web Development

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

Typesetting

Mrs. Radhika, Zooreach, Coimbatore, India

Mrs. Geetha, Zooreach, Coimbatore, India

Fundraising/Communications

Mrs. Payal B. Molur, Coimbatore, India

Subject Editors 2021–2023

Fungi

Dr. B. Shivaraju, Bengaluru, Karnataka, India

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

Dr. Vatsavaya S. Raju, 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

Dr. Kiran Ramchandra Ranadive, Annasaheb Magar Mahavidyalaya, Maharashtra, India

Plants

Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India

Dr. N.P. Balakrishnan, Ret. Joint Director, BSI, Coimbatore, India

Dr. Shonil Bhagwat, Open University and University of Oxford, UK

Prof. D.J. Bhat, Retd. Professor, Goa University, Goa, India

Dr. Ferdinando Boero, Università del Salento, Lecce, Italy

Dr. Dale R. Calder, Royal 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, 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. Karthigeeyan, 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 Baños, 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. Warriar, Institute of Forest Genetics and Tree Breeding, Tamil Nadu, India

Invertebrates

Dr. R.K. Avasthi, Rohtak University, Haryana, India

Dr. D.B. Bastawade, Maharashtra, India

Dr. Partha Pratim Bhattacharjee, Tripura University, Suryamaninagar, India

Dr. Kailash Chandra, Zoological Survey of India, Jabalpur, Madhya Pradesh, India

Dr. Ansie Dippenaar-Schoeman, University of Pretoria, Queenswood, South Africa

Dr. Rory Dow, National Museum of Natural History Naturalis, The Netherlands

Dr. Brian Fisher, California Academy of Sciences, USA

Dr. Richard Gallon, Llandudno, North Wales, LL30 1UP

Dr. Hemant V. Ghate, Modern College, Pune, India

Dr. M. Monwar Hossain, Jahangirnagar University, Dhaka, Bangladesh

For Focus, Scope, Aims, and Policies, visit https://threatenedtaxa.org/index.php/JoTT/aims_scope

For Article Submission Guidelines, visit <https://threatenedtaxa.org/index.php/JoTT/about/submissions>

For Policies against Scientific Misconduct, visit https://threatenedtaxa.org/index.php/JoTT/policies_various

continued on the back inside cover

Cover: Digital illustration of *Impatiens chamchumroonii* in Krita by Dupati Poojitha.



Floristic composition and conservation significance of vascular plants in Kalatop-Khajjjar Wildlife Sanctuary, Himachal Pradesh, India

Sumit¹, Gulshan Kumar², Sumit Singh³, Kanwaljeet Singh⁴, Taslima Sheikh⁵, P. Vishal Ahuja⁶ & Arvind Kumar⁷

¹Department of Botany, Govt. College Chamba, Himachal Pradesh 176314, India.

²Department of Botany, Career Point University, Hamirpur, Himachal Pradesh 176041, India.

³CSIR–Northeast Institute of Science and Technology, Jorhat, Assam 785006, India.

⁴Department of Education in Science and Mathematics, Regional Institute of Education, NCERT, Mysuru, Karnataka 570006, India.

⁵Citizen Science Expert, Inspire Foundation Trust, Baraura Hussain, Bari Balaganj, Lucknow, Uttar Pradesh 226003, India.

⁶Zoo Outreach Organisation, 3A2 Varadarajulu Nagar, FCI Road, Ganapathy, Coimbatore, Tamil Nadu 641006, India.

⁷Department of Botany, G.G.M Science College, Canal Road, Jammu 180001, India.

¹suminrankari@gmail.com, ²sharmagulshan1980@gmail.com, ³ssumitthakur14@gmail.com (corresponding author),

⁴botanistkanwal64@gmail.com, ⁵sheikhtass@gmail.com (corresponding author), ⁶vishal@zooreach.org, ⁷arvindkumarbotany@gmail.com

Abstract: Kalatop–Khajjjar Wildlife Sanctuary represents one of the ecologically significant forested landscapes of the northwestern Himalaya; however, updated and systematic documentation of its vascular flora has remained limited. In view of increasing anthropogenic pressures and climate variability, a comprehensive floristic survey was undertaken during 2023–2025 to assess the plant diversity and conservation status of the sanctuary. A total of 141 plant species representing 112 genera and 53 families were recorded. Out of these, 136 species belonged to angiosperms and five species to gymnosperms. Among dicotyledons, Asteraceae was the most dominant family, with 24 species. Among the monocotyledons, Orchidaceae was the most dominant family, with five species. The study area is dominated by native species, and only 9.93% of species were alien. The sanctuary hosts ten endangered plant species, including *Taxus contorta* and *Lilium polyphyllum*. The findings highlight the sanctuary as a reservoir of native and threatened plant diversity in the western Himalaya. The recorded baseline data serve as critical resources for biodiversity assessment, habitat management, and conservation strategy development. It is imperative to reinforce protective measures and support long-term ecological monitoring to safeguard this fragile ecosystem against emerging environmental challenges.

Keywords: Altitude gradient, angiosperms, conservation, endangered, endemism, flora, Himalayan plants, native, protected areas, threatened.

कलाटोप-खज्जियार वाइल्डलाइफ सैंक्चुअरी, उत्तर-पश्चिमी हिमालय रा इक बड़ा खास जंगली इलाका है, हालाँकि, इसदी संवहनी बूटियां री नोइ कने व्यवस्थित जानकारी घट है। बददे इंसानी दबाव कने बदलदे मौसमी हालातां जो दिखदे हुए, 2023 का लेई करी 2025 तिक इक बड़ा बड़ा पौध्यां रा सर्वे कीता गया ताकि सैंक्चुअरी रे पौध्यां कने तिना रे संरक्षण रे बारे पता लगी सके। इस अंदर कुल 141 पौध्यां री प्रजातियां, जे कि 112 जेनेरा ते 53 फैमिली कने संबंघित थीयां, दर्ज कीती गईयां। इनां बिच 136 प्रजातियां एंजियोस्पर्म ते पंज प्रजातियां जिन्मोस्पर्म री थीयां। डाइकोटाइलडॉन अंदर, एस्टेरेसी प्रमुख फैमिली थी, जिस अंदर 24 प्रजातियां थीयां। मोनोकोटाइलडॉन अंदर, ऑर्किडेसी प्रमुख फैमिली थी, जिस अंदर पंज प्रजातियां दर्ज कीतियां गईयां। इस इलाके अंदर देसी प्रजातियां ज्यादा हिन, कने सिर्फ 9.93% प्रजातियां बाहरे री थीयां। सैंक्चुअरी अंदर टैक्सस कॉन्टोर्टा कने लिलियम पॉलीफिलम समेत दस प्रजातियां संकटग्रस्त पाई गईयां। इनां नतीजेयां का पता लगदा कि ए सैंक्चुअरी पश्चिमी हिमालय अंदर देसी कने संकटग्रस्त पौध्यां रा खासमखास भंडार है। ए सर्वे इक जरूरी ते खास जानकारी दिन्दा, जिस कने आने वाले कल अंदर जैव विविधता रे मूल्यांकन कने आवास प्रबंधन ते सुरक्षा नीतियां बनाने अंदर मदद होई सकदी। इस नाजुक पारिस्थितिकी तंत्र जो पर्यावरण चुनौतियां का बचाणे तायाँ, बचाव के उपा जो मजबूत करणा कने लंबे समय तायाँ पारिस्थितिक निगरानी जो बढ़ावा देगा बड़ा जरूरी है।

Editor: Afroz Alam, Banasthali Vidyapith, Rajasthan, India.

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

Citation: Sumit, G. Kumar, S. Singh, K. Singh, T. Sheikh, P.V. Ahuja & A. Kumar (2026). Floristic composition and conservation significance of vascular plants in Kalatop-Khajjjar Wildlife Sanctuary, Himachal Pradesh, India. *Journal of Threatened Taxa* 18(2): 28263–28274. <https://doi.org/10.11609/jott.10030.18.2.28263-28274>

Copyright: © Sumit et al. 2026. 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: This research received no external funding.

Competing interests: The authors declare no competing interests.

Author details, Author contributions & Acknowledgements: See end of this article.



zooreach
Zoo Outreach Organisation



INTRODUCTION

A thorough knowledge of the floristic composition of a plant community is essential for understanding the overall structure and function of an ecosystem (Gairola et al. 2010). Even in the present day, floristic research holds significant value, especially in geographic regions with limited knowledge of their flora, within protected areas, and in biodiversity hotspots (Wagensommer 2023). Such studies also help us in understanding the changes that take place in forest plant communities (Lalithalakshmi et al. 2024). Moreover, such data are essential for formulating effective conservation strategies (Wani et al. 2023; Sherafu et al. 2024).

The Indian Himalayan Region (IHR) is one of the most ecologically significant and biologically rich areas in the world. It is globally recognized as a major biodiversity hotspot due to its extraordinary range of climatic conditions and diverse altitude gradients that span from subtropical foothills to alpine and glacial zones (Palni & Rawal 2010; Haq et al. 2023). Covering roughly 18% of India, the Indian Himalayan Region (IHR) stretches over 2,800 km and varies in width from 220–300 km, with its altitudes ranging 200–8,000 m, harbours nearly 8,000 species of flowering plants, about 40% of which are endemic (Samant 2021).

Himachal Pradesh holds a prominent position among the Indian states comprising the IHR, due to its expansive forest cover, rich flora, and diverse habitats. Notably, the Chamba District, which lies in the northwestern part of Himachal Pradesh, is characterized by its rugged terrain, high mountains, and deep valleys. The Chamba District is home to five designated Wildlife Sanctuaries: Gargol Siyabehi, Kalatop-Khajjiar, Kugti, Sech Tuan Nala, and Tundah (Kumar et al. 2018). Despite their ecological significance, these protected areas remain largely underexplored or, in some cases, completely unexplored in terms of their biodiversity and ecological potential. The Kalatop-Khajjiar Wildlife Sanctuary (KKWS) is the smallest sanctuary in the district and is an ecologically sensitive zone known for its scenic beauty and rich plant biodiversity. Khajjiar, 'Mini Switzerland' is a popular tourist destination that welcomes thousands of tourists annually (Verma & Kapoor 2011). This influx of vehicles on a daily basis leads to environmental pollution, posing a growing threat to the sanctuary's diverse flora due to both ecological and human-induced factors. Besides, a variety of abiotic and biotic factors, including pollution, deforestation, over-exploitation of forest resources, habitat destruction or fragmentation, and invasive species, significantly influence the ongoing transformation of

ecosystems (Haq et al. 2023). Consequently, it is essential to periodically update the floristic inventory to achieve a thorough understanding of species interactions within their environment and among themselves. Furthermore, these serve as important indicators of shifts in floristic composition, recent invasions, and the current status of endemic and threatened taxa in a given phytogeographical area (Ravi et al. 2016). Keeping this in view, the current study was conducted to investigate the floral diversity of KKWS. Information pertaining to the floristic diversity of KKWS is scanty. Verma & Kapoor (2011) studied the floristic composition of the Sanctuary. In continuation, the present communication describes and analyses the floristic composition and life forms of KKWS.

MATERIALS AND METHODS

Study area

The KKWS was founded in 1958. It currently spreads over an area of 17.17 km² (Kumar et al. 2014). The altitude ranges 1,850–2,750 m (Kumar et al. 2018). The sanctuary is divided into two blocks – Khajjiar and Lakkarmandi, and six beats – Khajjiar, Khajroth, Talai, Lakkarmandi, Kalatop, and Daikund (Kumar 2020). The area can be categorized into three ecosystems: dense forests of mixed fir, spruce and deodar with oak and rhododendron, a lake meadow-Khajjiar, surrounded on all sides by deodar trees, and a small portion of alpine pasture at the Daikund area. Precipitation is in the form of rain and snow. The temperature ranges from sub-zero in winters to 32 °C in summers. The sanctuary represents the flora of sub temperate to alpine climate (Verma & Kapoor 2011).

Data collection

Extensive field surveys were conducted from 2023–2025 across various growing seasons to collect plant samples and to record data from various geographic locations of the study area. For each species, GPS coordinates (latitude, longitude, and altitude), as well as field data on plant habit, floral morphology, and phenology, along with other data such as date, location, voucher number, information about the flower colour and other features that are lost during pressing, were recorded in the field book. Plants that are uncommon or threatened were thoroughly examined, and data were documented. Digital photos of the collected vouchers were taken to record the presence of specific species in the specified regions. Voucher specimens were processed according to the methodologies outlined by Jain & Rao (1977) in their Herbarium Techniques, which involve pressing, drying,

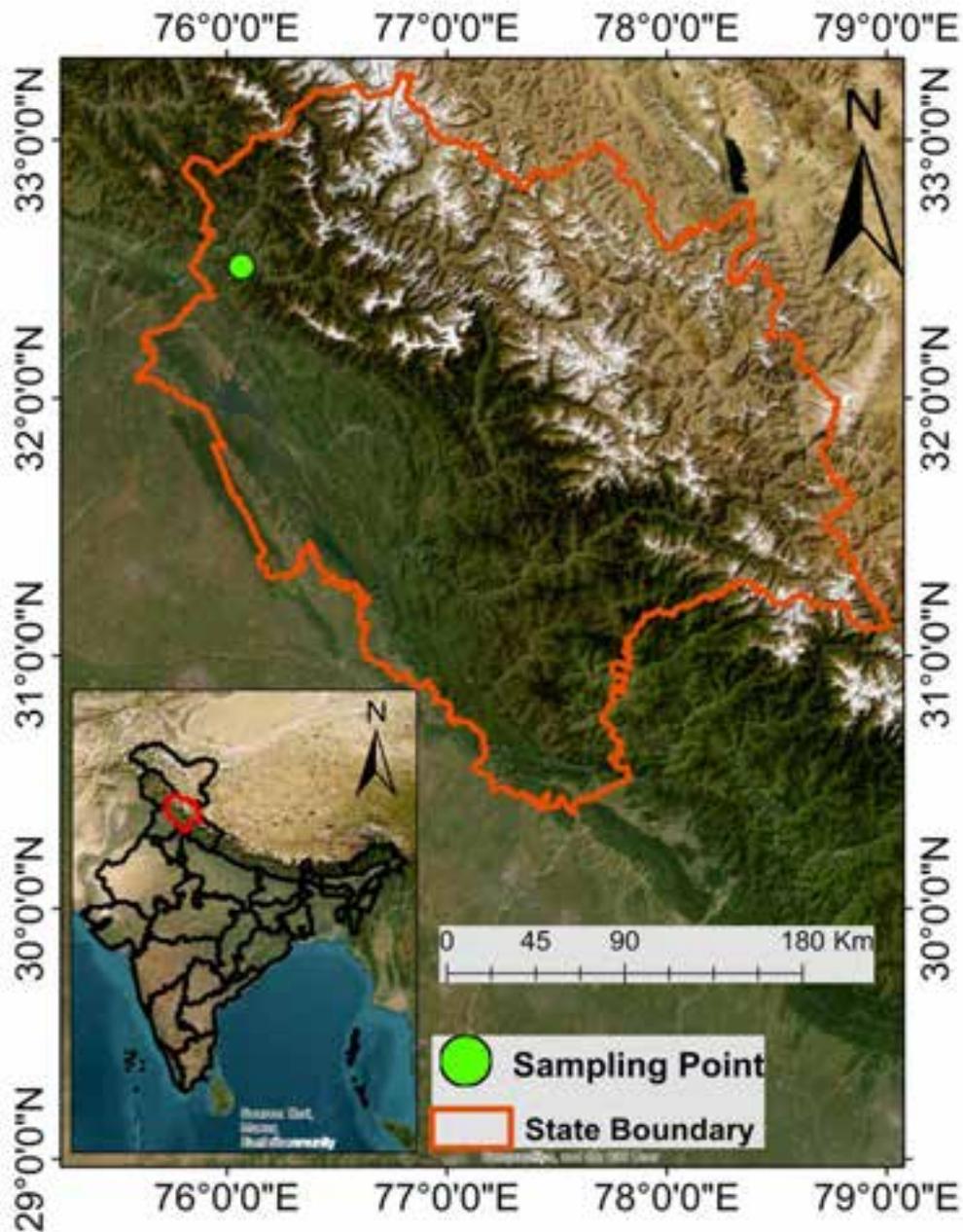


Figure 1. Map of the study area.

applying 1% mercuric chloride solution for preservation, mounting on standard-sized herbarium sheets of 28 x 42 cm, and subsequently stitching and labelling them. The identification of plant species was carried out using local and regional floras, including authoritative references such as Collett (1902); Chowdhery & Wadhwa (1984); Polunin & Stainton (1984); Stainton (1988); Aswal & Mehrotra (1994); Dhaliwal & Sharma (1999); Singh & Sharma (2006), scientific articles and herbarium of Career Point University Hamirpur. The collected plant specimens were deposited at the Herbarium of Career Point University,

Hamirpur. Voucher specimens marked with an asterisk (*) were previously collected and deposited as a part of an earlier ethnomedicinal study in the same area (Sumit et al. 2025). These voucher specimens were included in the current research, and additional information for these species was collected during this investigation. Plant species identified for the first time in the present study were collected, processed, authenticated and assigned new accession numbers.

RESULTS AND DISCUSSION

In the present study, a total of 141 plant species representing 112 genera and 53 families were documented (Table 1 & 3). This constitutes approximately 14.02% of the total flora of the Chamba District and about 4.33% of the overall flora of Himachal Pradesh. Native species dominated (90.07%); only 9.93% of species were found to be alien. Out of these, 136 species were angiosperms (115 species of dicotyledons and 21 species of monocotyledons), and five species were gymnosperms. Among the dicotyledons, Asteraceae was the most dominant family (24 species) followed by Lamiaceae (9 species), Rosaceae (8 species), Caryophyllaceae (6 species), Fabaceae (5 species), Polygonaceae (5 species), Apiaceae (4 species), Balsaminaceae (4 species), Berberidaceae (3 species), Primulaceae (3 species), Onagraceae (3 species), Acanthaceae (3 species). Amaranthaceae, Brassicaceae, Crassulaceae, Caprifoliaceae, Scrophulariaceae, Geraniaceae, Hydrangiaceae, Mazaceae, Urticaceae and Adoxaceae were represented by two species each. Rest of the dicot families, Apocynaceae, Aquifoliaceae, Campanulaceae, Cornaceae, Ericaceae, Euphorbiaceae, Fagaceae, Haloragaceae, Moraceae, Orobanchaceae, Phyllanthaceae, Plantaginaceae, Ranunculaceae, Rubiaceae, Sapindaceae, Saxifragaceae, Ulmaceae, and Vitaceae were represented by one species each. Among the monocotyledons, Orchidaceae was the most dominant family (5 species), followed by Zingiberaceae (3 species), Poaceae (2 species), Juncaceae (2 species), Asparagaceae (2 species), and Smilacaceae (2 species). Families Acoraceae, Araceae, Commelinaceae, Dioscoreaceae, Liliaceae, were represented by one species only. Pinaceae was found to be the most represented family with four species and Taxaceae was represented by one species only.

The overall diversity includes 101 herbs, 17 shrubs, two climbing shrubs, 12 trees, four climbers, and five orchids (Figure 2). *Chaerophyllum reflexum*, *Selinum vaginatum*, *Polygonatum verticillatum* (Image 2I), *Artemisia absinthium*, *Berberis lycium* (Image 2J), *Podophyllum hexandrum* (Image 1D), *Valeriana jatamansi*, *Dioscorea deltoidea* (Image 1C), *Rhododendron arboreum*, *Malaxis muscifera* (Image 1A), *Pyrus pashia*, *Rosa macrophylla* (Image 2H), *Ulmus wallichiana*, *Urtica dioica*, *Cautleya spicata* (Image 2K), *Hedychium spicatum* (Image 2L), *Roscoea alpina* (Image 1G), *Cedrus deodara* and *Taxus contorta* (Image 1F). Some exotic medicinal plants include *Acorus calamus*, *Vincetoxicum hirundinaria* and *Digitalis purpurea* (Image 1B). Some species were edible: leaves of

Table 1. Number of families, genera, and species reported from the study area.

Groups	Families total (% of the total)	Genera total (% of the total)	Species total (% of the total)
Angiosperms (i) Dicotyledons	40 (75.47)	89 (79.46)	115 (81.56)
(ii) Monocotyledons	11 (20.76)	18 (16.07)	21 (14.89)
Gymnosperms	02 (3.77)	05 (4.47)	05 (3.55)
Total	53 (100)	112 (100)	141 (100)

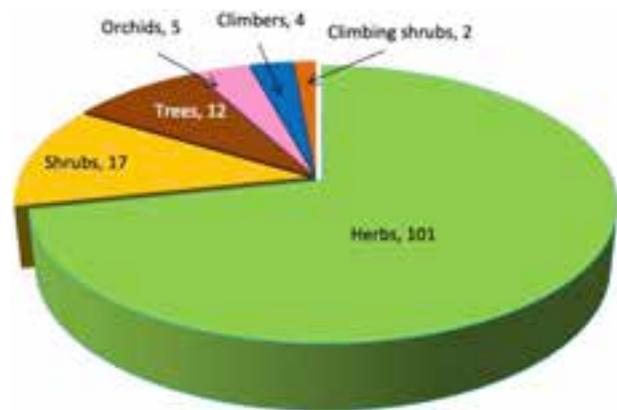


Figure 2. Floristic composition of Kalatop-Khajjiar Wildlife Sanctuary (depicts the total floristic diversity (native as well as exotic).

Stellaria media, *Rumex nepalensis*, *Nasturtium officinale*, *Pilea scripta*, and *Urtica dioica* are cooked as vegetables, flowers of *Rhododendron arboretum* and *Berberis napaulensis* (Image 2M) are used to make chutney, Ripe fruits of *Berberis lycium*, *Berberis napaulensis*, *Pyrus pashia*, and *Rubus macilentus* are edible. Leaves of *Quercus leucotrichophora*, *Ficus hederacea*, *Polygonum plebeium*, *Rumex nepalensis*, and *Cornus macrophylla* are used as fodder.

CONSERVATION STATUS

One-hundred-and-three of 114 species recorded from the study area are not assessed and 31 species as 'Least Concern' (LC) according to the IUCN Red List. Ten species from the study area were found to be threatened based on different assessment authorities. At the global level, as per IUCN Red List of Threatened Species, *Podophyllum hexandrum* and *Taxus contorta* are categorized as 'Endangered' (EN), while *Malaxis muscifera* and *Ulmus wallichiana* are listed as 'Vulnerable' (VU). *Lilium polyphyllum* is categorized as 'Critically Endangered' (CR) under the IUCN Red List.



Table 2. List of vascular flora of Kalatop-Khajjiar Wildlife Sanctuary, Chamba, Himachal Pradesh, India.

Family	Taxa	Voucher no.	Life form	Habitat	Flowering/fruitleting	Altitude (m)	Latitude N	Longitude E	IUCN Red List status	Nativity
Acoraceae	<i>Acorus calamus</i> L.	CPUH14232*	Herb	Marshy area	June–September	1961	32.546°	76.058°	–	Alien
	<i>Dicliptera bupleuroides</i> Nees	CPUH14215	Herb	Road side	November–June	1993	32.549°	76.059°	LC	Native
Acanthaceae	<i>Strabianthes attenuata</i> (Wall. ex Nees) Jacq. ex Nees	CPUH14135	Shrub	Forest margin, Road side	June–October	2374	32.549°	76.018°	NA	Native
	<i>Strabianthes penstemonoides</i> (Nees) T.Anderson	CPUH14171	Shrub	Forest trail	July–October	2029	32.539°	76.053°	NA	Native
Adoxaceae	<i>Viburnum grandiflorum</i> Wall. ex DC.	CPUH14045	Shrub	Road side	March–June	2442	32.529°	76.033°	NA	Native
	<i>Viburnum mullata</i> Buch.–Ham. ex D.Don	CPUH14100	Shrub	Forest area	May–October	2283	32.534°	76.044°	LC	Native
Amaranthaceae	<i>Cyathula capitata</i> Moq.	CPUH14133	Herb	Forest trail	July–October	2425	32.547°	76.019°	NA	Native
	<i>Cyathula tomentosa</i> (Schult.) Moq.	CPUH14177*	Herb	Forest margin	August–October	2198	32.535°	76.048°	NA	Native
	<i>Bupleurum longicaule</i> Wall. ex DC.	CPUH14137	Herb	Alpine slopes	June–September	2690	32.525°	76.026°	NA	Native
Apiaceae	<i>Chaerophyllum reflexum</i> Lindl.	CPUH14097*	Herb	Forest margin	May–September	2104	32.534°	76.054°	NA	Native
	<i>Sanicula elata</i> Buch.–Ham. ex D.Don	CPUH14075	Herb	Forest trail	June–October	2023	32.539°	76.054°	NA	Native
Apocynaceae	<i>Selinum vaginatum</i> (Edgew.) C.B.Clarke	CPUH14200	Herb	Alpine slopes	July–October	2662	32.525°	76.025°	VU (CAMP 2010)	Native
	<i>Vincetoxicum hirsutinaria</i> Medik.	CPUH14118*	Herb	Open meadow	April–August	2452	32.534°	76.044°	–	Alien
Aquifoliaceae	<i>Ilex diplyrena</i> Wall.	CPUH14223	Tree	Forest area	April–September	2080	32.534°	76.051°	LC	Native
Araceae	<i>Arisaema propinquum</i> Schott	CPUH14068	Herb	Forest margin	June–September	2372	32.529°	76.042°	NA	Native
	<i>Polygonatum govanianum</i> Royle	CPUH14040	Herb	Road side	May–August	2057	32.538°	76.054°	NA	Native
Asparagaceae	<i>Polygonatum verticillatum</i> (L.) All.	CPUH14041*	Herb	Forest margin	May–August	2029	32.539°	76.053°	EN (CAMP 2010)	Native
Asteraceae	<i>Anaphalis triplinervis</i> (Sims) C.B.Clarke	CPUH14178*	Herb	Forest margin	July–October	2365	32.529°	76.033°	NA	Native
	<i>Anaphalis busua</i> (Buch.–Ham.) DC.	CPUH14207	Herb	Mountain slopes	August–October	2730	32.522°	76.030°	NA	Native
	<i>Anaphalis nepalensis</i> (Spreng.) Hand.–Mazz.	CPUH14210	Herb	Mountain slopes	July–September	2690	32.524°	76.027°	NA	Native
	<i>Artemisia absinthium</i> L.	CPUH14099*	Herb	Road side	July–September	2265	32.534°	76.046°	LC	Native
	<i>Bidens pilosa</i> L.	CPUH14191*	Herb	Road side	July–October	1950	32.538°	76.052°	–	Alien
	<i>Bidens tripartita</i> L.	CPUH14198	Herb	Marshy area	August–October	1935	32.545°	76.059°	LC	Native
	<i>Carpesium abrotanoides</i> L.	CPUH14091	Herb	Road side	August–October	2034	32.534°	76.051°	NA	Native
	<i>Carpesium cernuum</i> L.	CPUH14078	Herb	Road side	August–October	2053	32.534°	76.053°	NA	Native

Family	Taxa	Voucher no.	Life form	Habitat	Flowering/fruitletting	Altitude (m)	Latitude N	Longitude E	IUCN Red List status	Nativity
	<i>Carpesium trachelifolium</i> Less.	CPUH14230	Herb	Mountain slopes	August–October	2707	32.524°	76.028°	NA	Native
	<i>Cardiophantis flexuosa</i> (Royle ex Lindl.) G.L.Nesom	CPUH14197	Herb	Mountain slopes	July–September	2690	32.524°	76.027°	NA	Native
	<i>Erigeron acris</i> var. <i>multicaulis</i> (Wall. ex DC.) C.B.Clarke	CPUH14067	Herb	Forest trail	May–October	2323	32.531°	76.044°	NA	Native
	<i>Erigeron canadensis</i> L.	CPUH14186	Herb	Road side	June–October	2370	32.530°	76.039°	NA	Alien
	<i>Gamochaeta pennsylvanica</i> (Willd.) Cabrera	CPUH14047	Herb	Road side	March–October	1979	32.539°	76.065°	NA	Alien
	<i>Hypochaeris radicata</i> L.	CPUH14055	Herb	Open grassland	July–October	2206	32.536°	76.046°	NA	Alien
	<i>Jacobaea analoga</i> (DC.) Veldkamp	CPUH14132	Herb	Forest margin	July–October	2285	32.532°	76.035°	NA	Native
	<i>Leucanthemum vulgare</i> Lam.	CPUH14049	Herb	Mountain slopes	April–October	1993	32.538°	76.065°	–	Alien
	<i>Melanoseris brunoniana</i> (Wall. ex DC.) N.Kilian & Ze H.Wang	CPUH14173	Herb	Forest margin	July–October	2167	32.533°	76.048°	NA	Native
	<i>Myriactis wallichii</i> Less.	CPUH14131	Herb	Road side	June–October	2009	32.544°	76.054°	NA	Native
	<i>Oreoseris gossypina</i> (Royle) X.D.Xu & V.A.Funk	CPUH14053*	Herb	Rocky surface	April–June	2201	32.534°	76.047°	NA	Native
	<i>Pseudognaphalium affine</i> (D. Don)	CPUH14106	Herb	Forest margin	May–October	2298	32.534°	76.046°	NA	Native
	<i>Sigesbeckia orientalis</i> L.	CPUH14182	Herb	Forest margin	August–October	2370	32.532°	76.036°	NA	Native
	<i>Synotis rufinervis</i> (DC.) C.Jeffrey & L.Chen	CPUH14179	Herb	Forest margin	August–October	2365	32.531°	76.035°	NA	Native
	<i>Taraxacum parvulum</i> DC.	CPUH14023	Herb	Grassy open space	March–November	2029	32.539°	76.053°	NA	Native
	<i>Youngia japonica</i> (L.) DC.	CPUH14046	Herb	Shady places	March–August	2198	32.530°	76.039°	NA	Native
Balsaminaceae	<i>Impatiens amphorata</i> Edgew.	CPUH14170	Herb	Mountain slopes	July–September	1984	32.542°	76.061°	NA	Native
	<i>Impatiens brachycentra</i> Kar. & Kir.	CPUH14008	Herb	Road side	May–October	2019	32.540°	76.052°	NA	Native
	<i>Impatiens edgeworthii</i> Hook.f.	CPUH14082	Herb	Mountain slopes	July–September	2365	32.528°	76.041°	NA	Native
	<i>Impatiens sulcata</i> Wall.	CPUH14196*	Herb	Mountain slopes	June–September	2381	32.528°	76.041°	NA	Native
Berberidaceae	<i>Berberis lycium</i> Royle	CPUH14058*	Shrub	Mountain slopes	April–June	2206	32.536°	76.046°	LC	Native
	<i>Berberis napaensis</i> (DC.) Spreng.	CPUH14005*	Shrub	Road side	January–April	2029	32.539°	76.053°	NA	Native
	<i>Podophyllum hexandrum</i> Royle	CPUH14025*	Herb	Forest trail	April–August	2057	32.538°	76.054°	EN	Native
Brassicaceae	<i>Nasturtium officinale</i> W.T.Aiton	CPUH14050*	Herb	Near water	April–September	1993	32.538°	76.065°	LC	Native
	<i>Nocca montana</i> (L.) F.K.Mey	CPUH14015	Herb	Forest trail	April–July	2198	32.529°	76.034°	–	Alien
Campanulaceae	<i>Campanula pallida</i> Wall.	CPUH14152	Herb	Road side	May–October	2249	32.534°	76.054°	NA	Native
Caprifoliaceae	<i>Leycesteria formosa</i> Wall.	CPUH14064	Shrub	Forest trail	June–October	2208	32.536°	76.044°	NA	Native
	<i>Valeriana jatamansi</i> Jones ex Roxb.	CPUH14021*	Herb	Forest trail	March–August	2009	32.544°	76.054°	CR (FRLHT)	Native



Family	Taxa	Voucher no.	Life form	Habitat	Flowering/fruiting	Altitude (m)	Latitude N	Longitude E	IUCN Red List status	Nativity
Caryophyllaceae	<i>Schizoteichium monospermum</i> (Buch.-Ham. ex D. Don) Pusalkar & S.K. Srivast.	CPUH14174	Herb	Mountain slopes	August–October	2167	32.533°	76.048°	NA	Native
	<i>Silene baccifera</i> (L.) Durande	CPUH14107	Herb	Road side	June–August	2172	76.044°	76.044°	NA	Native
	<i>Silene edgeworthii</i> Bocquet	CPUH14166	Herb	Road side	June–July	2330	76.054°	76.054°	NA	Native
Comelinaceae	<i>Spergularia rubra</i> (L.) J. Presl & C. Presl	CPUH14208	Herb	Alpine slopes	May–September	2730	76.048°	76.048°	–	Alien
	<i>Stellaria aquatica</i> (L.) Scop.	CPUH14044	Herb	Shady places	May–September	2029	76.044°	76.044°	NA	Native
	<i>Stellaria media</i> (L.) Vill.	CPUH14003	Herb	Shady places	March–October	1972	76.054°	76.054°	NA	Native
Cornaceae	<i>Cyanotis vaga</i> (Lour.) Schult. & Schult. f.	CPUH14154	Herb	Alpine slopes	July–October	2726	32.520°	76.034°	NA	Native
	<i>Cornus macrophylla</i> Wall.	CPUH14228	Tree	Road side	April–June	2076	32.534°	76.054°	LC	Native
	<i>Rosularia rosulata</i> (Edgew.) H. Ohba	CPUH14042*	Herb	Rocky surface	April–July	2029	32.535°	76.541°	NA	Native
Crassulaceae	<i>Sedum multicaule</i> Wall. ex Lindl.	CPUH14122	Herb	Shady places	July–September	1990	32.544°	76.054°	NA	Native
	<i>Dioscorea deltoidea</i> Wall. ex Griseb.	CPUH14059*	Climber	Mixed forest margin	May–September	2206	32.536°	76.046°	EN (CITES)	Native
	<i>Rhododendron arboreum</i> Sm.	CPUH14235*	Tree	Ban oak forest	March–June	1983	32.540°	76.071°	LC	Native
Euphorbiaceae	<i>Euphorbia cornigera</i> Boiss.	CPUH14066	Herb	Road side	May–September	2316	32.529°	76.042°	NA	Native
	<i>Campylotropis speciosa</i> (Royle ex Schindl.) Schindl.	CPUH14190	Shrub	Road side	August–October	2030	32.538°	76.052°	NA	Native
	<i>Hyloidesmum podocarpum</i> (DC.) H. Ohashi & R. Mill	CPUH14089	Herb	Road side	July–September	1901	32.541°	76.067°	NA	Native
Fagaceae	<i>Indigofera atropurpurea</i> Buch.-Ham. ex Hornem.	CPUH14048	Shrub	Road side	May–July	1979	32.539°	76.065°	LC	Native
	<i>Trifolium dubium</i> Sibth.	CPUH14051	Herb	Grassy meadow	April–May	1993	32.539°	76.065°	–	Alien
	<i>Trifolium resupinatum</i> L.	CPUH14229	Herb	Grassy meadow	May–October	2713	32.523°	76.029°	LC	Native
Geraniaceae	<i>Quercus leucotrichophora</i> A. Camus	CPUH14220*	Tree	Forest area	April–June	2198	32.535°	76.048°	NA	Native
	<i>Geranium rectum</i> Trautv.	CPUH14095	Herb	Forest margin	June–July	2365	32.528°	76.041°	NA	Native
	<i>Geranium ocellatum</i> Jacquem. ex Cambess.	CPUH14004	Herb	Road side	March–June	1975	32.540°	76.064°	NA	Native
Haloragaceae	<i>Myriophyllum verticillatum</i> L.	CPUH14090	Herb	Lake side	July–September	1935	32.545°	76.059°	LC	Native
	<i>Deutzia staminea</i> R. Br. ex Wall.	CPUH14037	Shrub	Road side	April–September	2029	32.535°	76.054°	NA	Native
	<i>Hydrangea anomala</i> D. Don	CPUH14225	Climbing shrub	Mixed coniferous forest	April–August	2000	32.539°	76.052°	NA	Native
Juncaceae	<i>Juncus articulatus</i> L.	CPUH14070	Herb	Lake side	May–October	1935	32.544°	76.058°	LC	Native
	<i>Juncus concinnus</i> D. Don	CPUH14140	Herb	Mountain slopes	July–October	2703	32.524°	76.028°	LC	Native

Family	Taxa	Voucher no.	Life form	Habitat	Flowering/fruiting	Altitude (m)	Latitude N	Longitude E	IUCN Red List status	Nativity
Lamiaceae	<i>Eisholtzia fruticosa</i> (D. Don) Rehder	CPUH14180	Herb	Road side	July–November	2365	32.529°	76.033°	NA	Native
	<i>Eisholtzia strobilifera</i> (Benth.) Benth.	CPUH14199	Herb	Alpine slopes	June–October	2662	32.525°	76.026°	NA	Native
	<i>Isodon coetosa</i> (Buch.-Ham. ex D. Don) Kudó	CPUH14172*	Herb	Road side	September–November	2158	32.535°	76.048°	NA	Native
	<i>Lamium album</i> L.	CPUH14030	Herb	Road side	April–October	2052	32.541°	76.054°	LC	Native
	<i>Leonurus cardiaca</i> L.	CPUH14116	Herb	Forest trail	July–September	2426	32.534°	76.015°	–	Alien
	<i>Melissa axillaris</i> (Benth.) Bakh.f.	CPUH14130	Herb	Road side	June–December	1997	32.541°	76.560°	NA	Native
	<i>Nepeta govaniiana</i> (Wall. ex Benth.) Benth.	CPUH14147	Herb	Forest area	August–October	2696	32.524°	76.027°	NA	Native
	<i>Nepeta podostachys</i> Benth.	CPUH14202	Herb	Alpine slopes	July–September	2690	32.525°	76.262°	NA	Native
	<i>Stachys splendens</i> Wall. ex Benth.	CPUH14109	Herb	Road side	September–November	2363	32.529°	76.040°	NA	Native
Liliaceae	<i>Lilium polyphyllum</i> D. Don	CPUH14086*	Herb	Forest area	June–August	2206	32.537°	76.462°	CR	Native
Mazaceae	<i>Mazus pumilus</i> (Burm.f.) Steenis	CPUH14088	Herb	Mixed forest slopes	April–October	1950	32.539°	76.066°	NA	Native
	<i>Mazus surculosus</i> D. Don	CPUH14072	Herb	Mixed forest slopes	May–October	1969	32.546°	76.056°	NA	Native
Moraceae	<i>Ficus hederacea</i> Roxb.	CPUH14098	Climber	Forest area	May–July	2127	32.534°	76.051°	NA	Native
Onagraceae	<i>Epilobium amurense</i> subsp. <i>amurense</i>	CPUH14087	Herb	Road side	May–October	2053	32.532°	76.049°	NA	Native
	<i>Epilobium laxum</i> Royle	CPUH14104	Herb	Road side	July–September	2285	32.534°	76.045°	NA	Native
	<i>Oenothera rosea</i> L'Hér. ex Alton	CPUH14092	Herb	Road side	May–October	2034	32.534°	76.051°	–	Alien
Orchidaceae	<i>Calanthe plantaginea</i> Lindl.	CPUH14024	Orchid	Forest area	April–May	2053	32.539°	76.054°	NA	Native
	<i>Epipactis helleborine</i> (L.) Crantz	CPUH14102*	Orchid	Forest area	July–September	2285	32.534°	76.045°	LC	Native
	<i>Goodyera repens</i> (L.) R.Br.	CPUH14158	Orchid	Forest area	July–September	2726	32.520°	76.035°	LC	Native
	<i>Malaxis muscifera</i> (Lindl.) Kuntze	CPUH14157*	Orchid	Forest area	July–September	2730	32.523°	76.029°	VU	Native
	<i>Spiranthes sinensis</i> (Pers.) Ames	CPUH14156	Orchid	Alpine slopes	March–September	2662	32.525°	76.026°	–	Alien
Orobanchaceae	<i>Euphrasia himalayica</i> Wettst.	CPUH14139	Herb	Alpine slopes	May– August	2690	32.524°	76.026°	NA	Native
Phyllanthaceae	<i>Leptopus cordifolius</i> Decne.	CPUH14162	Shrub	Forest trail	May–October	2001	32.532°	76.447°	NA	Native
Plantaginaceae	<i>Digitalis purpurea</i> L.	CPUH14110	Herb	Road side	May–October	2363	32.531°	76.032°	–	Alien
Poaceae	<i>Drepanostachyum falcatum</i> (Nees) Keng f.	CPUH14236	Bamboo	Road side	–	2033	32.545°	76.054°	NA	Native
	<i>Oplismenus undulatifolius</i> (Ard.) P. Beauv.	CPUH14129	Herb	Shady places	August–October	1993	32.538°	76.065°	NA	Native
Polygonaceae	<i>Persicaria pubescens</i> (Blume) H. Hara	CPUH14161	Herb	Moist places	July–October	2285	32.534°	76.045°	LC	Native



Family	Taxa	Voucher no.	Life form	Habitat	Flowering/fruiting	Altitude (m)	Latitude N	Longitude E	IUCN Red List status	Nativity
	<i>Persicaria minor</i> (Huds.) Opiz	CPUH14167	Herb	Road side	July–October	1901	32.540°	76.066°	NA	Native
	<i>Polygonum aviculare</i> L.	CPUH14145	Herb	Grassy meadow	July–October	2726	32.521°	76.032°	NA	Native
	<i>Polygonum plebeium</i> R.Br.	CPUH14203	Herb	Grassy meadow	October–April	2730	32.523°	76.029°	LC	Native
	<i>Rumex nepalensis</i> Spreng.	CPUH14043*	Herb	Road side	April–July	2029	32.539°	76.053°	NA	Native
Primulaceae	<i>Androsace rotundifolia</i> Hardw.	CPUH14032	Herb	Rocky surface	April–June	2057	32.540°	76.053°	NA	Native
	<i>Androsace sarmentosa</i> Wall.	CPUH14148	Herb	Alpine slopes	May–August	2726	32.520°	76.035°	NA	Native
	<i>Lysimachia debilis</i> Wall.	CPUH14073	Herb	Road side	June–July	1950	32.539°	76.066°	NA	Native
Ranunculaceae	<i>Clematis connata</i> DC.	CPUH14187	Climber	Forest area	August–October	1942	32.532°	76.049	NA	Native
Rosaceae	<i>Geum roylei</i> Wall.	CPUH14027	Herb	Road side	May–September	1942	32.542°	76.062°	NA	Native
	<i>Potentilla indica</i> (Andrews) Th.Wolf	CPUH14007*	Herb	Road side	March–August	2031	32.548°	76.055°	NA	Native
	<i>Potentilla nepalensis</i> Hook.	CPUH14117	Herb	Grassy meadow	June–October	2452	32.530°	76.024°	NA	Native
	<i>Pyrus pashia</i> Buch.-Ham. ex D.Don	CPUH14213	Tree	Road side	February–March	1960	32.540°	76.065°	LC	Native
	<i>Rosa macrophylla</i> Lindl.	CPUH14060*	Shrub	Road side	April–September	2206	32.536°	76.046°	NA	Native
	<i>Rubus macilentus</i> Cambess.	CPUH14031	Shrub	Road side	April–October	1984	32.542°	76.061°	NA	Native
	<i>Rubus pedunculatus</i> D.Don	CPUH14113	Shrub	Road side	June–August	2410	32.531°	76.032°	NA	Native
	<i>Sorbaria tomentosa</i> (Lindl.) Rehder	CPUH14063	Shrub	Road side	May–October	2208	32.536°	76.044°	NA	Native
Rubiaceae	<i>Galium elegans</i> Wall.	CPUH14074	Herb	Moist places	May–November	2009	32.544°	76.054°	NA	Native
Sapindaceae	<i>Acer cappadocicum</i> Gled.	CPUH14218	Tree	Road side	April–September	2080	32.534°	76.051°	LC	Native
Saxifragaceae	<i>Saxifraga moorcroftiana</i> (Ser.) Wall. ex Sternb.	CPUH14146	Herb	Alpine slopes	August–September	2726	32.520°	76.033°	NA	Native
Scrophulariaceae	<i>Buddleja crispa</i> Benth.	CPUH14219	Shrub	Road side	March–May	2167	32.534°	76.047°	NA	Native
	<i>Scrophularia himalensis</i> Royle ex Benth.	CPUH14183	Herb	Road side	July–September	2370	32.531°	76.039°	NA	Native
Smilacaceae	<i>Smilax elegans</i> Wall. ex Kunth	CPUH14009	Climber	Road side	May–October	2019	32.539°	76.052°	NA	Native
	<i>Smilax vaginata</i> Decne.	CPUH14226	Shrub	Road side	May–June	2204	32.536°	76.044°	NA	Native
Ulmaceae	<i>Ulmus wallichiana</i> Planch.	CPUH14227*	Tree	Road side	March–April	2198	32.536°	76.046°	VU	Native
Urticaceae	<i>Pilea scripta</i> (Buch.-Ham. ex D.Don) Wedd.	CPUH14076	Herb	Moist places	June–October	2029	32.534°	76.054°	NA	Native
	<i>Urtica dioica</i> L.	CPUH14115*	Herb	Forest area	June–August	2057	32.532°	76.044°	LC	Native
Vitaceae	<i>Parthenocissus semicordata</i> var. <i>semicordata</i>	CPUH14175*	Climbing shrub	Forest area	May–August	2193	32.537°	76.046°	NA	Native

Family	Taxa	Voucher no.	Life form	Habitat	Flowering/fruitletting	Altitude (m)	Latitude N	Longitude E	IUCN Red List status	Nativity
Zingiberaceae	<i>Caulleya spicata</i> (Sm.) Baker	CPUH14108*	Herb	Road side	August–September	2302	32.529°	76.042°	LC	Native
	<i>Hedychium spicatum</i> Sm.	CPUH14149*	Herb	Road side	August–September	2208	32.537°	76.045°	LC	Native
	<i>Roscoea alpina</i> Royle	CPUH14010*	Herb	Forest area	July–August	2398	32.529°	76.047°	VU (CAMP 2010)	Native
Pinaceae	<i>Abies pindrow</i> (Royle ex D. Don) Royle	CPUH14111*	Tree	Forest area	September–October	2397	32.538°	76.018°	LC	Native
	<i>Cedrus deodara</i> (Roxb. ex D. Don) G. Don	CPUH14221*	Tree	Forest area	October–November	2198	32.535°	76.048°	LC	Native
	<i>Picea smithiana</i> (Wall.) Boiss.	CPUH14205	Tree	Forest area	September–October	2730	32.524°	76.026°	LC	Native
Taxaceae	<i>Pinus wallichiana</i> A. B. Jacks.	CPUH14231*	Tree	Forest area	September–October	2422	32.530°	76.024°	LC	Native
	<i>Taxus contorta</i> Griff.	CPUH14114*	Tree	Forest area	October–November	2703	32.534°	76.020°	EN	Native

* denotes accession numbers used for ethnobotanical studies.

At the national and regional level, assessments by the Conservation Assessment and Management Plan, 2010 for Himachal Pradesh categorize *Dioscorea deltoidea* and *Polygonatum verticillatum* as Endangered (EN) within the state (CAMP 2010). Additionally, *Selinum vaginatum* and *Roscoea alpina* are listed as Vulnerable (VU) in Himachal Pradesh under CAMP assessments.

Regarding legal protection and trade regulation, *Dioscorea deltoidea* is included in Appendix II of CITES (2025) (Appendices 2025), indicating that although it is not necessarily threatened with extinction globally, its trade must be regulated to avoid utilization incompatible with its survival. Furthermore, *Valeriana jatamansi* has been categorized as Critically Endangered (CR) by FRLHT (Foundation for Revitalisation of Local Health Traditions) under national medicinal plant conservation assessments (ENVIS Centre on Medicinal Plants 2024).

CONCLUSION

The present study offers valuable insights into the floristic diversity and conservation status of the flora of KKWS, contributing to our understanding of its rich botanical heritage. The sanctuary, distinguished by its diverse ecosystems, serves as a vital habitat for a range of rare and threatened plant species. Despite its protected status, the sanctuary is not immune to anthropogenic disturbances, including tourism pressure, habitat fragmentation, resource extraction, and the growing impacts of climate variability. The outcomes of this investigation establish a significant baseline database that can support efforts in biodiversity management, restoration planning, and policy creation. Continuous floristic assessments, paired with habitat protection strategies and community-based conservation initiatives, are necessary to maintain the Sanctuary's ecological integrity. Strengthening awareness, regulating tourism, and implementing science-based management strategies will be crucial for the sustainable conservation of this ecologically sensitive and biologically rich Himalayan region.

REFERENCES

- Appendices (2025).** Appendix II of CITES, <https://cites.org/eng/app/appendices.php>. Accessed on 29.v.2025.
- Aswal, B.S. & B.N. Mehrotra (1994).** *Flora of Lahaul Spiti (A Cold Desert in North West Himalaya)*. Bishen Singh Mahender Pal Singh, Dehradun, 761 pp.
- CAMP (2010).** Threatened Medicinal Plants of Himachal Pradesh, Report of the 'CAMP' Workshop (Conservation Assessment & Management



Image 1. A—*Malaxis muscifera* (Lindl.) Kuntze | B—*Digitalis purpurea* L. | C—*Dioscorea deltoidea* Wall. ex Griseb. | D—*Podophyllum hexandrum* Royle | E—*Lilium polyphyllum* D. Don | F—*Taxus contorta* Griff. | G—*Roscoea alpina* Royle. © Sumit.



Image 2. H—*Rosa macrophylla* Lindl. | I—*Polygonatum verticillatum* (L.) All. | J—*Berberis lycium* Royle | K—*Cautleya spicata* (Sm.) Baker | L—*Hedychium spicatum* Sm. | M—*Berberis napaulensis* (DC.) Spreng. © Sumit.

- Prioritisation) held at Shimla on 1–4 December 2010. Sponsored by National Medicinal Plants Board, Government of India. Organised by Himachal Pradesh Forest Department, 3 pp.
- Chowdhery H.J. & B.M. Wadhwa (1984).** *Flora of Himachal Pradesh, Analysis, Vol 1–3*. Calcutta, Botanical Survey of India. <https://bsi.gov.in/page/en/state-flora>. Accessed on 9.ix.2023.
- Collett, H. (1902).** *Flora Simlensis*. Thacker Spink and Co. Calcutta and Shimla, Reprinted (1971). Bishen Singh Mahender Pal Singh, Dehradun, 652 pp.
- Dhaliwal, D.S. & M. Sharma (1999).** *Flora of Kullu District (Himachal Pradesh)*. Bishen Singh Mahender Pal Singh, Dehradun, 744 pp.
- ENVIS Centre on Medicinal Plants (2024).** Plant Details for *Valeriana jatamansi* JONES. <https://envis.frlht.org/plantdetails/c29831e028df24eeb3495344f850bd67/a26dfe103c612b61931ee48ce8884460>. Accessed on 29.v.2025.
- Gairola, S., C.M. Sharma, C.S. Rana, S.K. Ghildiyal & S. Suyal (2010).** Phytodiversity (angiosperms and gymnosperms) in Mandal-Chopta forest of Garhwal Himalaya, Uttarakhand, India. *Nature and Science* 8(1): 1–17.
- Haq, S.M., A.A. Khoja, F.A. Lone, M. Waheed, R.W. Bussmann, E.A. Mahmoud & H.O. Elansary (2023).** Floristic composition, life history traits and phytogeographic distribution of forest vegetation in the western Himalaya. *Frontiers in Forests and Global Change* 6: 1169085. <https://doi.org/10.3389/ffgc.2023.1169085>
- Jain, S.K. & R.R. Rao (eds.) (1977).** *A Handbook of Field and Herbarium Methods*. Today & Tomorrow's Printers & Publisher, New Delhi, 157 pp.
- Kumar, A., R. Paliwal & U. Saikia (2014).** Avifauna of Kalatop-Khajjiar Wildlife Sanctuary and adjacent areas, Himachal Pradesh, India. *Bird Populations* 13: 36–48.
- Kumar, A., S.S. Samant, L.M. Tewari & S. Paul (2018).** Diversity, distribution, indigenous uses, and status of orchids in Kalatop-Khajjiar Wildlife Sanctuary, Chamba district, Himachal Pradesh. *The Journal of the Orchid Society of India* 32: 93–98.
- Kumar, R. (2020).** Management Plan of Kalatop Khajjiar Wildlife Sanctuary (2019–20 to 2028–29). <https://hpforest.gov.in/storage/files/1/pdf/Management%20Plan/Approved%20MP%20Khajjiard.pdf>. Accessed on 27.xi.2025.
- Lalithalakshmi, K., A. Selvam & M. Udayakumar (2024).** Woody flora of Karumpuliyuthu Hill, Tenkasi, Tamil Nadu, India: a checklist. *Journal of Threatened Taxa* 16(6): 25453–25460. <https://doi.org/10.11609/jott.8855.16.6.25453-25460>
- Palni, L.M.S. & R.S. Rawal (2010).** Conservation of Himalayan bioresources: an ecological, economical and evolutionary perspective, pp. 369–402. In: Sharma, V.P. (ed.). *Nature at Work: Ongoing Saga of Evolution*. Springer, New Delhi. https://doi.org/10.1007/978-81-8489-992-4_23
- Polunin, O. & A. Stainton (1984).** *Flowers of the Himalaya*. Oxford University Press, Delhi, 580 pp.
- Samant, S.S. (2021).** Floristic diversity of the Himalaya in relation to climate change: status, values and conservation. *Journal of Graphic Era University* 9(1): 31–54.
- Sherafu, Z., M.C. Egiu & J.M. Sasikumar (2024).** Floristic composition, diversity, and regeneration of woody plant species of Dabal forest in southeastern Ethiopia: implication for Conservation. *Scientifica* 2024(1): 7414375. <https://doi.org/10.1155/2024/7414375>
- Singh, H. & M. Sharma (2006).** *Flora of Chamba District (Himachal Pradesh)*. Bishen Singh Mahender Pal Singh, Dehradun, 881 pp.
- Sumit, Singh, S., Kumar, G. & K. Singh (2025).** Revitalizing traditional wisdom: Exploring medicinal, plant-based healthcare practices in Kalatop-Khajjiar Wildlife Sanctuary, Himachal Pradesh, India. *Ethnobotany Research and Applications* 31. <https://doi.org/10.32859/era.31.26.1-30>
- Stainton, A. (1988).** *Flowers of Himalaya, A Supplement*. Oxford University Press, Delhi, 86 pp.
- Verma, R.K. & K.S. Kapoor (2011).** *Kalatop- Khajjiar Wildlife Sanctuary Chamba Himachal Pradesh—An Appraisal to its Plant Diversity*. Shimla, HFRI, 121 pp
- Wani, S.A., M.A. Mugal, F.A. Dar, C.S. Reddy, I. Rashid & A.A. Khuroo (2023).** Biodiversity data synthesis on trees of Indian Himalayan Region: Policy and management implications. *Global Ecology and Conservation* 48: e02698. <https://doi.org/10.1016/j.gecco.2023.e02698>
- Wagensommer, R.P. (2023).** Floristic studies in the light of biodiversity knowledge and conservation. *Plants* 12(16): 2973. <https://doi.org/10.3390/plants12162973>

Author details: Ms. SUMIT serves as an assistant professor of botany at Government College Chamba, Himachal Pradesh. She holds an M.Phil. and a master's degree in Botany and brings over 26 years of rich teaching experience at the undergraduate level. A committed educator and emerging researcher, she is currently pursuing her PhD in Botany, with a research focus on floristic diversity and ethnobotany, particularly within the Himalayan region. She has actively contributed to the academic community through participation in numerous national and international conferences. DR. GULSHAN KUMAR is an accomplished academician associate professor of botany at Career Point University, distinguished for his expertise in ethnobotany, agro-biodiversity, and climate-resilient agriculture. Born on 23 October 1980, he has extensive academic, research, and extension experience, advancing sustainable agro-technologies and indigenous knowledge systems for Himalayan ecosystems and rural development initiatives across regions today. DR. SUMIT SINGH is a renowned plant taxonomist currently working as scientist C at CSIR-NEIST, Assam. He has done his PhD from CSIR-IIIM, Jammu in the Year 2022 with expertise in alpine Himalayan flora. During his research tenure, Dr. Singh has published more than 20 research articles in different international Journals. Dr. Singh is also the Fellow of renowned scientific societies like Linnean Society of London, Royal Asiatic Society, Royal Geographic Society, etc. DR. TASLIMA SHEIKH is a biodiversity researcher specializing in species diversity and field based ecological documentation. Her work focuses on systematic assessments, distribution patterns, and conservation-oriented studies across India. During her research tenure, she has published more than 15 research articles and served as reviewer for various peer reviewed Journals. DR. KANWALJEET SINGH is currently working as assistant professor (botany) in the department of Education in Science and Mathematics, Regional Institute of Education Mysuru (NCERT). He holds the PhD degree in the field of plant taxonomy and ethnobotany. Dr Singh has published more than 20 research articles in renowned international journals. MR. P. VISHAL AHUJA is a dedicated conservation biologist and academic researcher from Chamba District, Himachal Pradesh, India. He holds a master's degree in botany reflecting both his scientific expertise and commitment to environmental awareness and education. Since joining the Zoo Outreach Organisation in 2012, he has been actively engaged in biodiversity conservation and ecological restoration initiatives. He currently serves as the principal investigator of a Native Forest Restoration Project in Chamba District, spearheaded by the Zoo Outreach Organisation. MR. ARVIND KUMAR is a renowned botanist currently serving as assistant professor (botany) in department of higher education, Jammu and Kashmir. Mr. Kumar is an accomplished teacher and author with teaching experience of more than 10 years. He has published various research articles in the field of plant diversity and ethnobotany.

Author contributions: Sumit Singh conceptualized and designed the study. Sumit and P. Vishal Ahuja conducted the field study, collected the specimens and wrote the manuscript. Sumit Singh and Taslima Sheikh were involved in supervision, data analysis, and critical review. Gulshan Kumar provided supervision, materials and assisted in data collection. Kanwaljeet Singh contributed to data interpretation. All authors reviewed and approved the final manuscript.

Acknowledgements: The authors express their sincere gratitude to the head, Department of Botany, Career Point University, and the vice chancellor for providing the necessary facilities. We are also thankful to the forest officials of Kalatop-Khajjiar Wildlife Sanctuary for their support and cooperation during the fieldwork.



Assessing the tree diversity along the Dudhganga River in Kolhapur District of Maharashtra, India

Sachin Chavan¹ & Rajaram Gurav²

^{1,2}Department of Botany, Shivaji University, Vidyanagar, Kolhapur, Maharashtra 416004, India.

¹botanysachin10@gmail.com, ²rvg_botany@unishivaji.ac.in (corresponding author)

Abstract: Riparian vegetation is the buffer zone between the aquatic ecosystem of a river and the terrestrial ecosystem. Trees are a typical feature of many ecosystems. Understanding the diversity and geographic distribution of trees holds significant theoretical and practical value. This study highlights the rich diversity of tree species along the river Dudhganga with 80 species from 30 families identified through an extensive field survey from October 2021 to June 2024. The species-rich families are Fabaceae with 10 native species, contributing 18% of the total native tree diversity, Moraceae with eight species, and Malvaceae & Lamiaceae each with four species. Species-rich and diverse genus *Ficus* dominated with seven species. *Ficus racemosa* exhibits a widespread distribution across riparian habitats, which is the most evenly distributed species, while *Pongamia pinnata* stands out as the most dominant species among riparian tree taxa. Among the 80 tree species, two species are endemic to India, 55 are native and 25 are invasive. The altitudinal gradient exerts a substantial influence, as evidenced by research indicating that the diversity and density of riparian trees escalate with ascending altitudes. This study reveals a relatively diverse tree flora in riparian areas and aims to serve as a tool for managing the tree species diversity of the riparian land.

Keywords: Altitudinal gradient, conservation planning, dominance pattern, endemic tree species, family-level diversity, floristic composition, full census approach, riverine ecosystem, riparian ecology, species richness.

सारांश: नदीकाठवरील वनस्पती नदीच्या जलीय परिसंस्था आणि स्थल परिसंस्था यांमधील एक महत्त्वपूर्ण संरक्षक पट्टा म्हणून कार्य करतात. या पट्ट्यातील वृक्ष समुदाय परिसंस्थेच्या रचना, कार्य आणि स्थैर्यासाठी अत्यावश्यक घटक आहे. वृक्षांची प्रजाती विविधता, भौगोलिक प्रसार आणि वर्चस्व संरचना समजून घेणे हे सैद्धांतिक तसेच व्यावहारिक दृष्टिकोनातून महत्त्वाचे आहे. प्रस्तुत संशोधनामध्ये महाराष्ट्राच्या कोल्हापूर जिल्ह्यातील दूधगंगा नदीकाठवरील वृक्ष विविधतेचे सविस्तर मूल्यांकन करण्यात आले आहे. जानेवारी २०२१ ते जून २०२४ या कालावधीत केलेल्या विस्तृत क्षेत्रीय सर्वेक्षणातून नदीकाठवरील पट्ट्यात आढळणाऱ्या वृक्ष प्रजातींची नोंद करण्यात आली. कुठ-स्तरावर फॅबेसी हे सर्वाधिक प्रजातीसमृद्ध कुठ आढळले, त्याखालोखाल मोरेसी, माल्वेसी आणि लॅमियासी ही कुठे महत्त्वाची ठरली. वंश-स्तरावर फायकस हा सर्वाधिक वैविध्यपूर्ण वंश आढळून त्याचे लक्षणीय वर्चस्व दिसून आले. उंबर (*फायकस रॅसिमोसा*) ही प्रजाती नदीकाठवरील अधिवासांमध्ये व्यापक व समसमान रीतीने प्रसार झालेली आढळली, तर करंज (*पोंगामिया पिन्नाटा*) ही प्रजाती संख्यात्मक दृष्ट्या सर्वाधिक आढळून आली. नोंदविलेल्या वृक्ष प्रजातींपैकी काही प्रदेशनिष्ठ (एन्डेमिक) असून बहुसंख्य प्रजाती स्वदेशी आहेत; तथापि, काही परकीय व आक्रमक प्रजातींची उपस्थितीही आढळून आली आहे. समुद्र सपाटीपासून उंचीनुसार बदलणाऱ्या पर्यावरणीय उताराचा वृक्ष विविधता व भौगोलिक प्रसारावर लक्षणीय प्रभाव दिसून आला असून, अधिक उंचीच्या भागात तुलनेने अधिक प्रजाती समृद्धता आणि घनता आढळली. हा अभ्यास दूधगंगा नदीच्या नदीकाठवरील वृक्ष जैवविविधतेचे महत्त्व अधोरेखित करतो आणि या परिसंस्थेच्या शाश्वत व्यवस्थापन व संवर्धन नियोजनासाठी मूलभूत माहिती प्रदान करतो.

Editor: S. Jeevith, Siddharth Foundation, Coimbatore, India.

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

Citation: Chavan, S. & R. Gurav (2026). Assessing the tree diversity along the Dudhganga River in Kolhapur District of Maharashtra, India. *Journal of Threatened Taxa* 18(2): 28275–28286. <https://doi.org/10.11609/jott.9455.18.2.28275-28286>

Copyright: © Chavan & Gurav 2026. 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: We sincerely thank the University Grants Commission (UGC), New Delhi, for providing financial support for this research. This study forms part of the PhD work of the first author submitted to Shivaji University, Kolhapur, Maharashtra, India.

Competing interests: The authors declare no competing interests.

Author details: SACHIN CHAVAN, senior research scholar, Department of Botany, Shivaji University, Kolhapur, Maharashtra, India. His research focuses on riparian vegetation ecology, biodiversity assessment, carbon sequestration studies, spatial mapping using GIS, and quantitative ecological analysis of riverine ecosystems in the Western Ghats. DR. R.V. GURAV, professor, Department of Botany, Shivaji University, Kolhapur, Maharashtra, India. Specialises in plant taxonomy and biodiversity conservation, with extensive contributions to floristic documentation, vegetation analysis, and conservation of threatened plant taxa. He has supervised several doctoral scholars and contributed to research in plant systematics, conservation biology, and sustainable plant resource management.

Author contributions: SC—lead in conceptualisation, field surveys, data collection, data analysis, GIS mapping, manuscript drafting, and visualisation; contributed equally to manuscript review and editing. RVG—lead supervision, research design refinement, methodological guidance, taxonomic validation, and manuscript review and editing.

Acknowledgements: We sincerely thank the Department of Botany, Shivaji University, Kolhapur, for providing laboratory and academic support. We also acknowledge the assistance of local communities and field assistants who supported vegetation surveys along the river stretches.

INTRODUCTION

Riparian zones form transitional interfaces between aquatic and terrestrial ecosystems, encompassing stream channels and adjacent landscapes influenced by hydrological processes such as flooding, elevated water tables, and soil moisture regimes (Naiman & Décamps 1997). Vegetation within these zones comprises plant communities adapted to dynamic environmental conditions and provides critical ecosystem services, including provisioning, regulating, supporting, and cultural functions (Mohan & Joseph 2024). Acting as ecological buffers and ecotones, riparian ecosystems enhance watershed stability by regulating nutrient flow, sediment retention, and energy exchange between land and water (Sumarmi et al. 2022).

Globally, riparian ecosystems are among the most threatened landscapes due to river regulation, land-use change, invasive species, and increasing anthropogenic pressures. While vegetation structure along free-flowing rivers is relatively stable, regulated rivers often show altered species composition and spatial patterns owing to modified flow regimes (Nilsson et al. 1997). Biological invasions and shifts in species dominance further disrupt ecosystem structure and function (Richardson et al. 2007). Despite their ecological importance, riparian landscapes are inherently rare, occupying only a small fraction of the Earth's surface (Hynes 1970).

Riparian vegetation zones are recognised as highly species-rich and productive systems, playing a key role in maintaining water quality by acting as natural filters for sediments and pollutants (Naiman et al. 2005; Liunima et al. 2022). However, most vegetation studies have focused on forest ecosystems, with comparatively fewer investigations addressing riparian tree diversity and structure (Gregory et al. 1991; Nilsson et al. 1997). In India, studies from the Western Ghats report high riparian diversity (Korse & Krishnakumar 2006), but in Maharashtra, systematic information on riparian tree diversity remains limited, with only a few studies such as that along the Panchganga River (Mohite & Mane 2020).

The Western Ghats serve as a major watershed for peninsular rivers and are recognised globally as a biodiversity hotspot (Myers et al. 2000). The Dudhganga River, a tributary of the Krishna River, originates in the Western Ghats and flows through the Radhanagari forest, a UNESCO World Heritage Site (UNESCO 2012). Despite its ecological and socioeconomic importance, comprehensive data on riparian tree species diversity, distribution, and altitudinal variation along the Dudhganga River are lacking.

Information on riparian tree diversity, dominance, and spatial distribution along the Dudhganga River across different altitudinal zones is currently insufficient, limiting effective conservation and management planning. Riparian tree species diversity and composition along the Dudhganga River vary significantly with altitude, with higher elevations supporting greater species richness and structural diversity.

The present study aims to document the tree species composition of riparian vegetation along the Dudhganga River, assess species richness, dominance, and family-level patterns of riparian trees, analyse spatial variation in riparian tree diversity across upstream, midstream, and downstream sections of the river, and generate baseline data to support conservation and sustainable management of riparian ecosystems in the Dudhganga River basin.

STUDY AREA AND METHODS

The Dudhganga River originates in the Western Ghats and flows eastward, joining the Krishna River at Danwad. Based on the composition of the recorded species, the riparian zone of the Dudhganga River occupies a transitional ecotone, with southern moist mixed deciduous forests predominating, and a gradual shift toward southern tropical semi-evergreen forests in the upper catchment. This vegetation pattern corresponds well with the established classifications for the northern Western Ghats (Singh & Karthikeyan 2000; Gunaga et al. 2013). The study area spans 131 km of riparian vegetation on both sides of the river (Image 1), extending from Kalamawadi Dam (16.353° N, 74.010° E) to Sangam Math at Danwad (16.514° N, 74.635° E), forming an integral part of the Krishna River basin.

The Western Ghats biodiversity is influenced by altitudinal changes, which contribute to the variation in tree diversity along the river's course. The field survey has been carried out on upstream, midstream, and downstream riparian vegetation of the river Dudhganga based on elevation gradient, vegetation composition, and distance from the starting point, ensuring a systematic division reflecting slope, species distribution, and flow characteristics.

The upstream (higher elevation) area starts from Panori (16.367° N, 74.032° E) to Sulambi (16.414° N, 74.066° E), the midstream (middle altitude) area comprises area from the Bidri (16.434° N, 74.137° E) to Belawale Budruk (16.506° N, 74.156° E), while the downstream (lower elevation) area starts from Dattawad

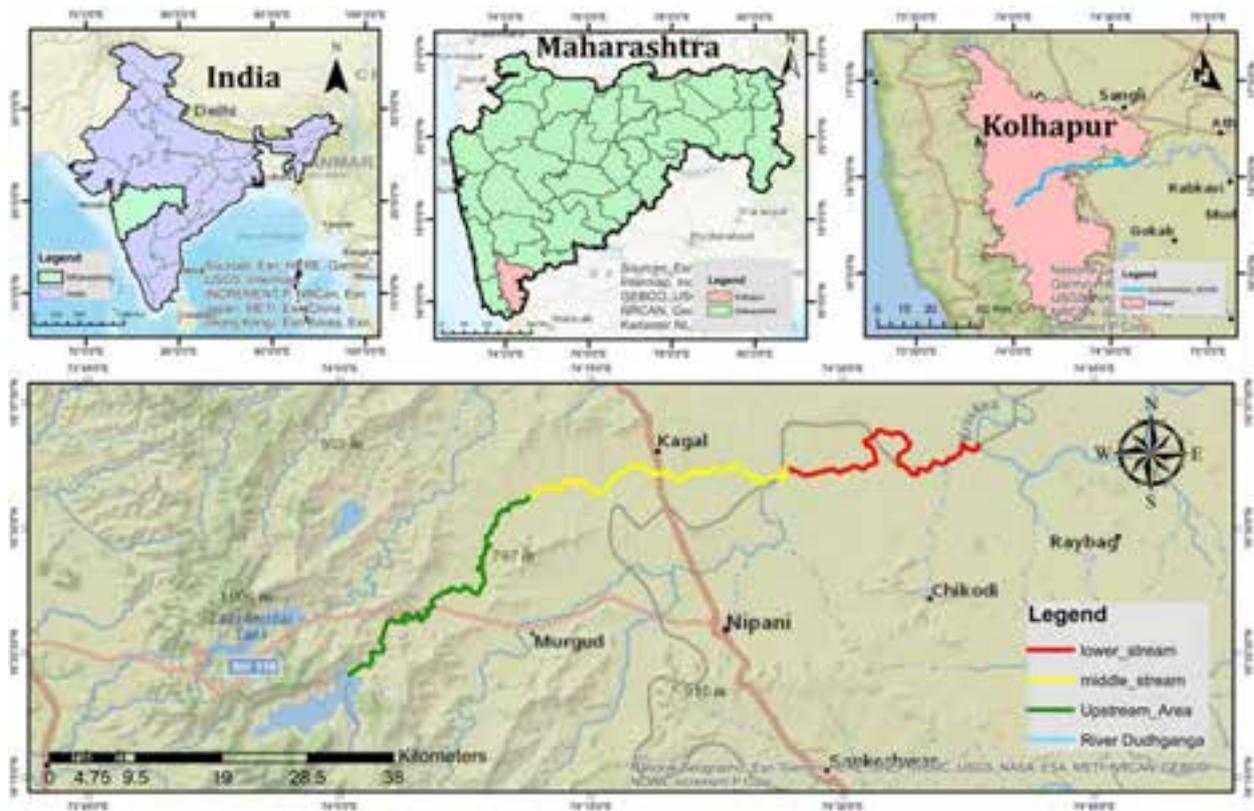


Figure 1. Map of the study area along the river Dudhganga in Maharashtra, India.

(16.584° N, 74.568° E) to Examba (16.564° N, 74.599° E) (Image 2 & 3).

Data Collection

The tree specimens were surveyed between October 2021 and June 2024. To ensure accurate estimation of tree diversity along the river Dudhganga, data was collected using the mobile GPS application, namely GPSWAYPOINT. Following the census approach described by Condit (1998), we conducted a systematic walk-through survey of the entire accessible riparian stretch and recorded all detectable individual trees. This approach represents the first application of a near-complete tree census method for riparian vegetation in this region and was adopted to minimise sampling bias commonly associated with plot-based methods. Although the survey was designed to maximise spatial coverage, complete access to all microhabitats was not always possible due to dense vegetation, steep slopes, and seasonally waterlogged sections typical of dynamic riparian environments. Consequently, a small proportion of individuals occurring in physically inaccessible or periodically inundated microhabitats may have been underrepresented. However, repeated surveys across

multiple post-monsoon seasons and continuous riverbank coverage ensured robust documentation of dominant, common, and ecologically significant riparian tree species across the Dudhganga River. This approach allowed for capturing the true distribution of species across the landscape and reduced the chances of missing rare or scattered species, which is a common limitation of fixed-area sampling methods such as quadrats or transects (Chazdon et al. 1998; Gotelli & Colwell 2001). By mapping every tree systematically, a comprehensive dataset was obtained, capturing the true representation of riparian vegetation across different altitude zones.

The riparian trees within the study area were identified and recorded. All individual trees with a girth at breast height (GBH) greater than 20 cm were measured. The collected specimens were identified with the help of Flora of Bombay (Cooke 1903) and Kolhapur Flora (Yadav & Sardesai 2002). The dry method was used to prepare the herbarium specimens and deposited at the herbarium of the Department of Botany, Shivaji University, Kolhapur (SUK), following the protocol of Jain & Rao (1977). The nomenclature and classification followed the Angiosperm Phylogeny Group IV System (Stevens 2001). Nomenclature and



Image 1. Riparian habitat of river Dudhganga at upstream (higher altitude) showing dense vegetation area dominated by the native species of *Salix tetrasperma* & *Pandanus furcatus* and the invasive *Acacia auriculiformis*. © Sachin Chavan.



Image 2. Habitat of midstream (middle altitude) showing moderate vegetation area dominated by *Ficus racemosa*, *Pongamia pinnata*, *Bambusa bambos*, and *Crateva magna*. © Sachin Chavan.



Image 3. Showing downstream with sparse vegetation of *Bambusa bambos* and *Syzygium salicifolium*. © Sachin Chavan.

distribution information was verified using Plants of the World Online (POWO 2024) and India Flora Online (Rao & Kumar 2024). Vernacular names were referred from Flowers of India (2024).

RESULTS AND DISCUSSION

Tree diversity and distribution along the riparian continuum

A total of 80 angiosperm tree species, belonging to 66 genera and 30 families, were recorded from the riparian vegetation of the Dudhganga River (Table

1). Tree diversity was unevenly distributed along the longitudinal gradient of the river, with species richness and community composition varying distinctly across the upstream, midstream, and downstream sections. Overall, 55 species (68.8%) were native, while the remaining species were classified as non-native / invasive, indicating a predominance of indigenous flora with increasing invasion pressure downstream. Notably, 21 tree species were common to all three zones, reflecting their broad ecological tolerance and adaptability to varying riparian conditions.

Upstream zone

The upstream section supported the highest tree species richness (62 species), comprising 47 native and 15 non-native / invasive species. This zone is characterized by higher elevation, steeper gradients, well-drained rocky to sandy soils, and higher water flow velocity. Dominant species such as *Salix tetrasperma*, *Syzygium salicifolium*, *Vitex leucoxylon*, *Terminalia arjuna*, and *Syzygium cumini* were well adapted to seasonal water fluctuations, moderate water stress, and occasional flooding. The strong dominance of native species reflects relatively intact riparian habitats, greater connectivity with adjoining natural vegetation, and lower levels of anthropogenic disturbance, favoring the persistence and regeneration of indigenous tree taxa.

Midstream zone

The midstream section recorded 50 tree species, including 29 native and 21 non-native / invasive species, representing a transitional phase in both species composition and disturbance intensity. This zone is characterized by moderate water flow, wider floodplains, and nutrient-rich alluvial soils. Species such as *Ficus hispida*, *Pongamia pinnata*, *Ficus racemosa*, and *Mitragyna parvifolia* were prevalent, benefiting from periodic inundation and higher soil moisture availability. Compared to the upstream zone, the midstream section exhibited a noticeable increase in invasive species, suggesting moderate anthropogenic influence from agriculture, settlements, and riverbank modifications, which create favorable conditions for invasion.

Downstream zone

The downstream section exhibited the lowest species richness (30 species), comprising 17 native and 13 non-native / invasive species. This zone is characterized by lower elevation, reduced flow velocity, prolonged inundation, and greater accumulation of fine sediments and organic matter. Flood-tolerant and disturbance-

adapted species such as *Neltuma juliflora*, *Bambusa bambos*, *Vachellia nilotica*, and *Syzygium salicifolium* were common. The relatively high proportion of invasive species in this zone reflects intensified human pressure, habitat fragmentation, and altered hydrological regimes, which collectively weaken native species dominance and facilitate invasive plant establishment.

Overall pattern

Across the riparian continuum, a clear longitudinal trend was observed, marked by a gradual decline in total tree species richness and native species dominance from upstream to downstream, accompanied by a proportional increase in invasive species. This zonation underscores the combined influence of hydrology, soil characteristics, elevation, flood frequency, and anthropogenic disturbance in structuring riparian tree communities along the river ecosystem.

Dominant families of the riparian region

Fabaceae was the most dominant family, contributing 10 species (18.2%) to the native riparian tree diversity of the Dudhganga River, followed by Moraceae with eight species (14.5%). Lamiaceae and Malvaceae were represented by four species each (7.3% each), while Rubiaceae contributed three species (5.5%). The remaining 20 families collectively accounted for 26 species (47.3%), indicating a broad but uneven distribution of native tree diversity across families (Figure 2).

Range-restricted taxa

A significant portion of the tree species was found to be restricted to specific sections of the riparian area. The upstream region has 28 unique species, representing 35.90% of the total restricted species. The midstream region had 19 restricted species, accounting for 24.34% of the total. Despite having a lower overall species richness, the downstream regions still contained three species exclusive to this area, comprising 11.11% of the restricted species. These findings emphasize the importance of conserving all three sections of the riparian ecosystem to maintain the overall biodiversity and protect unique genetic resources.

At-risk taxa

Out of the 80 tree species recorded in the riparian zone of the river Dudhganga, 20 species have a limited presence, with only a few individuals found in a single locality. Currently, two species, *Santalum album* and *Dalbergia latifolia*, are classified as 'Vulnerable'

Table 1. Checklist of tree species recorded in the riparian vegetation of the Dudhganga River.

	Riparian tree species	Family	Vernacular name	IUCN Red List status	Biogeographic status	Regional distribution
1	<i>Acacia auriculiformis</i> A.Cunn. ex Benth.	Fabaceae	Australian Babul	--	I	U, M, D
2	<i>Albizia lebbek</i> (L.) Benth.	Fabaceae	Siris Tree	LC	N	M, D
3	<i>Albizia procera</i> (Roxb.) Benth.	Fabaceae	Pandhra Shirish	LC	N	U
4	<i>Alstonia scholaris</i> (L.) R.Br.	Apocynaceae	Saptarni, Satvin	LC	N	M
5	<i>Annona reticulata</i> L.	Annonaceae	Ram-Phal	--	I	M
6	<i>Artocarpus heterophyllus</i> Lam.	Moraceae	Phans	NA	N	U, M
7	<i>Azadirachta indica</i> A.Juss.	Meliaceae	Kadu Limb	--	I	D
8	<i>Bambusa bambos</i> (L.) Voss	Poaceae	Kashti	NA	N	U, M, D
9	<i>Bambusa multiplex</i> (Lour.) Raeusch. ex Schult.f.	Poaceae	Bet	NA	N	U, M
10	<i>Bambusa vulgaris</i> Schrad. ex J.C.Wendl.	Poaceae	Bet	--	I	U
11	<i>Bauhinia purpurea</i> L.	Fabaceae	Rakta Kanchan	LC	N	U
12	<i>Bergera koenigii</i> L.	Rutaceae	Kadipatta	NA	N	U
13	<i>Bombax ceiba</i> L.	Malvaceae	Kate-Saver	LC	N	U, M
14	<i>Caryota urens</i> L.	Arecaceae	Fish-Tail Palm	LC	N	U
15	<i>Cassia fistula</i> L.	Fabaceae	Bahava	LC	N	U
16	<i>Ceiba pentandra</i> (L.) Gaertn.	Malvaceae	Safed Simal	--	I	U
17	<i>Citrus × limon</i> (L.) Osbeck	Rutaceae	Limbu	--	I	U, M
18	<i>Cocos nucifera</i> L.	Arecaceae	Narel	--	I	U, M,
19	<i>Cordia dichotoma</i> G.Forst.	Boraginaceae	Bhokar	LC	N	U, M, D
20	<i>Crateva magna</i> (Lour.) DC.	Capparaceae	Katarlingad	NA	N	U, M, D
21	<i>Dalbergia latifolia</i> Roxb.	Fabaceae	Biti, Sissu	VU	N	U, M
22	<i>Diospyros montana</i> Roxb.	Ebenaceae	Lohari	NA	N	U
23	<i>Erythrina variegata</i> L.	Fabaceae	Pangira	LC	N	U
24	<i>Eucalyptus rudis</i> Endl.	Myrtaceae	Nilgir	--	I	U, M, D
25	<i>Eucalyptus tereticornis</i> Sm.	Myrtaceae	Nilgir	--	I	U, M
26	<i>Ficus benghalensis</i> L.	Moraceae	Wad	NA	N	U, M
27	<i>Ficus hispida</i> L.f.	Moraceae	Bokeda, Kala-Umber	LC	N	U, M,
28	<i>Ficus microcarpa</i> L.f.	Moraceae	Kamarup	LC	N	M
29	<i>Ficus racemosa</i> L.	Moraceae	Umber	LC	N	U, M, D
30	<i>Ficus religiosa</i> L.	Moraceae	Pimpal	LC	N	U, M
31	<i>Ficus tinctoria</i> G.Forst.	Moraceae	Datir	LC	N	U
32	<i>Ficus virens</i> Aiton	Moraceae	Bassari, Gandhaumbara	LC	N	M
33	<i>Gliricidia sepium</i> (Jacq.) Kunth	Fabaceae	Undirmari	--	I	M
34	<i>Glochidion ellipticum</i> Wight	Phyllanthaceae	Bhoma	NA	N	U
35	<i>Gmelina arborea</i> Roxb. ex Sm.	Lamiaceae	Sivan	NA	N	U
36	<i>Grewia serrulata</i> DC.	Malvaceae	Kawri	NA	N	U
37	<i>Grewia tiliifolia</i> Vahl	Malvaceae	Dhaman	NA	N	U
38	<i>Holarrhena pubescens</i> Wall. ex G.Don	Apocynaceae	Indrajav	LC	N	U
39	<i>Jatropha integerrima</i> Jacq.	Euphorbiaceae	Jangli Erand	--	I	M, D
40	<i>Kydia calycina</i> Roxb.	Malvaceae	Warang	NA	N	U
41	<i>Lasiosiphon glaucus</i> Fresen.	Thymelaeaceae	Datpadi, Rametha	--	I	U
42	<i>Leucaena leucocephala</i> (Lam.) de Wit	Fabaceae	Subabul	--	I	U, M, D
43	<i>Macaranga peltata</i> (Roxb.) Müll.Arg.	Euphorbiaceae	Chandwar	NA	N	U

	Riparian tree species	Family	Vernacular name	IUCN Red List status	Biogeographic status	Regional distribution
44	<i>Mallotus philippensis</i> (Lam.) Müll.Arg.	Euphorbiaceae	Shendri	NA	N	U, M, D
45	<i>Mappia nimmoniana</i> (J.Graham) Byng & Stull	Icacinaceae	Amrita	NA	N	U
46	<i>Memecylon umbellatum</i> Burm.f.	Melastomataceae	Anjani	LC	N	U
47	<i>Mangifera indica</i> L.	Anacardiaceae	Amba	DD	N	U, M, D
48	<i>Mitragyna parvifolia</i> (Roxb.) Korth.	Rubiaceae	Kalam	NA	N	U, M
49	<i>Monoon longifolium</i> (Spreng.) Kosterm.	Annonaceae	Devdar	NA	N	M, D
50	<i>Moringa oleifera</i> Lam.	Moringaceae	Shevga	NA	N	U
51	<i>Morus alba</i> L.	Moraceae	Tuti	--	I	M
52	<i>Musa × paradisiaca</i> L.	Musaceae	Kel	--	I	U, M
53	<i>Neltuma juliflora</i> (Sw.) Raf.	Fabaceae	Vilayati Babul	--	I	D
54	<i>Neolamarckia cadamba</i> (Roxb.) Bosser	Rubiaceae	Kadamba	NA	N	U
55	<i>Oroxylum indicum</i> (L.) Kurz	Bignoniaceae	Broken Bones Tree	NA	N	U
56	<i>Pandanus furcatus</i> Roxb.	Pandanaceae	Bongi	NA	N	U
57	<i>Peltophorum pterocarpum</i> (DC.) Backer ex K.Heyne	Fabaceae	Peela Gulmohar	--	I	M
58	<i>Pithecellobium dulce</i> (Roxb.) Benth.	Fabaceae	Vilayatichinch	--	I	U, M, D
59	<i>Pongamia pinnata</i> (L.) Pierre	Fabaceae	Karanj	LC	N	U, M, D
60	<i>Psidium guajava</i> L.	Myrtaceae	Peru	--	I	U, M, D
61	<i>Ricinus communis</i> L.	Euphorbiaceae	Yerand	--	I	U, M, D
62	<i>Salix tetrasperma</i> Roxb.	Salicaceae	Walunj	NA	N	U, M, D
63	<i>Samanea saman</i> (Jacq.) Merr.	Fabaceae	Gulabi Siris	--	I	U, M, D
64	<i>Santalum album</i> L.	Santalaceae	Chandan	--	I	M
65	<i>Senegalia rugata</i> (Lam.) Britton & Rose	Fabaceae	Shikakai	NA	N	U
66	<i>Senna siamea</i> (Lam.) H.S.Irwin & Barneby	Fabaceae	Kassod	--	I	U, M, D
67	<i>Sesbania sesban</i> (L.) Merr.	Fabaceae	shewarie	LC	N	M, D
68	<i>Swietenia macrophylla</i> King	Meliaceae	Mahogany	--	I	M
69	<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	Jambhul	NA	N	U, M, D
70	<i>Syzygium salicifolium</i> J.Graham	Myrtaceae	Pan Jambhul	NA	N	U, M, D
71	<i>Tamarindus indica</i> L.	Fabaceae	Chinch	--	I	M, D
72	<i>Tamarix ericoides</i> Rottler & Willd.	Tamaricaceae	Kadsherni	NA	N	D
73	<i>Tectona grandis</i> L.f.	Lamiaceae	Sagwan	NA	N	U, M
74	<i>Terminalia arjuna</i> (Roxb. ex DC.) Wight & Arn.	Combretaceae	Arjun	NA	N	U, M, D
75	<i>Terminalia paniculata</i> B.Heyne ex Roth	Combretaceae	Kinjāl	NA	N	U
76	<i>Vachellia nilotica</i> (L.) P.J.H.Hurter & Mabb.	Fabaceae	Babhal	NA	N	U, M, D
77	<i>Vitex leucoxydon</i> L.f.	Lamiaceae	Sheras Songarbi	NA	N	U, M
78	<i>Vitex negundo</i> L.	Lamiaceae	Nirgundi	NA	N	U, M, D
79	<i>Wendlandia heynei</i> (Schult.) Santapau & Merchant	Rubiaceae	Til	NA	N	U
80	<i>Woodfordia fruticosa</i> (L.) Kurz	Lythraceae	Dhayati, Dowari	LC	N	U

DD—Data Deficient | EN—Endangered | NA—Not Assessed | LC—Least Concern | NT—Near Threatened | VU—Vulnerable | U—Upstream | M—Midstream | D—Downstream | I—Invasive | N—Native.

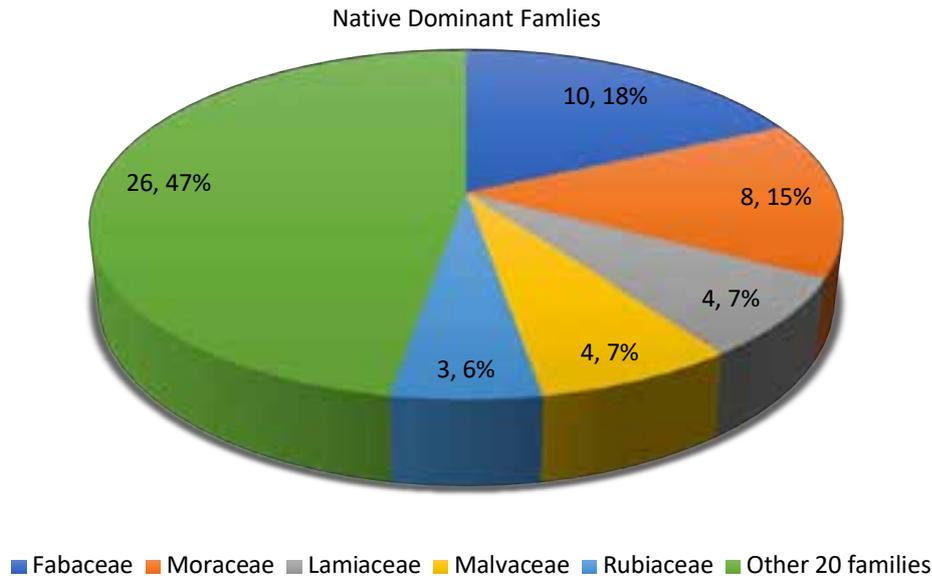


Figure 2. Native species per family in the tree flora.

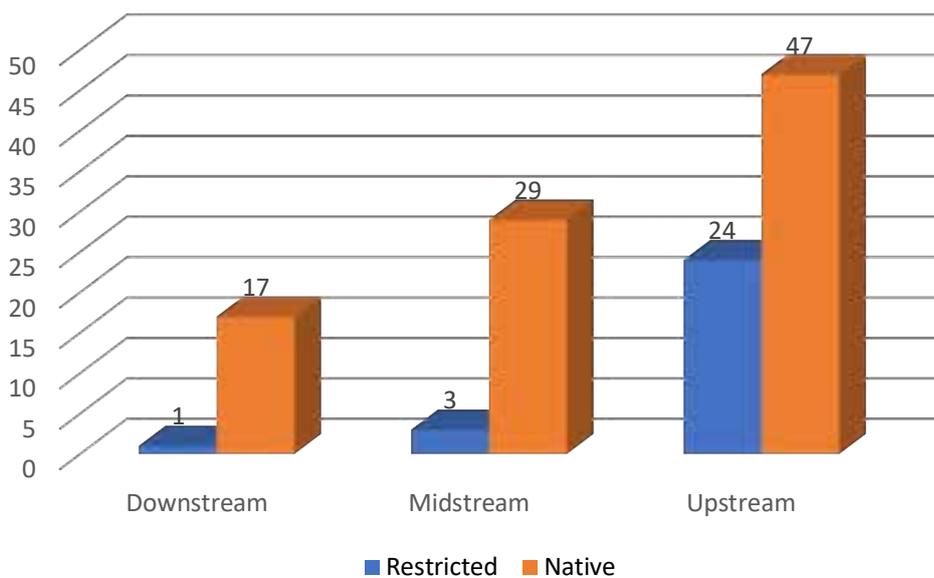


Figure 3. Zonal distribution of restricted tree species.

(IUCN 2024), while *Swietenia macrophylla* is listed as 'Endangered' according to IUCN conservation status (IUCN 2024). Twenty-four species are categorized as 'Least Concern', and *Mangifera indica* L. is classified as 'Data Deficient' (Table 1). The flagship species of the Western Ghats, *Memecylon umbellatum*, is also present in the study area and found to be restricted to the upstream area. The zonation of riparian vegetation along the river belt was evident, with distinct species distributions observed across all three sections.

Non-native trees

Non-native species such as *Eucalyptus rudis*, *Neltuma juliflora*, *Pithecellobium dulce*, and *Senna siamea* are prevalent in the riparian vegetation of the river Dudhganga. Twenty-five non-native tree species, including several invasive taxa, were recorded along the Dudhganga River. Although riparian zones are typically characterised by rapid successional dynamics, the proliferation of invasive species can disrupt natural regeneration processes by suppressing native species establishment, thereby posing a potential long-term

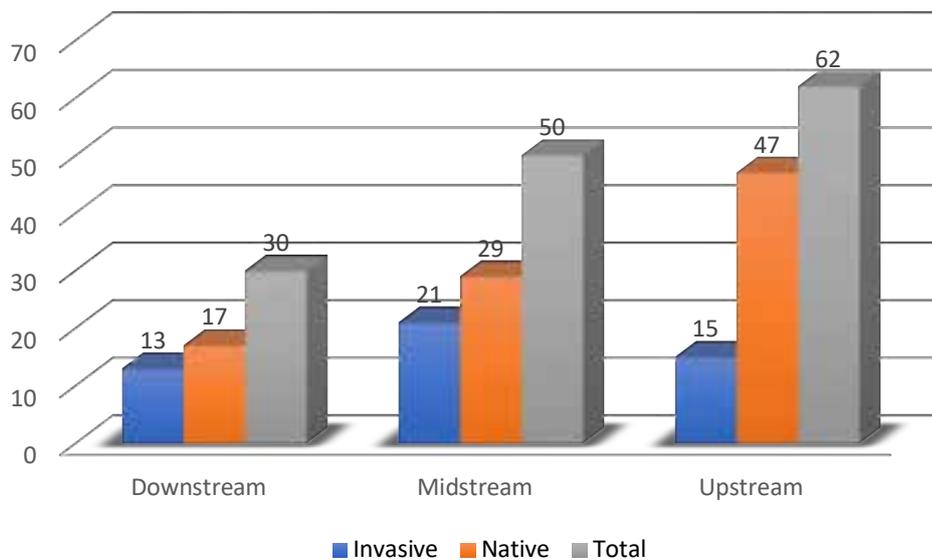


Figure 4. Zonal distribution of native and invasive species.

threat to riparian forest structure and stability. These invasive species can also disrupt watershed hydrology and riparian ecosystems (Richardson et al. 2007). Many researchers have reported that the riparian zone has served as a corridor for the introduction and spread of invasive species, primarily due to long-term human activities (Johansson et al. 1996; Hood & Naiman 2000; Tockner & Stanford 2002). Invasive tree species pose a significant threat to the ecological balance of riparian vegetation, often outcompeting native flora and altering habitat dynamics. Along the river Dudhganga, species such as *Neltuma juliflora*, *Pithecellobium dulce*, *Leucaena leucocephala*, and *Acacia auriculiformis* have established small but dominant micro populations. Among these, *Pithecellobium dulce* and *Neltuma juliflora* exhibit particularly aggressive invasion patterns, forming multiple micro populations that dominate certain localities. Notably, a large patch of *Pithecellobium dulce* is present at the confluence of the river Dudhganga and the river Krishna near Sangam Math, June Danwad. Their rapid spread can impact native biodiversity, water availability, and soil composition, making their management crucial for maintaining the ecological integrity of the riparian ecosystem.

Threats

Riparian vegetation is experiencing gradual degradation due to factors such as deforestation, soil erosion, mining and construction activities. Areas with intensive agriculture and other human activities, including water extraction, logging, grazing by cattle,

and recreation are particularly vulnerable to vegetation loss. Studies have demonstrated that the loss of riparian vegetation can have significant ecological consequences, including a reduction in biodiversity. Riparian corridors serve as vital habitats for numerous animal species and breeding grounds for many migratory birds. Anthropogenic disturbances can significantly alter the structure and composition of these plant communities (Mohan & Joseph 2024).

The study identified several anthropogenic and natural threats along the Dudhganga River, varying across the upper, mid, and lower courses.

Upstream—located in the higher altitudes with relatively undisturbed forested areas, the primary threats include deforestation due to agricultural expansion, encroachment, and soil erosion on steep slopes. Occasional illegal logging and grazing pressures also impact vegetation stability.

Midstream—this zone experiences moderate human interference, with threats such as sand and gravel mining, habitat fragmentation due to infrastructure development, and pollution from agricultural runoff. The conversion of riparian land for settlements and farming is gradually altering species composition.

Downstream—the most impacted zone, facing severe threats from industrial pollution, urban expansion, and intensive agricultural activities. Unregulated wastewater discharge, sand dredging, and invasive species proliferation have significantly degraded riparian vegetation, leading to biodiversity loss and altered hydrological patterns.

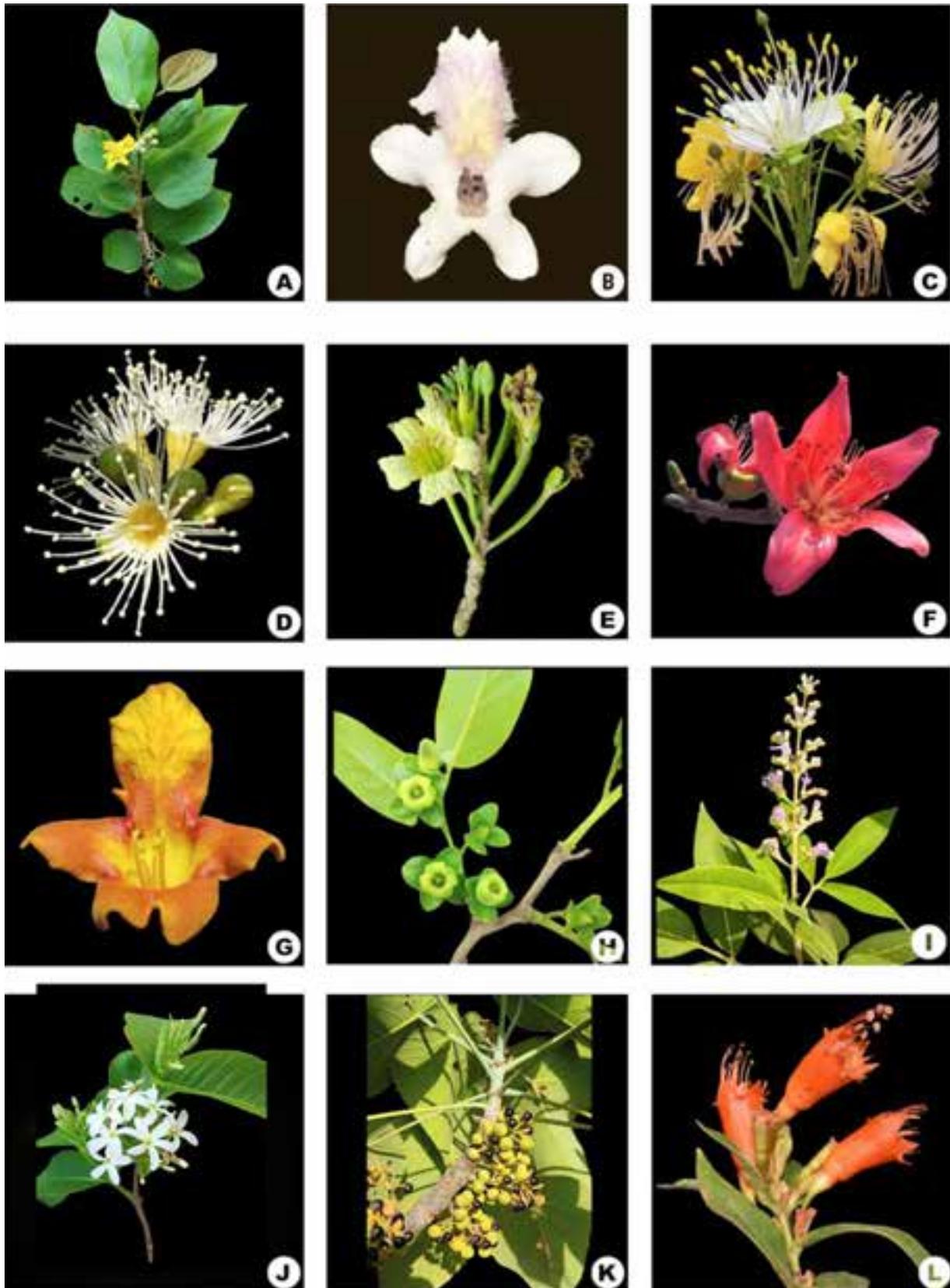


Image 4. Flowering diversity: A—*Grewia tiliifolia* | B—*Vitex leucoxydon* | C—*Crateva magna* | D—*Syzygium salicifolium* | E—*Oroxylum indicum* | F—*Bombax ceiba* | G—*Gmelina arborea* | H—*Diospyros montana* | I—*Vitex negundo* | J—*Holarrhena pubescens* | K—*Macaranga peltata* | L—*Woodfordia fruticosa*. © Sachin Chavan.

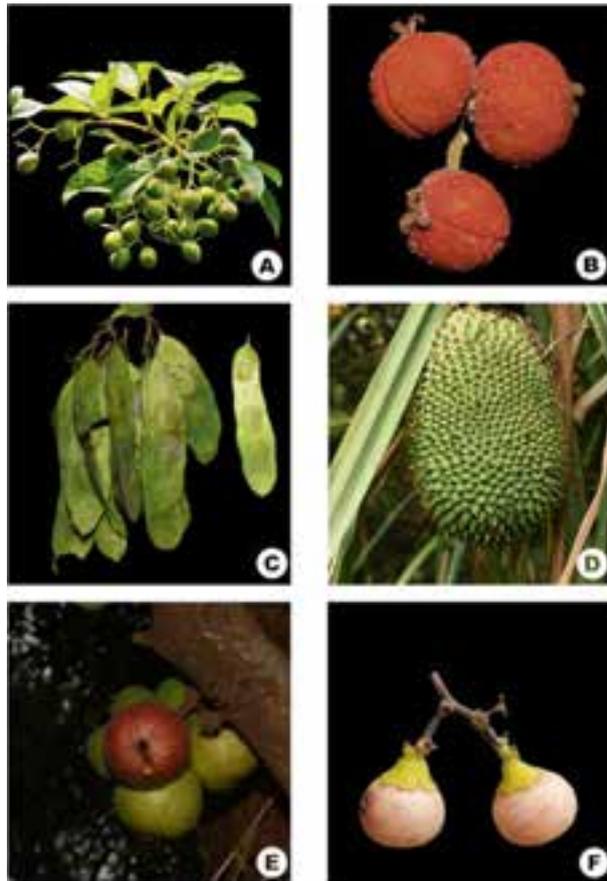


Image 5. Fruit diversity: A—*Vitex leucoxydon* | B—*Mallotus philippensis* | C—*Dalbergia latifolia* | D—*Pandanus furcatus* | E—*Ficus racemosa* | F—*Cordia dichotoma*. © Sachin Chavan.

CONCLUSION

These findings highlight the rich arboreal diversity of the Dudhganga riparian zone, with notable economically valuable species, including *Mappia nimmoniana* and *Pongamia pinnata*, underscoring its ecological significance and the need for continued conservation efforts. Notably, the Fabaceae family emerged as the most predominant, with *Ficus* standing out as the most diverse genus within the study area. Therefore, it is imperative to prioritize conservation efforts to safeguard this rich biodiversity along the river Dudhganga by encouraging local communities to participate in afforestation, especially planting native species, sustainable water management, and riparian conservation efforts including regulating anthropogenic activities.

REFERENCES

- Chazdon, R.L., R.K. Colwell, J.S. Denslow & M.R. Guariguata (1998). Statistical methods for estimating species richness of woody regeneration in primary and secondary rain forests of NE Costa Rica. *Forest Ecology and Management* 112: 1–10.
- Condit, R. (1998). *Tropical Forest Census Plots: Methods and Results from Barro Colorado Island, Panama and a Comparison with Other Plots*. Springer-Verlag, Berlin, 211 pp.
- Cooke, T. (1903). *The Flora of the Presidency of Bombay: Vol. 1*. Taylor and Francis, London, 645 pp. <https://www.biodiversitylibrary.org/item/42327>
- Flowers of India (2024). <http://www.flowersofindia.net>. Downloaded on 23.viii.2024.
- Gotelli, N.J. & R.K. Colwell (2001). Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. *Ecology Letters* 4: 379–391.
- Gregory, S.V., F.J. Swanson, W.A. McKee & K.W. Cummins (1991). An ecosystem perspective of riparian zones. *BioScience* 41(8): 540–551.
- Gunaga, S., N. Rajeshwari & R. Vasudeva (2013). Tree diversity and disturbance of kaan forests: relics of a community-protected climax vegetation in the Central Western Ghats. *Tropical Ecology* 54(1): 117–131.
- Hood, W.G. & R.J. Naiman (2000). Vulnerability of riparian zones to invasion by exotic vascular plants. *Plant Ecology* 148: 105–114.
- Hynes, H.B.N. (1970). *The Ecology of Running Waters*. University of Toronto Press, Toronto, 555 pp.
- IUCN (2024). The IUCN Red List of Threatened Species (Version 2022-1). <https://www.iucnredlist.org>. Downloaded on 01.viii.2024.
- Jain, S.K. & R.R. Rao (1977). *A Handbook of Field and Herbarium Methods*. Scholarly Publications, New Delhi, 157 pp.
- Johansson, M.E., C. Nilsson & E. Nilsson (1996). Do rivers function as corridors for plant dispersal? *Journal of Vegetation Science* 7(5): 593–598. <https://doi.org/10.2307/3236309>
- Korse, K.H. & G. Krishnakumar (2006). Riparian flora of perennial rivers in the Western Ghats: floristic diversity, ecological uniqueness and conservation strategies. *Proceedings of Lake 2006*. Indian Institute of Science, Bengaluru, 12 pp.
- Lacerda, A.V.D., N. Nordi, F.M. Barbosa & T. Watanabe (2005). Levantamento florístico do componente arbustivo-arbóreo da vegetação ciliar na bacia do rio Taperoá, PB, Brasil. *Acta Botanica Brasílica* 19(3): 647–656. <https://doi.org/10.1590/S0102-33062005000300027>
- Liunima, V., L. Banilodu & C.G. Semiun (2022). Composition and diversity of riparian vegetation of the Talau river, Belu Regency. *Edubiotik: Jurnal Pendidikan, Biologi dan Terapan* 7(02): 167–176. <https://doi.org/10.33503/ebio.v7i02.1934>
- Mohan, S.N. & S. Joseph (2024). Disturbances on riparian vegetation: a comprehensive review. *International Journal of Research and Review* 11(4): 200–208. <https://doi.org/10.52403/ijrr.20240422>
- Mohite, S. & S.A. Mane (2020). Phytosociological study of riparian trees in the Panchganga River system at Kolhapur District, Maharashtra, India. *Journal of Aquatic Biology & Fisheries* 8 (Special Issue): 62–67.
- Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. da Fonseca & J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403: 853–858. <https://doi.org/10.1038/35002501>
- Naiman, R.J. & H. Décamps (1997). The ecology of interfaces: Riparian zones. *Annual Review of Ecology and Systematics* 28(1): 621–658. <https://doi.org/10.1146/annurev.ecolsys.28.1.621>
- Naiman, R.J., H. Décamps & M. McClain (2005). *Riparia: Ecology, Conservation, and Management of Streamside Communities*. Academic Press, Burlington, MA, 448 pp. <https://doi.org/10.1016/B978-012663315-3/50003-4>
- Nilsson, C., R. Jansson & U. Zinko (1997). Long-term responses of river-margin vegetation to water-level regulation. *Science* 276(5313): 798–800. <https://doi.org/10.1126/science.276.5313.798>
- POWO (2024). Plants of the World Online. Royal Botanic Gardens, Kew. <https://www.plantsoftheworldonline.org>. Downloaded on

- 01.viii.2024.
- Rao, K.S. & D. Kumar (2024).** India Flora Online. <https://indiaflora-ces.iisc.ac.in/herbsheet.php?id=3517&cat=13>. Downloaded on 01.viii.2024.
- Richardson, D.M., P.M. Holmes, K.J. Esler, S.M. Galatowitsch, J.C. Stromberg, S.P. Kirkman, P. Pyšek & R.J. Hobbs (2007).** Riparian vegetation: degradation, alien plant invasions, and restoration prospects. *Diversity and Distributions* 13(1): 126–139. <https://doi.org/10.1111/j.1366-9516.2006.00314.x>
- Singh, N.P. & S. Karthikeyan (eds.) (2000).** *Flora of Maharashtra State: Dicotyledones – Vol. 1*. Botanical Survey of India, Calcutta, 898 pp.
- Stevens, P.F. (2001 onwards).** Angiosperm Phylogeny Website (Version 14, July 2017). <http://www.mobot.org/MOBOT/research/APweb/>.
- Downloaded on 01.viii.2024.
- Sumarmi, S., T.I. Pakarti, L.F.P. Destari, N. Aini & A. Tanjung (2022).** Preservation of vegetation diversity to maintain the riparian ecosystem of the Sampean watershed. *KnE Social Sciences* 7(16): 140–151. <https://doi.org/10.18502/kss.v7i16.12168>
- Tockner, K. & J.A. Stanford (2002).** Riverine flood plains: present state and future trends. *Environmental Conservation* 29: 308–330.
- UNESCO (2012).** Western Ghats (India) (No. 1342rev). UNESCO World Heritage Centre. <https://whc.unesco.org/en/list/1342/> Downloaded on 07.viii.2024.
- Yadav, S.R. & M.M. Sardesai (2002).** *Flora of Kolhapur District*. Shivaji University, Kolhapur, India, 680 pp.



Flower bud growth, mortality rate, and population structure of *Sapria himalayana* Griffith f. *albovinosa* Banziger & Hansen (Rafflesiaceae) in a subtropical forest, northeastern India

K. Shamran Maring¹ & Athokpam Pinokiyo²

^{1,2}Department of Botany, Dhanamanjuri University, Imphal, Manipur 795001, India.

¹puikans1996@gmail.com (corresponding author), ²pinkithokpam@gmail.com

Abstract: *Sapria himalayana* Griff. f. *albovinosa* Banziger & Hansen (Rafflesiaceae) is rare and endemic to northeastern Thailand, Vietnam, and Manipur, with a short flowering season ranging from late October to late November, due to which its detailed phenology is poorly understood. To protect this valuable taxon from extinction threats, monitoring the growth of flower buds is crucial. The objectives of this study were to analyse the growth of flower buds at various developmental stages, the mortality rate, and the population structure of *Sapria himalayana* f. *albovinosa*. The buds were monitored, vertically photographed, and measurements of the plant buds and flowers were recorded for every observation. The present study resulted in the flower bud growth having six different developmental stages, namely the copule, copule-bract transition, bract, bract-perigone transition (BPT), perigone, and anthesis stage, with a diameter range of 0.3–2.3 cm, 2.4–4.0 cm, 4.1–5.5 cm, 5.6–6.1 cm, 6.2–8.1 cm, and 16–20 cm, respectively. The population was dominated by the copule stage in the initial observation, while it was dominated by the perigone and anthesis stages in the final observation, which indicated that the optimal flowering season was from late October to late November. A total of 58 flower buds were recorded, out of which 24.13% of flower buds were dead without reaching maturity due to fungal infections and were injured due to anthropogenic interventions. Hence, the information on the growth of buds, flower development stages and their mortality rate is vital for taxonomic studies, field monitoring, and conservation purposes.

Keywords: Anthesis, anthropogenic, bract, conservation, copule, crucial, endemic, extinction, perigone, rare.

Maringa: *Sapria himalayana* Griffith f. *albovinosa* Banziger & Hansen (Rafflesiaceae) tou ung paar a beimak taangni Northeastern Thailand, Vietnam and Manipur bi khyum heirou tomcha paar. Heirou paar ayei paar nei kheen heiri beimakni thum hoilei. Kheen heiri Kumthil tangla rou youbi Bilwa tangla bil tomcha paar. Ngam heini paar ayei maram ra thimi rapni langaidui muchangmak. Ayei paar a beimakni taangni pha ngam hoibini paar aya lhaipang aro mitmak nanung kalthung ngaakthung nei tloubam khat khoi. Heitounei ngamrou paar ayei kat um younei kheen rou youbini paar kim kham bil thi thung silthung nei tloubam heirou paar ayei khi nei changchap heirou paar ayei mashing (population) thi nei tloubam a namyerwa asiyei thilhak thi thut nei che aro shershang thutlei. Paar heiyei paarna bi heirou photo kou kanlhonni paar heiyei tang mandi (diameter in cm) namyerwa markhe bi langaidui thilhakur. Asiyei thilhak thi thut yei kheen heirou paar heiyei kat um yei kheen youbi kim kham bil heirou tangkak lailai paar heiyei tang malnamak thruktam mupha. Heirap heiri copule, copule-bract transition, bract, bract-perigone transition, perigone heirou anthesis stages with a diameter range of 0.3-2.3 cm, 2.4-4.0 cm, 4.1-5.5 cm, 5.6-6.1 cm and 16-20 cm, respectively. Paar heiyei mashing thithut youri nei tangla heirou ri copule stage ni duichi, heitoubini dongwai rou tangla heirou ri perigone heirou anthesis stages ya khintam ni duichi. Heiyei mukna ri paar heiri Kumthil tangla rou youbi Bilwa tangla bil matachani paar he paarnei kheen hoilei. Bi heirou ri paar mashing somnga-le-chot (58) paar muphalei, heiyei rilla saruk 24.13% paarshomakni hukur. Paar he mapung phamakni paarshomakni hukur heiyei ngamri rikwai dawurbi chulwurnei hoilei heirou lhaipang thimi ni paar leina bi heirou manshok nei ngam khat khi hoilei. Thakrei minlhangkur heirap namyer wani ngam hoibini beimak taangei pha paar awa lhangaidui thilhak ngakthung-silthung bini paar aya lhaipangpal bi aro mitheimak kim heimaknung beimak lungkhohi tloubam khat hoilei.

Editor: Inocencio Buot Jr., University of the Philippines Los Banos, Laguna, Philippines.

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

Citation: Maring, K.S. & A. Pinokiyo (2026). Flower bud growth, mortality rate, and population structure of *Sapria himalayana* Griffith f. *albovinosa* Banziger & Hansen (Rafflesiaceae) in a subtropical forest, northeastern India. *Journal of Threatened Taxa* 18(2): 28287–28295. <https://doi.org/10.11609/jott.9964.18.2.28287-28295>

Copyright: © Maring & Pinokiyo 2026. 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: None.

Competing interests: The authors declare no competing interests.

Author details, Author contributions, Acknowledgements & Ethics and field compliance statement: See end of this article.



INTRODUCTION

Sapria himalayana Griffith f. *albovinosa* Banziger & Hansen (Banziger et al. 2000), a new form of the Hermit's Spittoon, is rare and endemic to the northeastern Thailand and Vietnam Lang Biang plateau, but a new distribution is recorded from India at the evergreen sub-tropical forest of Machi Village, Tengnoupal District, Manipur (Maring & Pinokiyo 2024). It is differentiated from the typical form in having white dotted warts more or less evenly distributed on the entire wine-red perigone lobe instead of having sulphur-yellow dotted warts on blood-red perigone lobes (Banziger et al. 2000). All members of the genus *Sapria* are distinctive and narrowly host-specific plants belonging to the family Rafflesiaceae. The typical form of *Sapria himalayana* is rare throughout its range from northeastern India, southwestern China, Thailand, Myanmar, to Vietnam. Being a member of the holoparasitic plant family, Rafflesiaceae, and growing on various species of *Tetrastigma* (Vitaceae), it is a little-understood species (Wu & Raven 2003; Nikolov & Davis 2017; Tran et al. 2018; Tanaka et al. 2019; Syiemiong et al. 2022). In India, the typical species of *Sapria* was first reported from the tropical wet evergreen forests of the Mishmi Hills of Lohit District by William Griffith in 1847 and later from the Aka Hills in Kameng District by Norman Loftus Bor in 1938 (Andreas & Jis 2014; Borah & Ghosh 2018). This species is the largest root parasitic angiosperm, having a host-specific relationship with the plant genus *Tetrastigma* of the Vitaceae family.

Tetrastigma bracteolatum (Wallich) Planchon and *T. serrulatum* (Roxb.) Planchon have been reported as the host plant of *Sapria* in Namdapha Park (Arunachalam et al. 2004; Borah & Ghosh 2018). The members of the Rafflesiaceae have a reduced vegetative body among all angiosperms (Nikolov et al. 2014). *Sapria* is well distinguished from the other two genera of Rafflesiaceae, *Rafflesia* R.Br. ex Thomson and *Rhizanthus* Dumort by the presence of 10 perianth lobes in two whorls (Meijer 1997; Nikolov & Davis 2017; Tanaka et al. 2019).

At present, the genus *Sapria* consists of four species, viz., *S. himalayana* Griffith, which has the widest distribution range among them (Wu & Raven 2003; Bendiksby et al. 2010; Ahmad et al. 2020; Syiemiong et al. 2022), with one form, *S. himalayana* Griffith f. *albovinosa* Banziger & Hansen (Banziger et al. 2000), endemic to northeastern Thailand, *S. poilanei* Gagnep, endemic to Cambodia (Gagnepian 1941), *S. ram* H Banziger & B Hansen, endemic to Thailand (Banziger & Hansen 1997), and *S. myanmerensis* Nob. Tanaka, Nagam, Tagane & M.M. Aung, endemic to Myanmar

(Tanaka et al. 2019). *Sapria himalayana* has lost about 44% of conserved genes in Eurosids that are enriched for functions like photosynthesis, plastid organisation, defence, stress response, and nutrient assimilation. It has also gained some genes from its hosts through horizontal gene transfer, showing extreme genome remodelling under parasitism (Cai et al. 2021).

In Rafflesiaceae, previous studies on the bud development, growth rate, mortality, flower phenology, life history and autecology have been conducted for several species of *Rafflesia*, where only a few were found for *Sapria* and none for *Rhizanthus*. Hidayati et al. (2006) and Nais (2001) studied *Rafflesia patma*, *R. keithii*, and *R. pricei* for their similar rapid later-stage bud growth and low bloom success. Sofiyanti et al. (2007) reconstructed the life cycle of *Rafflesia hasseltii*, which was redrawn from Nais (2001). Galindon et al. (2016) and Tolod et al. (2020) reported a new species of *Rafflesia*, namely *R. consueloae* and studied its first flower and fruit development and life history. Susatya (2020) reported the growth of the flower bud, life history and population structure of *R. arnoldii*. Recent work by Rambey et al. (2023) reported on the population and ecology of the endangered *R. meijeri* in Indonesia. Also, Wee et al. (2024) reported the bud development, flower phenology and life history of *R. cantleyi*. The earlier works on ecology, status, and conservation of *Sapria himalayana* Griffith, was done by Elliot (1992). Also, Arunachalam et al. (2004) reported on the population and conservation of *S. himalayana* Griffith, in Namdapha National Park, Arunachal Pradesh, India.

Currently, there is little information regarding the studies on the flower bud growth of *S. himalayana* Griffith f. *albovinosa* Banziger & Hansen (2000), even though it is essential for conservation purposes. The main objectives of this study were to observe the flower bud growth at different developmental stages of *S. himalayana* f. *albovinosa* and the change of its population structure with respect to the growth of the flower bud.

MATERIALS AND METHODS

Study area

The study was conducted in the subtropical evergreen rainforest of Machi Village, situated under the jurisdiction of Tengnoupal District, Manipur, northeastern India. The site is located at a latitude of 24.504° N and a longitude of 94.143° E with an elevation of about 1,477 m. Machi Village is about 62 km away from the capital city, Imphal,

of the state of Manipur. The motorable road to the village is in poor condition, with several potholes and uneven surfaces and is also prone to landslides during the monsoon season, which could completely block the way. The present research site is located in a remote area of the village, also there is no motorable road to the site as shown in Image 1. The village is situated in the Indo-Myanmar biodiversity hotspot, which is a region rich in floral and faunal diversity, and harbours numerous interesting and endangered species. The vicinity of the village is inhabited by the Maring Tribe, one of the indigenous tribes of Manipur, which has rich ethnic cultures and traditions. The people of the village practice jhumming cultivation as their main source of income. The entire region of the village crossing the International Indo-Myanmar Road harbours the tropical rainforest to sub-tropical evergreen, and deciduous forests. It is also an ideal habitat for various rare and endangered carnivores and birds.

Field data collection

The present study was carried out from July to November 2024 at the study site. *Sapria himalayana* f. *albovinosa* were found at the community evergreen forest of Machi Village, Manipur, and were monitored,

and the measurements of the plant buds and flowers were recorded for every observation at the study site. The observation was made at two-week interval for five months. The flower buds of *Sapria himalayana* f. *albovinosa* are found only on the roots of the host plant, *Tetrastigma*, unlike many species of *Rafflesia* found on both roots and climbing stems of the hosts. They are covered by the litter of the forest floors, making it difficult to observe at first sight. All the buds were discovered through thorough searching, scrutinising, and by removing forest litter in search of other buds whenever a bud was first detected at the study site. As such, this may prove to be an inevitable study limitation and may underestimate the actual population. While there were cases in which some undetected below-ground buds escaped the initial observation, when they grew bigger and surfaced above ground later, they were eventually added to the monitoring system (Wee et al. 2024). The diameters of *Sapria* buds and flowers were measured by the widest diameter length (Elliot 1992). The observation of this study was limited to the visible structure of bud and flower developmental stages of *Sapria himalayana* f. *albovinosa* (Susatya 2020). Each bud and flower was vertically photographed, and its diameter was measured at every observation (Nais 2001; Kamal et al. 2022). The

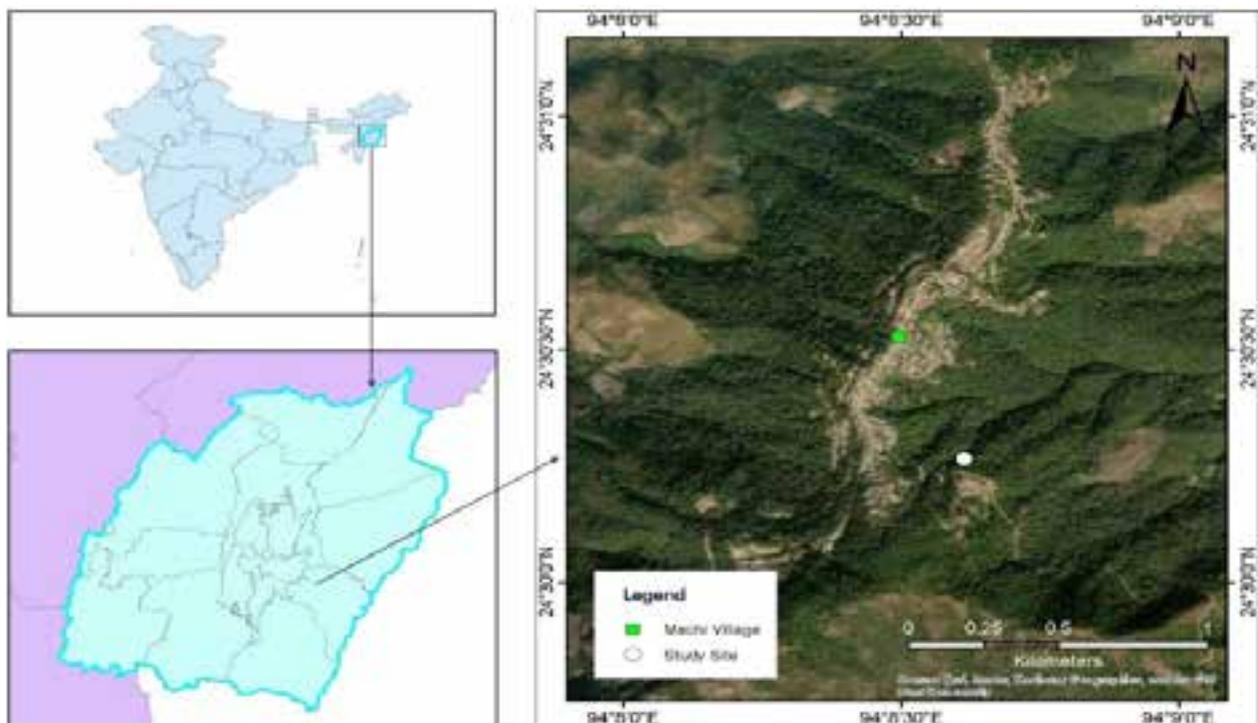


Image 1. A map showing the study area in the sub-tropical evergreen forest of Machi Village, Manipur, northeastern India. The white circle represents the location of *Sapria himalayana* f. *albovinosa*.

bud development was then categorized into different size classes for further analysis, following the methods by Nais (2001), Susatya (2020), and Tolod et al. (2020). The dead buds of all bud diameter sizes were recorded for every observation. Then the mortality rate of the *Sapria* buds was calculated by the formula given below (Nowak et al. 2004).

$$\text{Mortality rate} = \frac{\text{Total number of dead buds}}{\text{Total number of buds recorded}} \times 100$$

The abiotic parameters, such as air temperature, wind speed, humidity, soil temperature, soil moisture, soil pH, and light intensity, at the present study site were recorded using a thermometer and a 4-in-1 soil tester.

Statistical analysis

A non-linear regression analysis was conducted to obtain the exponential growth model equation and coefficient of determination (R^2) for the observed bud diameters to demonstrate a J-shaped bud growth curve. Also, correlation analysis was performed to examine the relationships between environmental factors such as ambient temperature, humidity, wind speed, soil pH, soil temperature, light intensity, and mortality of the buds for a five-month observation. A chi-square test was conducted to assess the bud stage distribution shifts across time of the observation. All statistical analyses were performed using SPSS version 26.

RESULTS AND DISCUSSIONS

Flower bud growth of *Sapria himalayana* f. *albovinosa*

The present study showed that the life cycle of *Sapria himalayana* f. *albovinosa* is complex, as most members of Rafflesiaceae have two parts – the invisible and visible parts (Hidayati et al. 2006; Nais 2001; Kamal et al. 2022). The invisible part includes the inoculation and germination of *Sapria*'s seed occurring inside its host plant roots, whereas the visible part is the emergence of the flower bud, mature bud, and anthesis. The visible part consists of several flower buds developing and is also the only plant structure that is exposed to external environmental factors. Therefore, flower buds at different sizes exhibited different growth rates and developmental stages. The observation limited to only the visible parts of the life cycle resulted in six different development stages of the flower, which were then categorized into the copule, copule-bract transition (CBT), bract, bract-perigone transition (BPT), perigone and anthesis stages (Image 2). Copule, bract

and perigone stages were defined by 80–100% of the images of vertically photographed bud respectively covered by copule, bract, and perigone structures. A bud was categorized into CBT, if it grew between copule and bract stages, and the coverage of the images of the photographed bud by the bract reached 40% to 80%. Meanwhile, a bud was grouped into BPT, if it grew between the bract and the perigone stages, with coverage of the images of the photographed bud by the perigone reaching 40% to 80%. Any bud with less than 40% of the coverage by either bract or perigone was also categorised into either copule or bract stages (Susatya 2020). The anthesis stage occurred once during the observation at the bud's diameter range of 16–20 cm. The observation resulted that the diameter range of copule, CBT, bract, BPT, and perigone stages respectively were 0.3–2.3 cm, 2.4–4.0 cm, 4.1–5.5 cm, 5.6–6.1 cm, and 6.2–8.1 cm (Table 1). The growth development of *Sapria*'s bud was not in a discrete pattern, where one stage was replaced completely by the next stage. The same growth development was also observed in the typical species of *Sapria* (Elliot 1992). It consisted of a series of overlapping development stages, where before one stage was complete, the following stage had already developed. It was a basic reason why transition stages were introduced in this research. The first visible structure was copule, which was basically the bark of the host plant root covering the actual *Sapria* structure. The first visible structure of *S. himalayana* f. *albovinosa* at Machi had the diameter range of 0.3–2.3 cm (Table. 1). The start of the development of the inner structures of *Sapria* was still unknown though it is needed to be studied whether all the inner structures had been developed in the copule stage or not. The inner structures in the species of *Rafflesia* had already developed in the copule stage while observing its dead bud of 6 cm diameter (Susatya 2020). As the bud grew, the upper copule started to crack to allow the first true structure of the *Sapria* or bract to be visible. Bract was originally pastel

Table 1. The range of diameters of buds and flowers according to its stages.

Name of bud stages	Range of bud diameter (cm)
Copule	0.3–2.3 cm
Copule-bract transition (CBT)	2.4–4.0 cm
Bract	4.1–5.5 cm
Bract perigone transition (BPT)	5.6–6.1 cm
Perigone	6.2–8.1 cm
Anthesis	16–20 cm

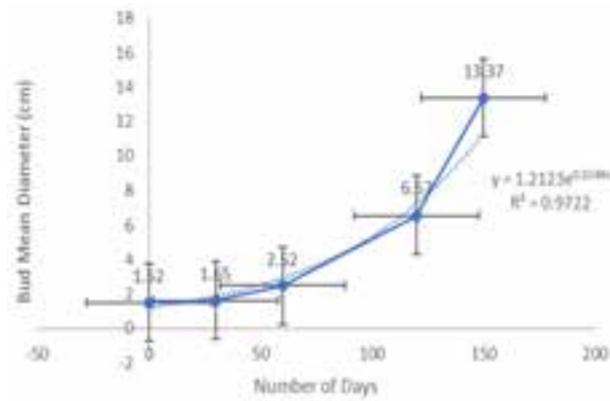


Figure 1. Growth curve of *Sapria himalayana* f. *albovinosa* during the five-month observation.

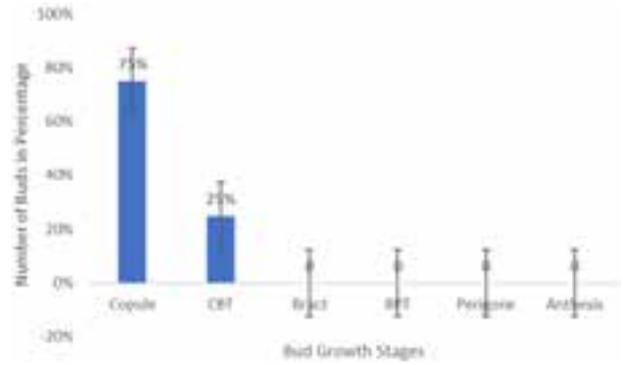


Figure 2. The population structure of *Sapria himalayana* f. *albovinosa* in August.

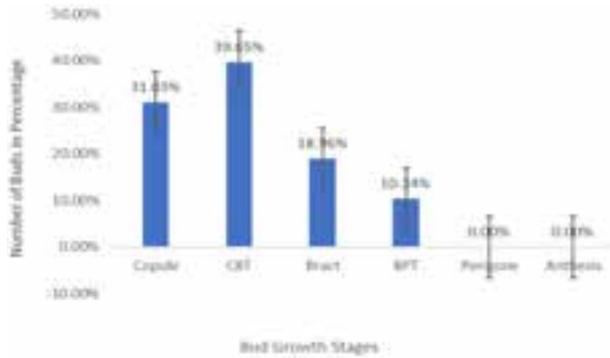


Figure 3. The population structure of *Sapria himalayana* f. *albovinosa* in September.

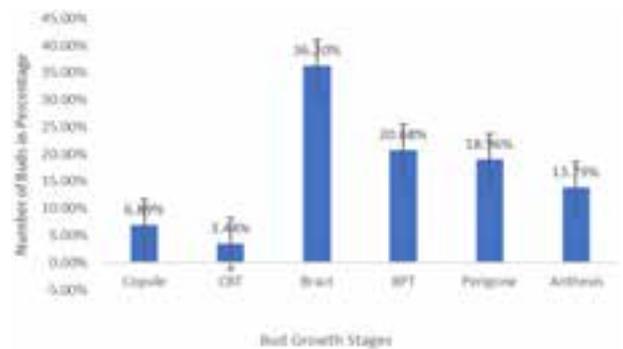


Figure 4. The population structure of *Sapria himalayana* f. *albovinosa* in October.

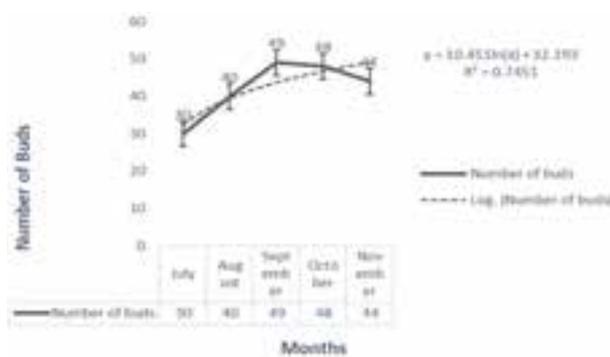


Figure 5. Population growth curve showing number of buds with respect to the month of observation.

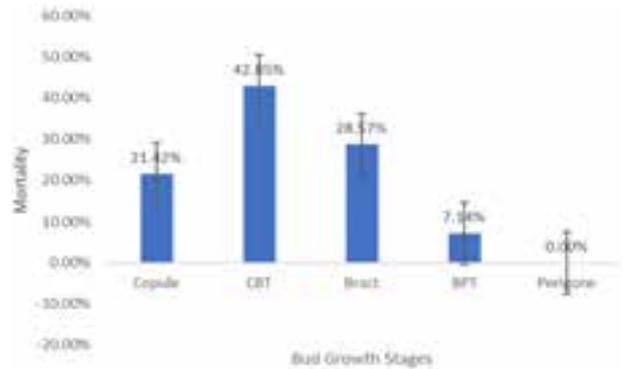


Figure 6. The bud mortality rate of *Sapria himalayana* f. *albovinosa* according to its growth development stage.

pink and white colour, but eventually turned black as it grew older. The bract was gradually replaced by a pale pink perigone stage consisting of buds with a diameter range of 6.2–8.1 cm (Image 2). The bract consisted of two series of five imbricate and whorled scales (Elliot 1992). The pinkish perigone lobes of the bud indicated anthesis to occur within 3–4 days. The field observation

showed that when the upper layer of the perigone lobe was slightly raised, then the anthesis would take place within 2–3 days, and lasted between 4–5 days. All flower structures decomposed within a month after flowering. The column was the only female structure that did not decompose and further developed into mature fruit (Elliot 1992). As the flowers opened, they emitted an



Image 2. The flower bud development stages of *Sapria himalayana* f. *albovinosa*: A—copule stage | B—copule-bract transition stage (CBT), copule (cp) gradually replaced by bracts (br) | C—bract stage, a stage where a visible bud is a bract, a similar structure to a sepal | D—bract-perigone transition stage (BPT), a stage where bracts are still largely recognized (br) and gradually replaced by perigone (pr) | E—perigone stage, a visible bud at this stage is all covered by the perigone, a similar structure to a petal | F—Anthesis stage, a flower fully bloomed. © K. Shamran Maring.

odour similar to that of rotting meat, which lasted for 2–3 days. Within 3–4 days after opening, flowers started to darken and eventually turned black. As the flowers turned black, all the plant structures shrank. The base of male flowers and their attachment to the host shriveled rapidly and eventually detached from their host roots. In female flowers, the perigone tube and lobes, diaphragm and disk shriveled as in males, but the column, ovary and surrounding tissues at the base of the column remained alive (Elliot 1992). The base of the perigone tube swelled and remained white externally for about two months after flower opening. This structure constituted the fruit of *S. himalayana* f. *albovinosa*, though a detailed study on the fruits and seeds dispersal is required. The growth rate of flower buds at earlier stages was found to be very slow, while the buds at older stages showed higher growth rates. Therefore, the growth curve of the flower bud showed a typical J-shaped growth curve or an exponential growth curve (Figure 1).

The non-linear regression equation $y = 1.2123 e^{0.0149x}$ and $R^2 = 0.9722$ was obtained by plotting the

bud mean diameter across the number of observed days. The bud diameter grows by about 1.49% of its current size in every additional day. This means the bud diameter doubles roughly every 46–47 days under the observed growth pattern. Therefore, on the initial day of observation, the bud starts at about 1.5 cm in diameter, then, by about 150 days, they grow to above 13 cm in diameter, matching the measured data points (Figure 1).

The present study showed that *S. himalayana* Griffith f. *albovinosa* found at Machi comparatively has crateriform and bilobed or multilobed rammenta apices in male and female flowers, respectively, while the Vietnamese taxon is also bilobed or multilobed (female) or crateriform (male) (Maring & Pinokiyo 2024). The diameter of the crest disk and aperture of the diaphragm for the Machi individuals are 3.4–3.5 cm and 1.9–2.0 cm, respectively. The *S. himalayana* Griffith f. *albovinosa* from Machi Village has a comparatively larger floral span (13–20 cm diameter) than the *S. himalayana* Griffith f. *albovinosa* (11–16 cm diameter) (Banziger et al. 2000), *S. myanmerensis* (10 cm) (Tanaka et al. 2019), *S. poilanei*

Table 2. The abiotic factors of *Sapria himalayana* f. *albovinosa* in Machi evergreen rainforest, Manipur.

Abiotic factors	July	August	September	October	November
Mean air temperature (°C)	23	23	22	20	19
Mean humidity (%)	80	84	86	72	67
Mean wind speed (m/s)	1.60	1.66	1.66	1.66	1.66
Mean soil temperature (°C)	19	24	21	20	18
Mean soil pH	6.5	6.5	6.0	5.5	5.5
Mean soil moisture	Wet+	Wet	Wet	Normal	Dry
Mean light intensity (lux)	90	90	100	100	100

(6.5–12 cm), and *S. ram* (5.5–11 cm) (Banziger & Hansen 1997).

Population structure of *Sapria himalayana* f. *albovinosa*

The population status of *S. himalayana* f. *albovinosa* is very small when compared to the other higher plants. Also, the population of this endemic infraspecific taxon is much smaller than that of the typical species of *Sapria* (Elliot 1992). The initial observation in the month of July showed that the total population is 100% dominated by the copula stage. At the second observation in August, the population structure was 75% copule and 25% copule bract transition (CBT) Stage (Figure 2). Meanwhile, buds at CBT were fewer due to the changes in the flower bud development stage. Larger stages, such as bract and BPT, were observed respectively with 18.96% and 10.34% in September (Figure 3). Within three months, the population structure was significantly changed due to the mortality, new recruitment, and growth of buds from one stage to the next growth development stages. The population structure of this period was shifted toward bract and BPT. During the next observation, in the month of October, the population structure interestingly exhibited all six bud stages, where the bract stage dominated it with 36.20% (Figure 4). The pattern of population structure appeared to be opposite to the initial one, where the perigone and anthesis stages were exhibited with 18.96% and 13.79%, respectively. In the last month's observations, the population structure was dominated by full bloom/anthesis and after-blooming flowers. The flower buds were found at their full bloom stage in October to December, but the optimal flowering season is from late October to late November. During the initial period of research, the number of flower buds increased gradually due to the new recruitment of the buds, while the population size decreased in the later months of observation. This condition could be due to insufficient nutrients for the population of the flower bud to maintain its viability and complete its life cycle

(Figure 5). A chi-square test revealed a significant shift in bud stage distribution across time ($X^2 = 202.997$, $df = 20$, $p = 2.87 \times 10^{-32}$), this indicates that the proportion of buds at different developmental stages varied markedly with time and did not remain constant over time.

In the five-month observation, a total of 58 flower buds were recorded, out of which 28 buds were recruits and 14 buds died without reaching maturity. The causes of the bud mortality were fungal infections and injuries from anthropogenic interventions, where the injured parts of flower buds were immediately followed by a rotting process that led to the bud mortality. All losses occurred at buds belonging to the copule, CBT, bract, and BPT with copule-bract transition (CBT) stage showing the highest mortality rate of 42.85% (Figure 6). The population structure of *S. himalayana* f. *albovinosa* showed a mortality rate of 24.13%, which is much lower when compared to the mortality rate 40% of the typical species (Elliot 1992). Although the mortality rate is much lower than that of the typical species of *Sapria*, the total population status of this endemic taxon is very small, indicating an alarming signal concerning the future population of *S. himalayana* f. *albovinosa*.

Abiotic factors of *Sapria himalayana* f. *albovinosa* habitat

The ambient temperature of the study site was found to decrease from 23°C (July) to 19°C (November), which is due to the onset of the winter season. The air humidity ranges 67–86 %, and the light intensity was found to be very low, ranging 90–100 lux, probably be caused by the dense canopy cover (Table 2). The high air humidity and low light intensity play a vital role in the existence of *S. himalayana* f. *albovinosa* because the plant preferably grows on the understory of forest floors. Also, in the present study, the flower buds showed higher mortality rates as the light intensity increased. There is a moderately strong positive correlation between light intensity and bud mortality, with a correlation value

(r) = 0.6123, indicating that higher mortality rates are generally associated with higher light intensity. Whereas, the soil pH showed a moderate negative correlation (r = -0.326) with the bud mortality. In Table 2, the soil pH ranges 5.5–6.5, and it is classified as acidic, while the soil temperature ranges 18–24 °C. The soil moisture showed very wet conditions in July, which could be due to the monsoon season, while the soil was dry in November, which could be due to the winter season. Therefore, the abiotic parameters of the environment play an important role in the growth of flower buds as well as in the population dynamics of this rare endemic taxon.

CONCLUSION

The flower bud growth of *Sapria himalayana* f. *albovinosa* has six developmental stages consisting of the copule, CBT, bract, BPT, perigone, and anthesis stages. More detailed studies on the growth rate, mortality rate and population structure of this rare parasitic plant are required to determine the fate of the young flower buds and to estimate its complete life cycle. The findings from this study are useful in intensifying the knowledge of this rare parasitic plant that is becoming vulnerable and is on the brink of extinction. Due to its rarity, ongoing habitat loss, vandalism of existing colonies, and high degree of host specificity, various conservation actions are required to protect this taxon. Hence, the information on the growth of buds, different flower bud developmental stages, and population status is vital for taxonomic studies, field monitoring, and conservation purposes.

REFERENCES

- Ahmad, A., A. Kumar, G.S. Rawat & G.V. Gopi (2020). Recent record of a threatened holoparasitic plant *Sapria himalayana* Griff. In Mehao Wildlife Sanctuary, Arunachal Pradesh, India. *Journal of Threatened Taxa* 12(10): 16399–16404. <https://doi.org/10.11609/jott.5168.12.10.16399-16401>
- Andreas, H. & S. Jis (2014). *Sapria himalayana* Griffith, an endangered species from the Mishmi Hills, Dilbang Valley, Arunachal Pradesh. *Indian Forester* 140(4): 433–434.
- Arunachalam, A., D. Adhikari, R. Sarmah, M. Majumder & M.L. Khan (2004). Population and conservation of *Sapria himalayana* Griffith. in Namdapha National Park, Arunachal Pradesh, India. *Biodiversity and Conservation* 13: 2391–2397. <https://doi.org/10.1023/B:BOC.0000048488.94151.f8>
- Bänziger, H. & B. Hansen (1997). Unmasking the real identity of *Sapria poilanei* Gagnepain emend., and description of *Sapria ram* sp. n. (Rafflesiaceae). *Natural History Bulletin of the Siam Society*. 45: 149–170.
- Bänziger, H., B. Hansen & K. Kreetiyutanont (2000). A new form of the hermit's spittoon, *Sapria himalayana* Griffith f. *albovinosa* Bänziger and Hansen f. nov. (Rafflesiaceae), with notes on its ecology. *Natural History Bulletin Siam Society* 48: 213–219.
- Bendiksby, M., T. Schumacher, G. Gussarova, J. Nais, M. Kamarudin, S. Nery, D. Madulid, S.A. Smith & T.J. Barkman (2010). Elucidating the evolutionary history of the southeast Asian, holoparasitic, giant-flowered Rafflesiaceae: Pliocene vicariance, morphological convergence and character displacement. *Molecular Phylogenetic and Evolution* 57(2): 620–633. <https://doi.org/10.1016/j.ympev.2010.08.005>
- Borah, D. & D. Ghosh (2018). *Sapria himalayana*: The Indian cousin of the world's largest flower. *Resonance* 23(4): 479–489. <https://doi.org/10.1007/s12045-018-0637-8>
- Cai, L., B.J. Arnold, Z. Xi, D.E. Khost, N. Patel, C.B. Hartmann, S. Manickam, S. Sasirat, L.A. Nikolov, S. Mathews, T.B. Sackton & C.C. Davis (2021). Deeply altered genome architecture in the endoparasitic flowering plant *Sapria himalayana* Griff. (Rafflesiaceae). *Current Biology* 31(5): 1002–1011. <https://doi.org/10.1016/j.cub.2020.12.045>
- Elliot, S. (1992). Status, ecology and conservation of *Sapria himalayana* Griffith. (Rafflesiaceae) in Thailand. *Journal of Wildlife Thailand* 2(1): 44–52.
- Galindon, J.M.M., P.S. Ong & E.S. Fernando (2016). *Rafflesia consueloae* (Rafflesiaceae), the smallest among giants; a new species from Luzon Island, Philippines. *PhytoKeys* (61): 37–46. <https://doi.org/10.3897/phytokeys.61.7295>
- Gagnepain, F. (1941). U neespece nouvelle d'un genre monotype: *Sapria*. *Notulae systematicae* (Paris) 9: 144–145. <https://biostor.org/reference/266807>
- Hidayati, S.N., W. Meijer, J.M. Baskin & J.L. Walck (2006). A contribution to the life history of the rare Indonesian holoparasite *Rafflesia patma* (Rafflesiaceae). *Biotropica* 32(3): 408–414. <https://doi.org/10.1111/j.1744-7429.2000.tb00487.x>
- Kamal, S.H.S., M.N. Suratman, S. Khamis, A.N.N. Hassan & M.S. Mohammad (2022). Growth rate, mortality rate and life cycle of *Rafflesia azlanii* and *R. cantleyi* in Belum-Temenggor Forest Complex, Perak, Malaysia. *Sains Malaysiana* 51(4): 943–957. <https://doi.org/10.17576/jsm-2022-5104-01>
- Maring, K.S. & A. Pinokoyo (2024). A taxonomic note on *Sapria himalayana* f. *albovinosa* Bänziger and B. Hansen from India. *Indian Forester* 150(3): 292–295. <https://doi.org/10.36808/if/2024/v150i3/169401>
- Meijer, W. (1997). Rafflesiaceae. In: Kalkman, C., D.W. Kirkup, H.P. Nootboom, P.F. Stevens & W.J.J.O. de Wilde (eds.). *Flora Malesiana*, Series I: Spermatophyta, 13: 1–42. Rijksherbarium/HortusBotanicus, Leiden, The Netherlands.
- Nais, J. (2001). *Rafflesia* of the world. Sabah Park in association with Natural History Publications (Borneo) Sdn. Bhd., Kota Kinabalu Smith RL. 1986. *Elements of Ecology*. Harper & Row Publishers. New York, 243 pp.
- Nikolov, L.A. & C.C. Davis (2017). The big, the bad, and the beautiful: Biology of the world's largest flowers. *Journal of Systematics and Evolution* 55(6): 516–524. <https://doi.org/10.1111/jse.12260>
- Nikolov, L.A., P.B. Tomlinson, S. Manickam, P.K. Endress, E.M. Kramer & C.C. Davis (2014). Holoparasitic Rafflesiaceae possess the most reduced endophytes and yet give rise to the world's largest flowers. *Annals of Botany* 114(2): 233–242. <https://doi.org/10.1093/aob/mcu114>
- Nowak, D.J., M. Kuroda & D.E. Crane (2004). Tree mortality rates and tree population projections in Baltimore, Maryland, USA. *Urban Forestry & Urban Greening* 2(3): 139–147. <https://doi.org/10.1078/1618-8667-00030>
- Rambey, R., N. Saputra, I.F. Rambe, B. Nopandry, S. Zunaidi, E.L. Christy, T. Setiawan, Y. Affuddin & A. Hartanto (2023). Population and autecology of the endangered *Rafflesia meijeri* in Batang Gadis National Park, Indonesia. *Biodiversitas* 24(3): 1845–1852. <https://doi.org/10.13057/biodiv/d240360>
- Sofiyanti, N., K. Mat-Salleh, P. Puruwanto & E. Syahputra (2007). The Note on Morphology of *Rafflesia hasseltii* Surigar from Bukit Tiga Puluh National Park, Riau. *Biodiversitas* 8(4): 257–261. <https://doi.org/10.13057/biodiv/d080402>

- Susatya, A. (2020).** The growth of flower bud, life history, and population structure of *Rafflesia arnoldii* (Rafflesiaceae) in Bengkulu, Sumatra, Indonesia. *Biodiversitas* 21(2): 792–798. <https://doi.org/10.13057/biodiv/d210247>
- Syiemiong, P., S.S. Chaturvedi, T. Arbenz & T. Tamaş (2022).** A note on *Sapria himalayana* (Griffith 1844) (Rafflesiaceae) from Jaintia Hills (Meghalaya, India). *Biodiversity Journal* 13(1): 73–78. <https://doi.org/10.31396/Biodiv.Jour.2022.13.1.73.78>
- Tanaka, N., H. Nagamasu, S. Tagane, M.M. Aung, A.K. Win & P.P. Hnin (2019).** Contributions to the flora of Myanmar IV: A new species and a newly recorded taxon of the genus *Sapria* (Rafflesiaceae). *Taiwania* 64(4): 357–362. <https://doi.org/10.6165/tai.2019.64.357>
- Tolod, J.R., J.M.M. Galindon, R.R. Atienza, M.V. Duya, E.S. Fernando & P.S. Ong (2020).** Flower and Fruit Development and Life History of *Rafflesia consueloae* (Rafflesiaceae). *Philippine Journal of Science* (150): 321–334. <https://doi.org/10.56899/150.sl.23>
- Trần, H.D., H.T. Lu’u, Q.D. Nguyen, H.C. Nguyen, P. Athen & K.M. Wong (2018).** Identification, sexual dimorphism and aspects of the natural history of *Sapria himalayana* (Rafflesiaceae) on Vietnam’s Lang Biang Plateau. *Botanical Studies* 59: 29. <https://doi.org/10.1186/s40529-018-0243-9>
- Wee, S.K., S.B. Tan, S.H. Tan & B.K.B. Lee (2024).** Bud development, flower phenology and life history of holoparasitic *Rafflesia cantleyi*. *Journal of Plant Research* (137): 423–443. <https://doi.org/10.1007/s10265-024-01522-7>
- Wu, Z. & P.H. Raven (2003).** *Flora of China, No.5 Science Press*. Beijing and Missouri Botanical Garden Press, St. Louis, 505 pp.
- Author details:** K. SHAMRAN MARING is currently pursuing PhD degree at Dhanamanjuri University, Manipur, working on the angiosperm flora of Tengnoupal District, Manipur. Her research focuses on plant taxonomy, primarily concentrating on floristic, ecological studies, and biodiversity conservation. PROF. ATHOKRAM PINOKIYO is currently working as the Head, Department of Botany, Dhanamanjuri University, Imphal, Manipur, and she has got a teaching experience for about 15 years. Her keen work is on taxonomy, diversity, ecology, and conservation of lichens (including Angiosperms). She has got a research experience of more than 24 years in the field of taxonomy (angiosperms and lichens).
- Author contributions:** KSM: conceptualised the study design, carried out the field surveys, data collection, data handling, data curation, photography, visualisation, statistical analysis, writing, review and editing of the manuscript. AP: supervised the research work and revision of the manuscript. Both authors read and agreed to the final manuscript.
- Ethics and field compliance statement:** The field research was conducted with prior permission from the relevant forest and community authorities. Prior informed consent was obtained from the Machi Village Authority, a Maring community, inhabiting the study area, with approval letter no. MCI-VA/85/2-2025 dated 03 October 2025. All field activities were conducted in accordance with the local customs, cultural values, community protocols, traditional knowledge and the ethical standards for research in the Machi Village community forest. No endangered or protected species were harmed or removed from their natural habitats during the course of this research. All observations and data collection were conducted in a non-destructive and minimally invasive manner consistent with best ecological research practices.
- Acknowledgements:** The authors are grateful to the Department of Botany, Dhanamanjuri University, Imphal, Manipur, for helpful advice and permission given for this study. K SHAMRAN MARING express gratitude to the National Fellowship for Higher Education for Schedule Tribe Students (NFST), bearing Award No. 202223-NFST-MAN-02118, Ministry of Tribal Affairs, Government of India, for the financial assistance provided. Also, thanks are due to the local people of Machi Village who gave a helpful hand in the field survey of the present study.

The Wildlife Organization
Threatened Taxa



Comparing three sampling techniques for surveying and monitoring arthropods in Moroccan agroecosystems

Hanae El Harche

University Ibn Tofail, Faculty of Sciences, Department of Biology, Laboratory of Plant, Animal and Agro-Industry Productions, Kenitra, Morocco.
hanae.elharche@yahoo.com

Abstract: Insect monitoring is a key component of sustainable and productive crop management. Among the various methods used to observe insect communities, pitfall trapping, visual searching, and sweep-net sampling of vegetation are the most widely applied. Selecting an appropriate sampling method is essential to obtain a comprehensive and accurate representation of species diversity. However, there is a notable lack of quantitative studies comparing the relative effectiveness of these techniques across different insect taxa in Morocco. In this study, the efficiency of three sampling strategies—pitfall trapping, mowing (sweep sampling of herbaceous plants), and visual searching—was evaluated to assess arthropod abundance and diversity in agroecosystems of northwestern Morocco. Between spring and summer 2020, a total of 69 species belonging to seven orders and 27 families were recorded. Pitfall traps and visual searching proved most effective for capturing ground beetles, whereas mowing herbaceous vegetation was particularly effective for collecting flying insects. These results highlight the importance of carefully selecting sampling techniques to ensure accurate estimates of arthropod diversity and abundance. Combining multiple methods provides a more comprehensive overview of arthropod communities in any ecosystem, including agroecosystems.

Keywords: Arthropod abundance, arthropod diversity, ground beetles, flying insects, insect sampling, Morocco, mowing vegetation, pitfall traps, sight hunting, sustainable crop management.

ملخص

تعد مراقبة الحشرات عنصراً أساسياً في إدارة المحاصيل المستدامة والمنتجة، ومن بين الطرق المختلفة المستخدمة لمراقبة مجتمعات الحشرات، فإن أكثرها استخداماً هي مصائد الحفر، والبحث الجري، والصيد باستخدام الشبكة. ويعد اختيار طريقة مناسبة لجمع العينات أمراً ضرورياً للحصول على صورة شاملة ودقيقة لتنوع الأصناف. غير أن هناك فجوة ملحوظة في الدراسات الكمية التي تقارن الفعالية النسبية لهذه التقنيات عبر مختلف أصناف الحشرات في المغرب. في هذه الدراسة، تم مقارنة كفاءة ثلاث طرق للصيد (مصائد الحفر، والبحث الجري، والصيد باستخدام الشبكة)، لتقييم وفرة وتنوع المفصليات في النظم الزراعية في شمال غرب المغرب. خلال الفترة الممتدة بين ربيع وصيف عام 2020، تم تسجيل ما مجموعه 69 نوعاً تنتمي إلى سبع فئات و27 عائلة. أثبتت مصائد الحفر والبحث الجري أنها الأكثر فعالية في اصطياد الخنافس الأرضية، في حين كان الصيد باستخدام الشبكة فعالاً بشكل خاص في جمع الحشرات الطائرة. تسلط هذه النتائج الضوء على أهمية اختيار تقنيات أخذ العينات بعناية لضمان تقديرات دقيقة لتنوع ووفرة المفصليات. يوفر الجمع بين طرق متعددة نظرة عامة أكثر شمولاً على مجتمعات المفصليات في أي نظام بيئي، بما في ذلك النظم البيئية الزراعية.

الكلمات المفتاحية

وفرة المفصليات، نوع المفصليات، خنافس الأرض، الحشرات الطائرة، جمع الحشرات، المغرب، الصيد باستخدام الشبكة، مصائد الحفر، الصيد الجري، الإدارة المستدامة للمحاصيل.

Editor: Shiju T. Raj, St. Joseph's College, Devagiri, Kozhikode, India.

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

Citation: El Harche, H. (2026). Comparing three sampling techniques for surveying and monitoring arthropods in Moroccan agroecosystems. *Journal of Threatened Taxa* 18(2): 28296–28306. <https://doi.org/10.11609/jott.9639.18.2.28296-28306>

Copyright: © El Harche 2026. 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: None.

Competing interests: The author declares no competing interests.

Author details: HANA EL HACHE, PhD, from Ibn Tofail University in Morocco, is a specialist in animal ecology, entomology, systematics, and faunistics. Her work focuses on understanding spatial and seasonal patterns of arthropod communities and assessing the influence of human activities on their distribution. She has played a pivotal role in creating a comprehensive checklist of terrestrial arthropods in agroecosystems of northwest Morocco, providing a valuable resource for biodiversity research and conservation.

Acknowledgements: I would like to thank the reviewers and editors for their careful reading of the manuscript and for their insightful comments and suggestions, which greatly improved the quality of this work.

INTRODUCTION

Over the past few decades, the importance of biodiversity in agroecosystems has been increasingly recognized, largely due to the ecosystem services it provides, including nutrient cycling, biotic regulation, pest control, and pollination (Gardarin et al. 2018; Galloway et al. 2021). Beneficial arthropods, such as crop pollinators and natural enemies of arthropod pests and weeds, play a central role in sustaining the ecological and economic productivity of these systems (Carvalho et al. 2010; Galloway et al. 2021). These services are a direct result of biological processes within the ecosystem, highlighting the intrinsic link between biodiversity and ecosystem functionality (Taraborelli et al. 2022). However, land use practices, particularly intensive agricultural management, pose significant risks to arthropod diversity and abundance (El Harche et al. 2023). Declines in insect populations, especially pollinators and their associated plant species, provide strong indirect evidence of these impacts (Biesmeijer et al. 2006).

Given the high rates of species loss caused by human activities (Dirzo et al. 2014), obtaining reliable estimates of species richness and abundance is critical for both biodiversity monitoring and conservation efforts. Standardized sampling methods are essential to minimize biases and ensure that assessments accurately reflect the composition of arthropod communities. While numerous insect sampling techniques exist, most are designed to target specific taxa or respond to particular stimuli, which limits their ability to capture the full diversity present in a habitat (Russo et al. 2011). This limitation is especially pronounced in highly diverse groups such as Coleoptera, where relying on a single method can provide an incomplete or misleading picture of the community (García-López et al. 2011).

To address this, entomologists frequently combine multiple sampling methods in species inventory and monitoring studies to improve the representativeness of collected data (Quinto et al. 2013). Using complementary techniques increases the likelihood of detecting both common and rare species and allows for a more accurate estimation of community abundance. The careful selection and combination of methods are therefore critical to avoid biased or insufficient assessments, which can arise from limited sampling effort or methodological constraints (Vasconcelos et al. 2014). By employing integrated sampling strategies, researchers can obtain comprehensive data on species richness and relative abundance, providing a stronger foundation for

ecological studies and conservation initiatives.

In this study, we aimed to evaluate the relative effectiveness of three distinct sampling methods for capturing insect assemblages in agricultural landscapes: (1) pitfall traps, (2) visual searching, and (3) mowing vegetation combined with sweep-netting. Specifically, we addressed three research questions: (1) Which of the three methods collects the highest number of species and individual insects? (2) Does species composition vary between methods? and (3) Are particular species more effectively captured by specific techniques? To answer these questions, we conducted a comprehensive, side-by-side comparison of the three methods, both individually and in combination, to identify the most effective approach for inventorying insect communities in agroecosystems

MATERIAL AND METHODS

Study area

The study took place in three localities in the Sidi Kacem zone, situated in northwestern Morocco at 34.217 °N & 5.700 °W. This zone is characterized by a semi-arid climate. In autumn, it can go down to 6°C, and during summer over 40°C.

Station 1 has a crop of *Vicia faba* L. (Fabaceae), commonly called beans, with a geographical location of 34.210 °N & 5.709 °W, on silty clay soil. Station 2, located at 34.245 °N & 5.704 °W, is a field of *Triticum aestivum* L. (Poaceae) commonly called soft wheat; it shares the same soil type as Station 1, silty clay. Station 3; 34.255 °N & 5.734 °W, comprises an alfalfa field with *Medicago sativa* L. (Fabaceae) and wasteland mainly covered by *Dittrichia viscosa* L. (Asteraceae) with a sandy clay loam.

Arthropod sampling

Insect sampling was conducted from spring to summer of 2020, employing three distinct techniques: pitfall, mowing, and sight hunting. Data was recorded twice a month, from March to September 2020. All insects were transferred into clean glass bottles or vials with alcohol (70–80 %) for further processing like pinning, drying, labelling, and identification in the laboratory.

Pitfall trap

Pitfall traps are a very effective and widely used method that is accepted for sampling epigeal arthropods, including beetles, spiders, and ants. Normally, the traps are placed on the ground to collect insects that live in

terrestrial environments. When an insect approaches the edge of the trap, theoretically, it becomes destabilized and then falls into the receptacle. Following the inspection of the container, captured insects are either collected or counted before the trap is reset. Pitfall traps are in wide use and represent a relatively inexpensive method for estimating populations of insects. Interestingly, a number of recent reviews have discussed the methods involved in pitfall trapping (Skvarla et al. 2014; Hohbein & Conway 2018). It is also not unusual for pitfall traps to inadvertently capture aerial insects. This statement is especially true for traps without a roof and painted in white or yellow colours (Buchholz & Hannig 2013). For the present study, we built pitfall traps using 1 L clear plastic containers, 10 cm in diameter and 17 cm in height, by placing them into the substrate so that their edges are level with the surrounding terrain. Plastic plates attached to rods were placed at the entrances to prevent the entry of rainwater and foreign materials. The soil around the entrance was then compressed to reduce any obstruction that may occur to smaller

arthropod species. The specimens collected were stored in glass containers with 70% alcohol, where they were kept until they were processed in the laboratory.

Sight hunting

Involved in looking for all the wildlife that was observable by the eyes, wherever it is likely to be located. This includes the ground surface, under rocks, the interior of rotting wood, vegetation, and the surface of tree trunks. When possible, efforts should be made to collect at least 20 to 25 specimens.

Mowing vegetation

Mowing vegetation by a sweep-netting is a commonly used method of sampling arthropods on vegetation. This method can collect a variety of arthropods, including lepidopterans as well as hemipterans, beetles, and dipterans. Sweep-netting has important advantages, including low equipment cost and the potential for a high yield of specimens per unit effort. A focused sweep was conducted utilizing an entomological net.

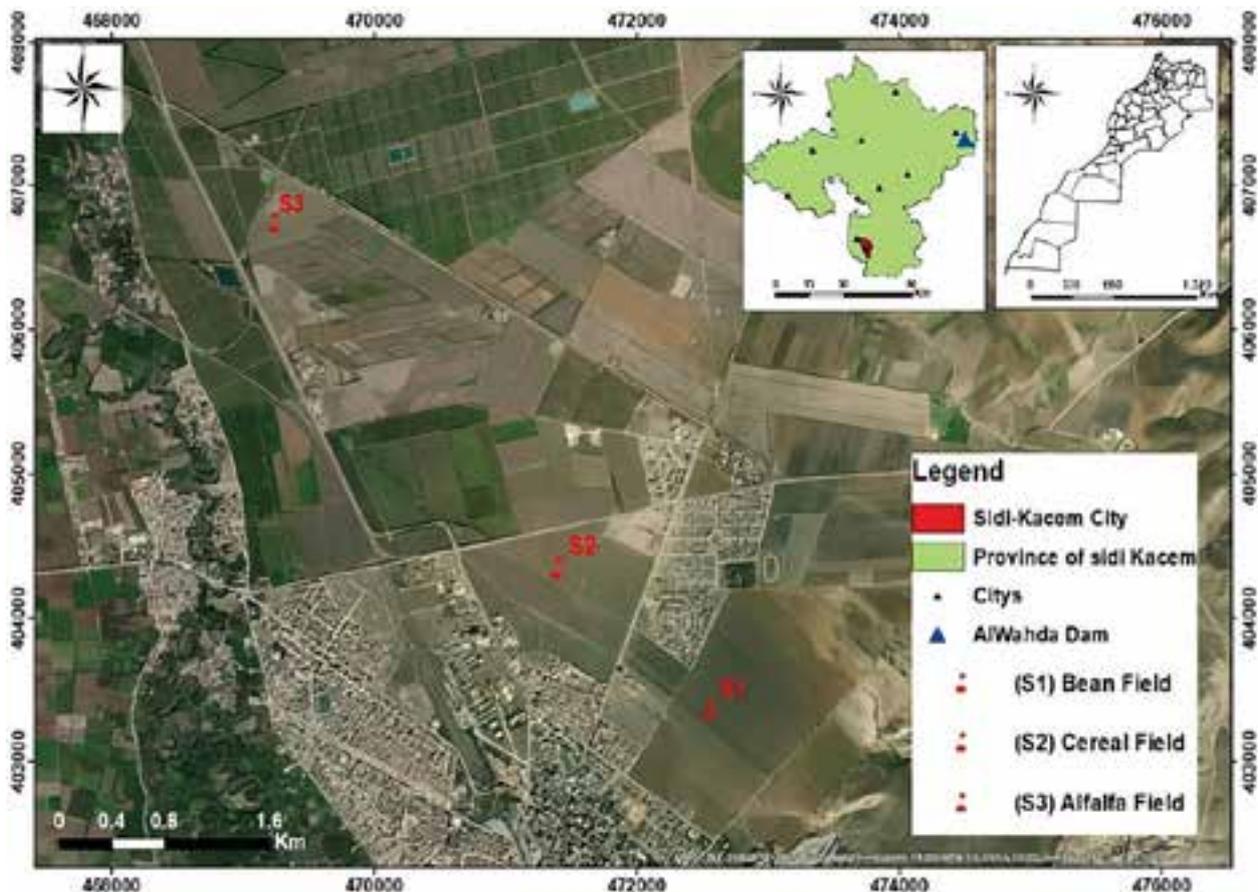


Image 1. Geographic and sampling location of the study area in Sidi Kacem, northwestern Morocco.

We employed a targeted netting strategy combined with timed observations, employing an active search and net approach. This involved walking randomly across the site while carefully observing the fields. Any captured insects were subsequently transferred to vials containing 70% alcohol for later identification.

Data analysis

To exploit the data obtained, various ecological indices and statistical analyses were performed. Some of the analyses include the ecological composition indices (species richness), as well as the ecological structure indices (Shannon and equitability indices). The data were analyzed using Microsoft Excel Worksheet (version 16.0 for Windows) and presented as frequency and percentage for comparison between the different stations and trapping methods.

RESULTS

Invertebrate abundance and composition at the three study stations

The results of this study revealed that a total of 735 insects representing 27 families and 69 species were collected (Table 1). Among the sampled habitats, the cereal field exhibited the highest species richness with 55 species, followed by the bean field with 31 species and the alfalfa field with 28 species. Overall, the recorded species belonged to seven insect orders: Hemiptera, Coleoptera, Orthoptera, Lepidoptera, Odonata, Hymenoptera, and Diptera. Coleoptera was the most species-rich order, accounting for 42 species, followed by Hemiptera (7 species), Diptera (6 species), Lepidoptera & Hymenoptera (4 species each), and Orthoptera & Odonata (3 species each), as shown in Table 1. In terms of abundance, Coleoptera also dominated across all three sampling stations with 582 individuals, followed by Hymenoptera (68 individuals) and Hemiptera (31 individuals). The least abundant orders were Diptera, Lepidoptera, Odonata, and Orthoptera, represented by 20, 16, 11, and seven individuals, respectively. These results highlight the marked dominance of Coleoptera both in species richness and individual abundance, while the low representation of other orders underscores the distinct structure and distribution of insect communities within agroecosystems.

Comparison and description of the efficacy of sampling methods.

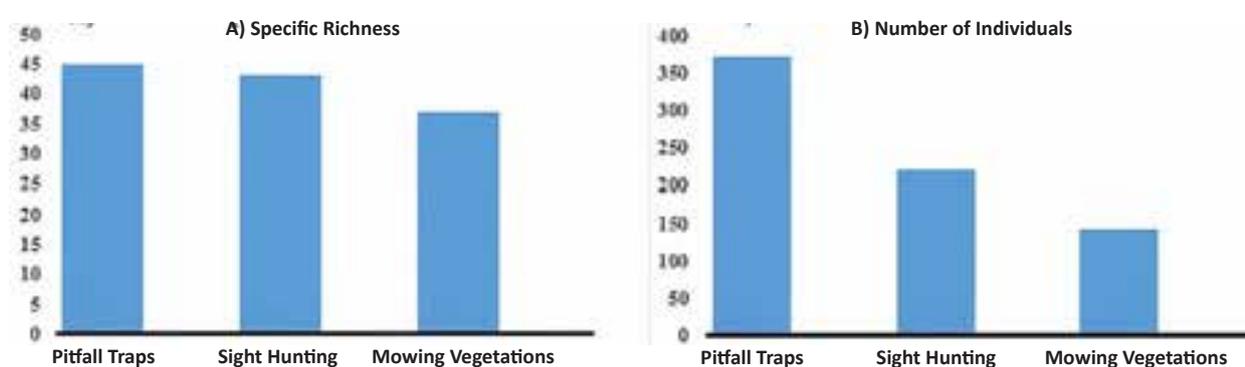
The distribution of individuals captured by the three sampling methods is presented in Table 2. Statistically significant differences were observed in both species richness and abundance among the sampling techniques, indicating variation in their capture efficiency. Pitfall trapping recorded the highest species richness with 45 species and accounted for 36% of the total individuals collected. Sight hunting yielded a comparable level of efficiency, capturing 43 species and representing 34% of the total individuals, differing only slightly from pitfall trapping in terms of species richness. In contrast, sweep netting conducted during vegetation mowing was less effective, recording 37 species and 30% of the individuals (Table 2; Figure 1). These results demonstrate that both pitfall trapping and sight hunting are highly effective sampling methods, whereas sweep netting captures a relatively

At the order level, sampling efficiency varied markedly among methods. Coleoptera dominated pitfall trap captures, reflecting the prevalence of ground-active taxa with surface-oriented movement. In contrast, sight hunting and vegetation mowing were most effective for volant orders such as Hymenoptera, Lepidoptera, Diptera, and Odonata, which are more abundant in vegetation and aerial strata. Hemiptera and Orthoptera displayed intermediate patterns, being captured by all methods but more frequently during sight hunting and mowing, consistent with their mixed mobility and plant associations (Table 2).

At the family level, clear differences in capture efficiency were observed among pitfall traps, sight hunting, and vegetation mowing. Pitfall traps excelled in sampling ground-dwelling Coleoptera, particularly Carabidae and Silphidae, which had the highest abundances (138 & 135 individuals, respectively) and species richness. This method also uniquely captured Staphylinidae, Lygaeidae, and Oedemeridae, yielding the highest overall abundance (372 individuals) and species richness (45 species). Sight hunting was similarly efficient for visually conspicuous and mobile taxa, including Coccinellidae, Reduviidae, and several Diptera and Lepidoptera families, resulting in high species richness (43 species) and substantial abundance (221 individuals). Sweep netting during vegetation mowing was more effective for plant-associated and flying insects, such as Apidae, Vespidae, Pieridae, and Libellulidae, but recorded the lowest overall abundance (142 individuals) and species richness (37 species) (Table 2).

Table 1. The numbers of species and individuals captured at the three study stations.

	Beans field		Cereal field		Alfalfa field		Total	
	# ind.	# sp.	# ind.	# sp.	# ind.	# sp.	# ind.	# sp.
Coleoptera	180	22	297	37	105	12	582	42
Hemiptera	6	2	10	5	15	2	31	7
Orthoptera	3	2	2	2	2	2	7	3
Lepidoptera	1	1	4	2	11	2	16	4
Hymenoptera	10	3	25	4	33	4	68	4
Odonata	1	1	5	3	5	2	11	3
Diptera	0	0	2	2	18	4	20	6
Total	201	31	345	55	189	28	735	69

**Figure 1. Species richness (A) & (B) number of individuals of insects collected by different types of traps at three study sites.**

Seasonal distribution

Overall, the abundance of arthropods was observed to be higher during the spring season compared to the summer season, as depicted in Figure 2. It was found that pitfall traps were more effective than other traps in both seasons, exhibiting the highest Shannon-Weiner's diversity index (3.81 for spring and 3.49 for summer captures). Conversely, mowing vegetation resulted in the lowest values of the diversity index (2.18 for spring and 2.09 for summer), as shown in Table 3.

In terms of evenness index, pitfall traps had the highest values (0.98 for the spring season), followed by sight hunting (0.79 for the spring season) and mowing vegetation (0.70 for the summer season). Overall, mowing had the least diversity index values in both seasons (Table 3).

The relative abundances of the main insect groups varied according to both sampling method and season (spring and summer). Overall, Carabidae emerged as the dominant taxon across all sampling techniques, reflecting their high activity levels and broad ecological distribution within the studied habitats.

The sight hunting method primarily captured

actively moving and visually detectable insects. Carabidae showed the highest abundances, particularly during spring, while Tenebrionidae and Silphidae were represented at intermediate levels. Other taxa, including Apidae, Vespidae, Libellulidae, and Lepidoptera, occurred at relatively low abundances, suggesting limited detectability using this method. In summer, a general decline in abundance was observed, although Carabidae remained dominant (Figure 2).

Pitfall traps proved to be the most effective method for sampling ground-dwelling insects. During spring, Carabidae and Silphidae exhibited particularly high abundances, followed by Tenebrionidae. In contrast, Scarabaeidae, Oedemeridae, and Lygaeidae were captured in low numbers. Although overall abundances decreased in summer, Silphidae remained highly represented, indicating sustained activity during this season.

The vegetation mowing method highlighted insect groups associated with the herbaceous layer. Carabidae continued to dominate in both seasons; however, this method revealed a higher representation of secondary taxa. In spring, several groups occurred at

Table 2. The numbers of species and individuals captured by different types of traps.

			Pitfall traps	Sight hunting	Mowing vegetations
Coleoptera	Carabidae	No. of individuals	138	68	32
		Species richness	23	11	10
	Tenebrionidae	No. of individuals	60	34	15
		Species richness	3	3	2
	Scarabaeidae	No. of individuals	12	8	0
		Species richness	3	2	0
	Coccinellidae	No. of individuals	4	9	6
		Species richness	2	2	2
	Staphylinidae	No. of individuals	2	0	0
		Species richness	2	0	0
	Cantharidae	No. of individuals	3	5	7
		Species richness	1	2	2
	Chrysomelidae	No. of individuals	0	4	1
		Species richness	0	1	1
	Silphidae	No. of individuals	135	19	13
		Species richness	5	4	2
Oedemeridae	No. of individuals	3	7	4	
	Species richness	1	1	1	
Hemiptera	Reduviidae	No. of individuals	3	10	2
		Species richness	1	2	1
	Pentatomidae	No. of individuals	0	2	0
		Species richness	0	1	0
	Cercopidae	No. of individuals	0	3	0
		Species richness	0	1	0
	Scutelleridae	No. of individuals	0	2	0
		Species richness	0	1	0
	Alydidae	No. of individuals	0	1	1
		Species richness	0	1	1
Lygaeidae	No. of individuals	5	3	0	
	Species richness	1	1	0	
Orthoptera	Acrididae	No. of individuals	2	4	1
		Species richness	1	3	2
Lepidoptera	Pieridae	No. of individuals	0	4	7
		Species richness	0	2	2
	Nymphalidae	No. of individuals	0	3	1
		Species richness	0	1	1
Hymenoptera	Apidae	No. of individuals	0	8	21
		Species richness	0	2	2
	Vespidae	No. of individuals	0	3	10
		Species richness	0	1	1
	Andrenidae	No. of individuals	4	6	7
		Species richness	1	1	1
Odonata	Libellulidae	No. of individuals	0	5	8
		Species richness	0	2	3
Diptera	Muscidae	No. of individuals	1	4	0
		Species richness	1	1	0
	Stratiomyinae	No. of individuals	0	3	4
		Species richness	0	1	2
	Tabanidae	No. of individuals	0	2	0
		Species richness	0	1	0
	Syrphidae	No. of individuals	0	3	2
		Species richness	0	1	1
	Asilidae	No. of individuals	0	1	0
		Species richness	0	1	0
7	27	No. of individuals	372	221	142
		Species richness	45	43	37

low abundances, including Apidae, Libellulidae, and Lepidoptera. In summer, a marked increase in Apidae was observed, reflecting enhanced activity of pollinators (Figure 2). The exclusive occurrence of Coccinellidae in summer may be related to increased prey availability and seasonal changes in vegetation structure. From a seasonal perspective, spring was characterized by higher overall abundances, likely due to favourable climatic conditions and increased biological activity. Conversely, summer showed a general decline in insect abundance, accompanied by shifts in community composition.

DISCUSSION

Several studies have been conducted to compare the efficiency of different methods used to assess arthropods (Sabu et al. 2011; Corti et al. 2013; Zaller et al. 2015; Sial et al. 2022). To the best of existing knowledge, the current study stands out as one of the first to compare the effectiveness of pitfall traps, sight hunting, and mowing vegetation in agroecosystems. This study aimed to provide a detailed evaluation of different sampling methods. By conducting this research, the study seeks to shed light on the effectiveness and practicality of employing these methods collectively. The utilization of pitfall traps, sight hunting, and mowing vegetation offers a unique opportunity to comprehensively evaluate arthropod populations. The findings will not only enhance the scientific community's understanding of these assessment techniques and explore the synergistic effects of combining these methods but also pave the way for their wider adoption in ecological studies.

The primary objective was to evaluate the efficacy of pitfall traps, sight hunting, and mowing vegetation in assessing insect diversity across three designated study sites. To ensure comprehensive analysis, the number of insects captured by each sampling method were examined from spring to summer. Throughout the course of the experiment, all sampling traps exhibited remarkable variations in insect populations. When comparing the different sampling methods, differences were found in the number and diversity of the recorded taxa among the tested sampling methods. It became evident that pitfall trapping yielded the highest number of species and individuals, capturing a total of 45 species and accounting for 36% of the overall insect population. These results underscore the reliability of pitfall traps for assessing insect diversity, as their ability to capture a broad range of species and individuals demonstrates their effectiveness in representing the insect communities

within the study sites. Bouget et al. (2020) similarly reported that pitfall traps are highly specific and efficient for sampling invertebrate assemblages that move across the soil surface, effectively capturing carabids as well as numerous flying insects that land on the ground or are displaced by wind. Sight hunting also proved highly effective, accounting for 43 species and 34% of the individuals collected, and together with pitfall trapping, it has been recognized as a particularly useful method for sampling coleopterans. Both techniques are not only efficient but also easy to implement and cost-effective. The utility of these methods is further supported by previous studies, including Pizzolotto et al. (2018) and Ganaoui et al. (2019), which successfully applied similar approaches to sample arthropod communities in various habitats.

In terms of capturing flying insects, mowing herbaceous vegetation proved particularly effective. This method efficiently sampled insects that feed on plants, prey on plant-feeding insects, or utilize foliage and flowers, including Hymenoptera and some Lepidoptera. In this study, mowing traps captured the largest number of Apidae (21 individuals) and also effectively sampled Vespidae (10 individuals), highlighting its suitability for foliage-associated and flying taxa. Coleoptera and Hymenoptera were among the most accessible groups to sample due to their high taxonomic richness, as observed in other studies (Forbes et al. 2018; von Hoermann et al. 2018). The abundance of these taxa is likely influenced by favourable environmental conditions such as temperature, humidity, and availability of food sources (El Harche et al. 2023; Morshed et al. 2023). Pitfall traps, in contrast, were particularly efficient at capturing ground-dwelling insects, including Carabidae (138 individuals), Silphidae (135 individuals), and Tenebrionidae (60 individuals), reflecting their design to ensnare species active on the soil surface. Sight hunting offered a versatile approach, allowing for the collection of both ground-dwelling and flying insects, with a total of 43 species and 221 individuals recorded across taxa. By actively observing insect behaviour and movement, this method successfully captured a wide range of species, complementing the results obtained from pitfall traps and mowing. Together, these three methods provide a comprehensive representation of insect communities within the studied agroecosystems.

Seasonal variation played a significant role in structuring insect assemblages, with higher abundances generally recorded in spring. This pattern is likely linked to favourable climatic conditions, increased soil moisture, and enhanced resource availability during early crop

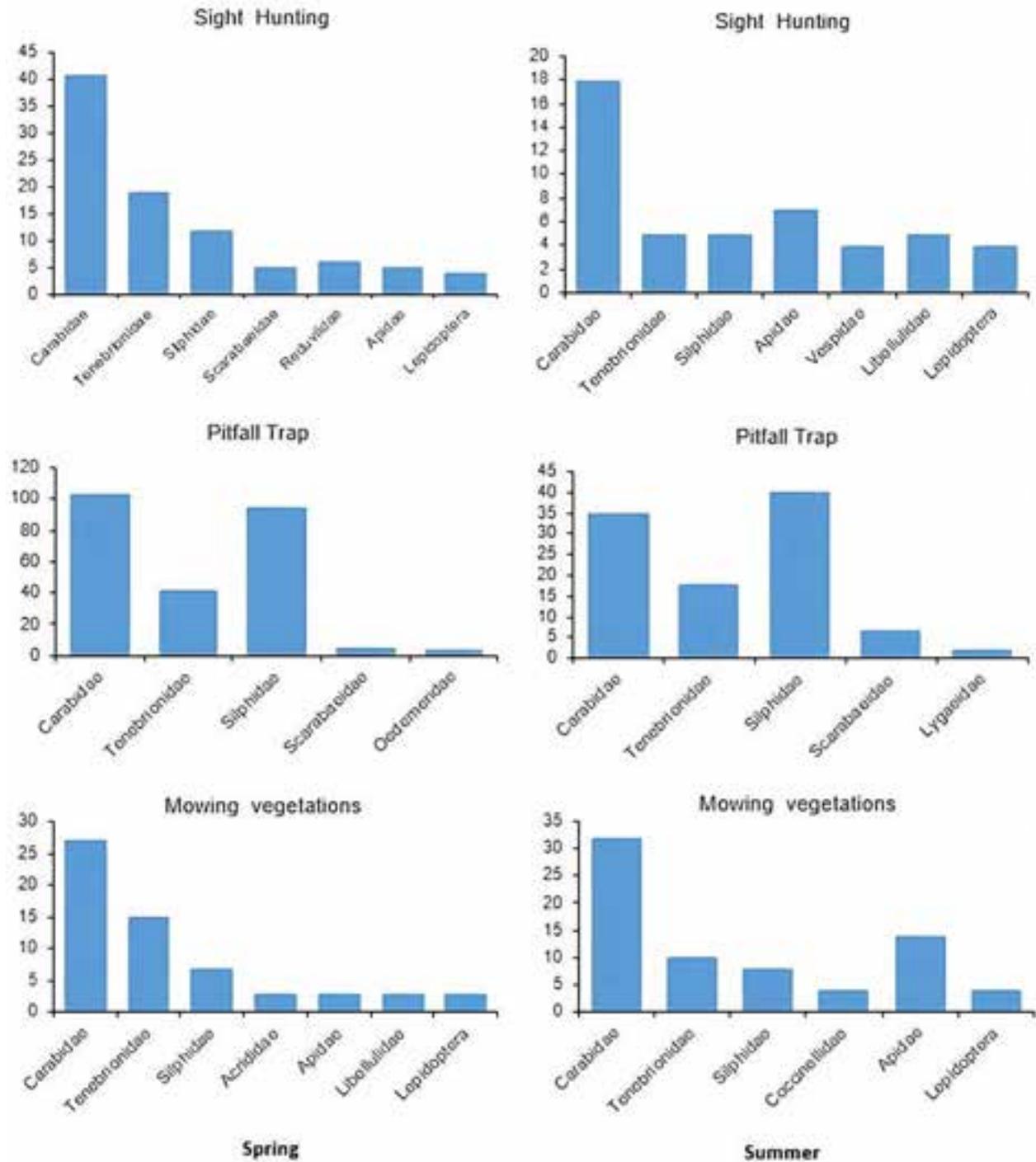


Figure 2. The taxonomic composition of the most dominant family captured during the spring and summer seasons using three different types of collection traps.

development stages (Colinet et al. 2015; Haavik & Stephen 2023). In contrast, the observed decline in abundance during summer may reflect the combined effects of thermal stress, reduced vegetation cover, and increased agricultural disturbance, including irrigation, mechanical operations, and agrochemical applications

(El Harche et al. 2022, 2023). Similar seasonal declines in insect abundance have been reported in Mediterranean and semi-arid agroecosystems, where summer conditions impose strong physiological and ecological constraints on arthropod communities (Coscarón et al. 2009; Robinson et al. 2018; El Abdouni et al. 2022; Zhao

Table 3. Diversity indices of different arthropod orders captured by different types of traps.

Trap type	Spring			Summer		
	Pitfall traps	Sight hunting	Mowing vegetations	Pitfall traps	Sight hunting	Mowing vegetations
Shannon Index	3.81	3.68	2.18	3.49	3.36	2.09
Evenness Index	0.98	0.79	0.58	0.87	0.74	0.70

et al. 2022; El Harche et al. 2023).

The effectiveness of pitfall traps in capturing large numbers of Carabidae and Silphidae emphasizes the importance of soil surface conditions in agroecosystems. Ground-dwelling insects are particularly sensitive to soil compaction, tillage frequency, and residue management, all of which directly affect their mobility, shelter availability, and prey access. Recent evidence suggests that intensive soil management simplifies carabid community composition and reduces functional diversity, potentially impairing ecosystem services such as biological control (Makwela et al. 2025). The persistence of Silphidae during summer may indicate tolerance to disturbance and an ability to exploit ephemeral organic resources commonly associated with agricultural activities and livestock presence.

In contrast, vegetation mowing revealed taxa associated with the herbaceous layer, particularly pollinators such as Apidae, whose abundance increased markedly during summer. This seasonal increase likely corresponds to flowering phenology and the availability of floral resources within or near cultivated fields. Recent studies stress that pollinator communities in agroecosystems are highly dependent on landscape heterogeneity, field margins, and the presence of semi-natural habitats (Potts et al. 2010; El Abdouni et al. 2022). Agricultural intensification, characterized by monocultures and the removal of non-crop vegetation, has been shown to reduce pollinator diversity and abundance by limiting nesting sites and floral continuity (Sentil et al. 2024).

Anthropogenic pressures, particularly the use of agrochemicals, represent a major driver of insect community alteration in agricultural landscapes. Recent comparative studies have demonstrated significantly lower pollinator abundance and species richness in agrochemical-contaminated habitats compared to protected or low-input systems, highlighting both direct toxic effects and indirect impacts via habitat degradation (Sentil et al. 2024; El Harche 2023). These findings are consistent with the reduced representation of sensitive taxa observed in the present study, suggesting that chemical inputs may selectively favour disturbance-

tolerant species while excluding more specialized or vulnerable groups.

The exclusive occurrence of Coccinellidae during summer further illustrates the influence of anthropogenic factors on trophic interactions. Lady beetles are closely associated with aphid populations, which often increase in fertilized crops during warmer periods. Their seasonal presence likely reflects prey availability rather than habitat preference, supporting the notion that agricultural inputs indirectly shape predator dynamics through bottom-up effects (Landis et al. 2000).

The different traps used to assess insect diversity, while varying in efficiency, are not only cost-effective but also simple to construct and deploy, allowing their use across a variety of locations. This is particularly advantageous in agricultural areas, where sampling can be challenging and where farmers may be reluctant to allow complex equipment, such as malaise traps or light traps, that could damage crops. The materials and methods selected in our study provide a practical solution that benefits both researchers and farmers, enabling representative sampling of insect diversity without disturbing the fields. The observed variation in abundances among taxa across different collection methods underscores the importance of combining multiple techniques to obtain a more accurate representation of arthropod communities in agroecosystems. Furthermore, the choice of sampling method should be tailored to the specific taxonomic group under investigation.

No single sampling method is sufficient to capture the full diversity of arthropod communities, as efficiency varies according to the ecology, mobility, and microhabitat of each taxon. Flying insects, such as Lepidoptera, Diptera, Hymenoptera, and Odonata, are most effectively sampled through active methods like visual searching and sweep netting, while ground-dwelling taxa, including Carabidae and Tenebrionidae, are best collected with pitfall (Barber) traps. Vegetation-associated and less mobile groups, such as Hemiptera, Orthoptera, and some Coleoptera, are efficiently captured by sweep netting. These findings emphasize the importance of a taxon-oriented, multi-method

sampling approach to obtain comprehensive arthropod inventories and reduce methodological bias in agroecosystem studies.

REFERENCES

- Biesmeijer, J.C., S.P.M. Roberts, M. Reemer, R. Ohlemüller, M. Edwards, T. Peeters, A.P. Schaffers, S.G. Potts, R. Kleukers, C.D. Thomas, J. Settele & W.E. Kunin (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313(5785): 351–354. <https://doi.org/10.1126/science.1127863>
- Bouget, C., L.M. Nageleisen & C. Bouget (2009). Les groupes d'insectes cibles en forêt tempérée: chapitre 4, part I Les coléoptères carabidae. *L'étude des insectes en forêt: méthodes et techniques, éléments essentiels pour une standardisation*. Les dossiers forestiers 19: 91–98.
- Buchholz, S. & K. Hannig (2013). Do covers influence the capture efficiency of pitfall traps. *European Journal of Entomology* 106: 667–671. <https://doi.org/10.14411/eje.2009.083>
- Carvalho, L.G., C.L. Seymour, R. Veldtman & S.W. Nicolson (2010). Pollination services decline with distance from natural habitat even in biodiversity-rich areas. *Journal of Applied Ecology* 47(4): 810–820. <https://doi.org/10.1111/j.1365-2664.2010.01829.x>
- Colinet, H., B.J. Sinclair, P. Vernon & D. Renault (2015). Insects in fluctuating thermal environments. *Annual Review of Entomology* 60: 123–140. <https://doi.org/10.1146/annurev-ento-010814-021017>
- Corti, R., S.T. Larned & T. Datry (2013). A comparison of pitfall-trap and quadrat methods for sampling ground-dwelling invertebrates in dry riverbeds. *Hydrobiologia* 717: 13–26. <https://doi.org/10.1007/s10750-013-1563-0>
- Coscarón, M.D.C., M.C. Melo, J. Coddington & J. Corronca (2009). Estimating biodiversity: a case study on true bugs in Argentinian wetlands. *Biodiversity and Conservation* 18: 1491–1507.
- Dirzo, R., H.S. Young, M. Galetti, G. Ceballos, N.J.B. Isaac & B. Collen (2014). Defaunation in the Anthropocene. *Science* 345(6195): 401–406. <https://doi.org/10.1126/science.1251817>
- El Harche, H., G. Chavanon, J. Dahmani & M. Fadli (2022). Checklist of terrestrial beetles (Arthropoda: Insecta: Coleoptera) associated with agroecosystems in North-West Morocco. *Arxius de Miscel·lània Zoològica* 20: 59–81. <https://doi.org/10.32800/amz.2022.20.0059>
- El Harche, H., S. El Hassouni, M. Fadli & J. Dahmani (2023). Spatial, seasonal variation and impacts of anthropogenic factors on insect assemblages (Arthropoda: Insecta) in northwest Morocco. *Biodiversitas* 24(10): 5368–5375. <https://doi.org/10.13057/biodiv/d241019>
- Forbes, A.A., R.K. Bagley, M.A. Beer, A.C. Hippee & H.A. Widmayer (2018). Quantifying the unquantifiable: why Hymenoptera, not Coleoptera, is the most speciose animal order. *BMC Ecology* 18: 1–11. <https://doi.org/10.1186/s12898-018-0176-x>
- Ganaoui, N., M.C. Maazi & A. Chefrour (2019). Spatio-temporal variation of scarab beetles (Coleoptera: Scarabaeidae) in two oak biotopes of Ouled Bechih Forest, Souk-Ahras region (north-eastern Algeria). *Polish Journal of Entomology* 88(4): 301–319.
- Galloway, A.D., C.L. Seymour, R. Gaigher & J.S. Pryke (2021). Organic farming promotes arthropod predators, but this depends on neighbouring patches of natural vegetation. *Agriculture, Ecosystems & Environment* 310: 107295. <https://doi.org/10.1016/j.agee.2020.107295>
- García-López, A., E. Micó, M.A. Zumbado & E. Galante (2011). Sampling Scarab Beetles in Tropical Forests: The Effect of Light Source and Night Sampling Periods. *Journal of Insect Science* 11(95): 1–14. <https://doi.org/10.1673/031.011.9501>
- Gardarin, A., M. Plantegenest, A. Bischoff & M. Valantin-Morison (2018). Understanding plant–arthropod interactions in multitrophic communities to improve conservation biological control: useful traits and metrics. *Journal of Pest Science* 91(3): 943–955. <https://doi.org/10.1007/s10340-018-0958-0>
- Haavik, L.J. & F.M. Stephen (2023). Insect Ecology, pp. 91–114. In: Allison, D.J., T.D. Paine, B. Slippers & M.J. Wingfield (eds.). *Forest Entomology and Pathology*. Springer, Cham., 789 pp. <https://doi.org/10.1007/978-3-031-11553-0>
- Hohbein, R.R. & C.J. Conway (2018). Pitfall traps: a review of methods for estimating arthropod abundance. *Wildlife Society Bulletin* 42: 597–606.
- Landis, D.A., S.D. Wratten & G.M. Gurr (2000). Habitat management to conserve natural enemies of arthropod pests. *Annual Review of Entomology* 45: 175–201. <https://doi.org/10.1146/annurev.ento.45.1.175>
- Makwela, M.M., R. Slotow & T.C. Munyai (2025). Ecological response of carabid beetles (Coleoptera: Carabidae) to contrasting agroecosystem management. *Community Ecology* 26: 705–716. <https://link.springer.com/article/10.1007/s42974-025-00261-6>
- Morshed, M.N., M.A. Al Mamun, S.A.I. Nihad, M.M. Rahman, N. Sultana & M.M. Rahman (2023). Effect of weather variables on seasonal abundance of rice insects in southeast coastal region of Bangladesh. *Journal of Agriculture and Food Research* 11: 100513. <https://doi.org/10.1016/j.jafr.2023.100513>
- Potts, S.G., J.C. Biesmeijer, C. Kremen, P. Neumann, O. Schweiger & W.E. Kunin (2010). Global pollinator declines: trends, impacts and drivers. *Trends in Ecology & Evolution* 25(6): 345–353. <https://doi.org/10.1016/j.tree.2010.01.007>
- Pizzolotto, R., A. Mazzei, T. Bonacci, S. Scalerio, N. Iannotta & P. Brandmayr (2018). Ground beetles in Mediterranean olive agroecosystems: Their significance and functional role as bioindicators (Coleoptera, Carabidae). *PLoS ONE* 13(3): e0194551. <https://doi.org/10.1371/journal.pone.0194551>
- Quinto, J., M. de los Á. Marcos-García, H. Brustel, E. Galante & E. Micó (2013). Effectiveness of three sampling methods to survey saproxylic beetle assemblages in Mediterranean woodland. *Journal of Insect Conservation* 17(4): 765–776. <https://doi.org/10.1007/s10841-013-9559-7>
- Robinson, S.I., Ó.B. McLaughlin, B. Marteinsdóttir & E.J. O’Gorman (2018). Soil temperature effects on the structure and diversity of plant and invertebrate communities in a natural warming experiment. *Journal of Animal Ecology* 87: 634–646. <https://doi.org/10.1111/1365-2656.12798>
- Russo, L., R. Stehouwer, J.M. Heberling & K. Shea (2011). The composite insect trap: an innovative combination trap for biologically diverse sampling. *PLoS ONE* 6(6): e21079. <https://doi.org/10.1371/journal.pone.0021079>
- Sabu, T.K., R.T. Shiju, K. Vinod & S. Nithya (2011). A comparison of the pitfall trap, Winkler extractor and Berlese funnel for sampling ground-dwelling arthropods in tropical montane cloud forests. *Journal of Insect Science* 11: 1–19. <https://doi.org/10.1673/031.011.0128>
- Sentil, A., P. Rosa, C. Tourbez, A. Dorchin, P. Bogusch & D. Michez (2024). New records of bees (Hymenoptera: Apoidea) from Morocco. *Journal of Hymenoptera Research* 97: 513–530. <https://doi.org/10.3897/jhr.97.125408>
- Skvarla, M., J. Larson & A. Dowling (2014). Pitfalls and preservatives: a review. *The Journal of the Entomological Society of Ontario* 145: 15–43.
- Sial, M.U., M.Z. Majeed, A. Atiq, T. Farooq, H.M. Aatif, W. Jaleel & H.A. Ghrahmah (2022). Differential efficacy of edaphic traps for monitoring arthropods diversity in subtropical regions. *Journal of King Saud University-Science* 34(1): 101686. <https://doi.org/10.1016/j.jksus.2021.101686>
- Taraborelli, P., N. Carrasco, M. Malaspina, M. Domínguez, A. Belaus, A. López, A. Scavone, A. Barbera & M. Zamora (2022). Evaluation of agrobiodiversity and its trophic interactions as an indicator of sustainability in productive systems. *Open Journal of Environmental Biology* 7(1): 006–013. <https://doi.org/10.17352/ojeb.000027>
- Vasconcelos, C., M. Dittrich & J.A. McKenzie (2014). Evidence of microbiocoenosis in the formation of laminae in modern stromatolites. *Facies* 60: 3–13. <https://doi.org/10.1007/s10347-013-0000-0>

013-0371-3

Von Hoermann, C., D. Jauch, C. Kubotsch, K. Reichel–Jung, S. Steiger & M. Ayasse (2018). Effects of abiotic environmental factors and land use on the diversity of carrion–visiting silphid beetles (Coleoptera: Silphidae): A large-scale carrion study. *PLoS ONE* 13(5): e0196839. <https://doi.org/10.1371/journal.pone.0196839>

Zhao, L., R. Gao, J. Liu, L. Liu, R. Li, L. Men & Z. Zhang (2023). Effects of Environmental Factors on the Spatial Distribution Pattern and

Diversity of Insect Communities along Altitude Gradients in Guandi Mountain, China. *Insects* 14(3): 224. <https://doi.org/10.3390/insects14030224>

Zaller, J.G., G. Kerschbaumer, R. Rizzoli, A. Tiefenbacher, E. Gruber & H. Schedl (2015). Monitoring arthropods in protected grasslands: comparing pitfall trapping, quadrat sampling and video monitoring. *Web Ecology* 15(1): 15–23. <https://doi.org/10.5194/we-15-15>





Community structure of Lepidoptera in Nantu-Boliohuto Wildlife Reserve, Sulawesi, Indonesia

Chairunnisah J. Lamangantjo¹ , Marini Susanti Hamidun² , Sasmianti³  & Dewi Wahyuni K. Baderan⁴ 

^{1,3}Biology Department, Faculty of Mathematics and Natural Sciences, Gorontalo State University, Bone Bolango, Gorontalo 961282, Indonesia.

^{2,4}Environmental Science Department, Faculty of Mathematics and Natural Sciences, Gorontalo State University, Bone Bolango, Gorontalo 961282, Indonesia.

¹chairunnisah@ung.ac.id (corresponding author), ²marinish70@ung.ac.id, ³sasmiantijhula@gmail.com, ⁴dewi.baderan@ung.ac.id

Abstract: Lepidoptera diversity serves as a vital bioindicator of ecosystem health and environmental quality. This research investigated the Lepidoptera community structure within the Nantu-Boliohuto Wildlife Reserve, Celebes, Indonesia, using a purposive sampling method with insect nets at three distinct stations. Diversity indices at all stations were categorized as moderate: Station I, far from the river area adjacent to Camp Yayasan Adudu Nantu International ($H' = 1.57$); Station II, at the Babi Rusa wallow area ($H' = 2.48$); and Station III, the waterfall area ($H' = 2.64$). Evenness was high at all stations (Station I: $E = 0.99$; Station II: $E = 0.94$; Station III: $E = 0.98$). Dominance was low across all stations: Station I ($C = 0.21$), Station II ($C = 0.09$), and Station III ($C = 0.08$). The species abundance index of *Elymnias resplendens* Martin, 1929 (Nymphalidae) was the highest ($Di = 0.124$). These findings contribute to environmental quality assessment and serve as a data inventory for Lepidoptera in the Nantu-Boliohuto Wildlife Reserve.

Keywords: Butterfly, checklist, conservation, Gorontalo, Nymphalidae, protected area, specimens, species diversity, tropical forest, Wallacea.

Indonesian: Keanekaragaman Lepidoptera berfungsi sebagai bioindikator vital bagi kesehatan ekosistem dan kualitas lingkungan. Penelitian ini mengkaji struktur komunitas Lepidoptera di Suaka Margasatwa Nantu-Boliohuto, Sulawesi, Indonesia, menggunakan metode purposive sampling dengan jaring serangga pada tiga stasiun yang berbeda. Indeks keanekaragaman di seluruh stasiun dikategorikan sedang: Stasiun I, yang jauh dari area sungai dan berdekatan dengan Camp Yayasan Adudu Nantu Internasional ($H' = 1.57$); Stasiun II, di area kubangan Babi Rusa ($H' = 2.48$); dan Stasiun III, di area air terjun ($H' = 2.64$). Nilai kemerataan tergolong tinggi di semua stasiun (Stasiun I: $E = 0.99$; Stasiun II: $E = 0.94$; Stasiun III: $E = 0.98$), sedangkan nilai dominansi tergolong rendah di seluruh lokasi: Stasiun I ($C = 0.21$), Stasiun II ($C = 0.09$), dan Stasiun III ($C = 0.08$). Indeks kelimpahan spesies *Elymnias resplendens* Martin, 1929 (Nymphalidae) adalah yang tertinggi ($Di = 0.124$). Temuan ini berkontribusi pada penilaian kualitas lingkungan dan berfungsi sebagai inventarisasi data Lepidoptera di Suaka Margasatwa Nantu-Boliohuto.

Editor: James Young, Hong Kong Lepidopterists Society, Tuen Mun, Hong Kong SAR.

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

Citation: Lamangantjo, C.J., M.S. Hamidun, Sasmianti & D.W.K. Baderan (2026). Community structure of Lepidoptera in Nantu-Boliohuto Wildlife Reserve, Sulawesi, Indonesia. *Journal of Threatened Taxa* 18(2): 28307–28316. <https://doi.org/10.11609/jott.9415.18.2.28307-28316>

Copyright: © Lamangantjo et al. 2026. 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: None.

Competing interests: The authors declare no competing interests.

Author details: CHAIRUNNISAH J LAMANGANTJO is currently a permanent lecturer at Universitas Negeri Gorontalo. Her extensive research focuses on agricultural entomology, biology, and the biodiversity of animal species in Gorontalo. Since 2013, she has been dedicated to the utilization of local plants for organic fertilizers and pesticides, continuously deepening her expertise in the development and production of botanical-based organic solutions. MARINI SUSANTI HAMIDUN is a lecturer in Universitas Negeri Gorontalo. Her academic focus is on Natural Resource and Environmental Management, with research interests primarily centered on ecotourism. Sasmianti Sasmianti is a graduate of the Department of Biology who has a keen interest in entomology, specifically focusing on insects found within the Sulawesi region. DEWI WAHYUNI K. BADERAN is currently the head of the Sulawesi Mangrove Conservation and Biotechnology Study Center. Her academic expertise and research focus are primarily in the fields of biodiversity and conservation.

Author contributions: CJL—research design, conceptualization, taxonomic assessment, field data collection, data analysis, writing, and editing the manuscript. MSH—research design, conceptualization, methodological guidance, data analysis, writing, and editing the manuscript. SS—field data collection, data compilation, methodological guidance, and writing. DWK—data curation, writing, editing the manuscript, and manuscript review.

Acknowledgements: The researcher would like to express gratitude to the Natural Resources Conservation Agency (BKSDA) II of Gorontalo, for providing significant assistance in completing this research.



INTRODUCTION

The Nantu-Bolihuto Wildlife Reserve is a conservation forest located administratively in three districts: Gorontalo, Boalemo, and northern Gorontalo. Initially designated as a wildlife reserve in 1999 with an area of 31,215 ha, it was later expanded to 51,507.33 ha by Minister of Forestry Decree No. 325/Menhut-II/2010. This area is a tropical forest that retains its original ecosystem, with high biodiversity of plants and animals. The forest vegetation is largely dominated by tall trees with dense canopies, mainly from the families Anacardiaceae, Salicaceae, Guttiferae, Datisceae, Annonaceae, Myristicaceae, Apocynaceae, Moraceae, Ebenaceae, Sapotaceae, and a small portion from the Dipterocarpaceae family. There are 204 plant species, 17 of which are endemic and protected under Government Regulation No. 7 of 1999 (Hamidun & Baderan 2014). Additionally, the Nantu-Bolihuto Wildlife Reserve is a habitat and exploration area for endemic species such as Babirusa *Babirusa celebensis* (Deninger, 1909), Anoa *Bubalus depressicornis* (C.H. Smith, 1827), Sulawesi Black Macaque *Macaca hecki* (Matschie, 1901), Tarsier *Tarsius tarsier* (Erxleben, 1777), Sulawesi Bear Cuscus *Strigocuscus celebensis* (Gray, 1858), Sulawesi Wild Pig *Sus celebensis* (Müller & Schlegel, 1843), 80 bird species, various reptiles, and insects. The biodiversity of the area is a source of livelihood for the surrounding communities, the majority of whom depend on the forest for their livelihoods (Laindi et al. 2021).

Butterflies (Lepidoptera) are among the insects inhabiting the Nantu-Bolihuto Wildlife Reserve and form part of the biodiversity that must be conserved to prevent extinction or a decline in species diversity, as they play a crucial role in maintaining ecosystems. They aid in the pollination of flowering plants, enabling the natural process of plant reproduction (Adom et al. 2021; Boukouvala et al. 2022). The presence of butterfly populations in a habitat depends heavily on the diversity of host plants, establishing a close relationship between biodiversity and habitat conditions (Ho & Altermatt 2024). Ecologically, butterflies help maintain ecosystem balance and serve as bioindicators of environmental quality (Körösi et al. 2022). Habitat destruction, which leads to a decrease in host plant diversity, is a key factor contributing to the decline in butterfly diversity. Tyler (2020) notes that habitat destruction results from human activities converting natural habitats. Additionally, butterfly diversity is influenced by factors such as altitude, temperature, humidity, light intensity, weather, seasons, and nectar volume in plants.

Butterfly diversity varies from one location to another because their presence in a habitat is closely linked to environmental factors, including abiotic factors such as sunlight intensity, temperature, air and water humidity, and biotic factors such as vegetation and other animals. Indonesia, as an archipelagic country, has diverse environmental factors. These differences cause butterfly species to vary across island habitats. The presence of species in a habitat is inseparable from their distribution and adaptation abilities (Lestari et al. 2015).

Like other animals, butterflies can also face scarcity and extinction. Research by Hamidun et al. (2016) states that there are many butterfly species of the Order Lepidoptera in the Nantu-Bolihuto Wildlife Reserve, but the distribution and diversity of butterflies in various habitat types in the area have not been studied or published. This information is crucial, as many butterfly species rely heavily on one or two host plant species that exist only in certain habitats, and the potential for forest degradation is undeniable. Therefore, before biodiversity, especially butterflies, is lost, it is essential to study their distribution and analyze their diversity as fundamental biodiversity data, for environmental quality assessment, and to establish a Lepidoptera data inventory for the Natural Resources Conservation Center, Conservation Section II, Gorontalo Region. The objective of this research is to analyze the distribution and community structure of Lepidoptera across diverse habitat types within the Nantu-Bolihuto Wildlife Reserve to provide fundamental biodiversity data for environmental quality assessment and an updated species checklist inventory.

MATERIALS AND METHODS

Study area

The research was conducted in the Nantu-Bolihuto Wildlife Reserve, Boalemo, Gorontalo Province, Sulawesi, Indonesia (Image 1A). Three observation stations were involved (Image 1B): Station I, near Camp Yayasan Adudu Nantu International (YANI) (1.314° N, 122.482° E); Station II, Babirusa Wallow area (1.321° N, 122.468° E); and Station III, waterfall areas (1.330° N, 122.470° E). The research took place over five months, from February–June 2023.

Tools and materials

Tools used include an insect net (sweep net) for capturing butterflies and moths, writing utensils for recording collected data, a camera for documenting

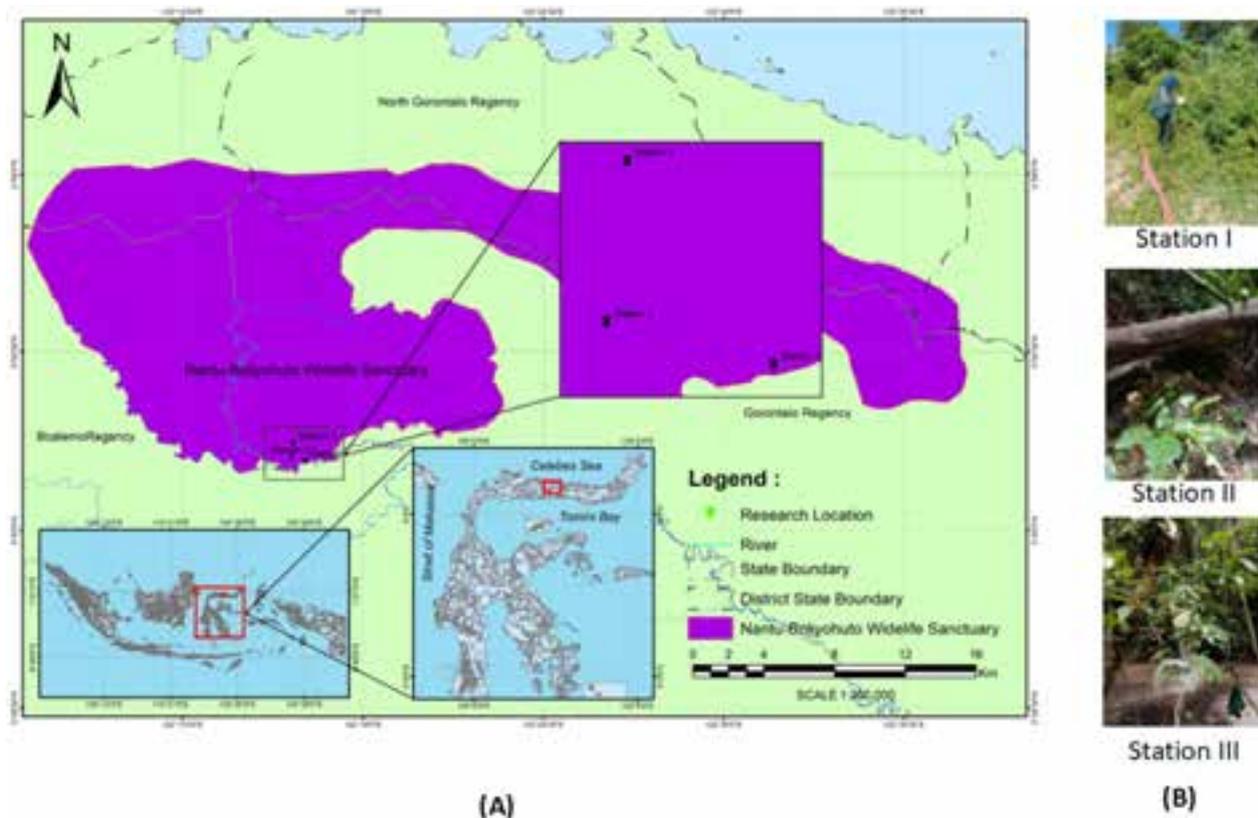


Image 1. Research location: A—map of Nantu-Bolihuto Wildlife Reserve, Boalemo, Gorontalo Province | B—types of habitats present at different observation stations.

activities and specimen samples, perforated plastic jars as temporary containers for butterflies in the field, a thermohygrometer for measuring humidity, a lux meter for measuring light intensity, a thermometer, GPS (global positioning system) for marking locations, a ruler for measuring specimens, butterfly identification books, insect specimen boxes, and insect pins. Materials used include captured Lepidoptera, ethyl acetate, and envelope paper or paper envelopes as specimen containers.

PROCEDURES

Collection, specimen fixation, and identification

Data collection was conducted through survey methods using purposive sampling at three observation stations, following the modified Pollard Walk method (Caldas & Robbins 2003; Longcore et al. 2004). Two transects were placed in each habitat type at predetermined locations based on the need to represent distinct habitat types and environmental characteristics variations of each station, specifically the open-canopy near camp area, the semi-closed canopy babirusa wallow areas, and the dense-canopy waterfall

zone. Transect lines were established along lengths of 200 m, totaling 400 m per station, which aligns with the standard observation by Hamer et al. (1997). Lepidoptera, including diurnal moths, were collected using the sweep net method (Hamer et al. 1997; Le & Vu 2024) between 0800–1200 h and 1300–1600 h (Scherrer et al. 2013; Peggie et al. 2022). Only one specimen of each species was collected. If the same species was encountered again, it was released to prevent possible double-counting. Specimens were fixed by placing them in jars containing cotton soaked in ethyl acetate, which were then closed and left until the specimens died. They were then placed in triangular paper envelopes measuring 30 × 20 cm with wings spread.

Identification and classification of the lepidopterans were conducted at the Zoology Laboratory, Department of Biology, Faculty of Mathematics and Natural Sciences, Gorontalo State University using identification books: referring to “Butterflies of the South East Asian Island, Part I Papilionidae, Part II Pieridae-Danaidae, Part III Satyridae-Lybytheidae, Part IV Nymphalidae (I), Part V Nymphalidae (II)” (Tsukada & Nishiyama 1982), “The Complete Field Guide to Butterflies of Australia” (Braby

2004), “Practical Guide to Butterflies at Bogor Botanical Gardens” (Peggie & Amir 2006), “Neotropical Genera of Emerald Moths (Geometrinae)” (Pitkin 1996), “Geometrid Moths of the World: A Catalogue” (Scoble 1999), and “The Moths of Borneo: Family Geometridae” (Holloway 1996). The Global Biodiversity Information Facility (GBIF 2025), Funet (Savela 2025), and Catalogue of Life (Bánki et al. 2025) online databases were also consulted for species occurrence data, updated accepted names, and digital images of species. After identification, classification was carried out. The protection status of the recorded butterfly species was assessed according to the Regulation of the Ministry of Environment and Forestry Indonesia No. P. 106/2018, and the International Union for Conservation of Nature’s Red List of Threatened Species (IUCN Red List) was used to determine the conservation status of the Lepidoptera species.

Data analysis

Community structure was evaluated based on species abundance, defined as the total number of individuals per species recorded in each habitat. Species diversity was assessed using the Shannon-Wiener diversity index $H' = -\sum_{i=1}^S p_i \ln p_i$, where: $p_i = n_i / N$, n_i is the number of individuals of the i -th species, N is the total number of individuals, and S is the total number of species. Diversity levels were categorized as high ($H' > 3$), moderate, ($1 \leq H' \leq 3$) and low ($H' < 1$) (Shannon & Wiener, 1963). Relative abundance ($Di = \frac{n_i}{N} \times 100\%$) was calculated to determine if a species is dominant ($Di > 5\%$), sub-dominant ($2 < Di < 5\%$), and non-dominant ($Di < 2\%$). Additionally, the distribution of individuals was analyzed using the Pielou Evenness Index ($E = H' / \ln S$) (Ludwig & Reynolds 1988). Dominance (D) is analyzed using the Simpson formula

$$D = \sum \frac{(n_i (n_i - 1))}{(N (N - 1))}$$

where the value of $0 < D < 0.5$ indicates no species dominate over others, suggesting a stable community structure; $0.5 < D < 1$ indicates some species dominate over others, suggesting a labile community structure due to ecological pressures.

RESULTS AND DISCUSSION

RESULT

Based on the results in Table 1, eight families of Lepidoptera were found: Geometridae, Erebidae, Uraniidae, Nymphalidae, Hesperidae, Papilionidae,

Lycaenidae, and Pieridae. There are 18 genera: namely *Eumelea* Duncan [& Westwood], 1841; *Asura* Walker, 1854; *Idea* Fabricius, 1807; *Acropteris* Geyer, 1832; *Erionota* Mabille, 1878; *Moduza* Moore, [1881]; *Elymnias* Hübner, 1818; *Sithon* Hübner, [1819]; *Cepora* Billberg, 1820; *Graphium* Scopoli, 1777; *Hebomoia* Hübner, [1819]; *Chilasa* Moore, 1881; *Appias* Hübner, [1819]; *Parthenos* Hübner, [1819]; *Catopsilia* Hübner, [1819]; *Parnara* Moore, [1881]; *Faunis* Hübner, [1819]; and *Hypolimnias* Hübner, [1819]. The total number of Lepidoptera found in the Nantu-Bolihuto Wildlife Reserve was 1,269 individuals. At Station I, located near the Adudu International Foundation (YANI) camp, far from the river and dominated by shrub and grass habitat, 186 individuals were found. Station II, the Babirusa Wallow Area, with habitat dominated by trees and proximity to a water source, recorded 487 individuals. The highest number, 596 individuals, was found at Station III, the Waterfall Area, which has a plant-and understory-dominated habitat near the river (Table 1 & Image 1B). The identification of Lepidoptera species in the Nantu-Bolihuto Wildlife Reserve is presented in Image 2.

Based on Figure 1, all stations showed moderate diversity. As their Shannon diversity index (H') values fell within the $1 \leq H' \leq 3$ range. Station I, near the Adudu International Foundation (YANI) Camp, recorded the lowest diversity among the stations with an H' of 1.57. Station II, in the Babirusa Wallow area, showed a higher diversity level with an H' of 2.48, while the highest diversity was found at Station III, located in the waterfall area, with an H' of 2.64. Although all stations are classified as moderate, the increasing trend from Station I to III reflects the greater habitat complexity and proximity to water sources in the waterfall zone.

Based on Figure 2, the species with the highest

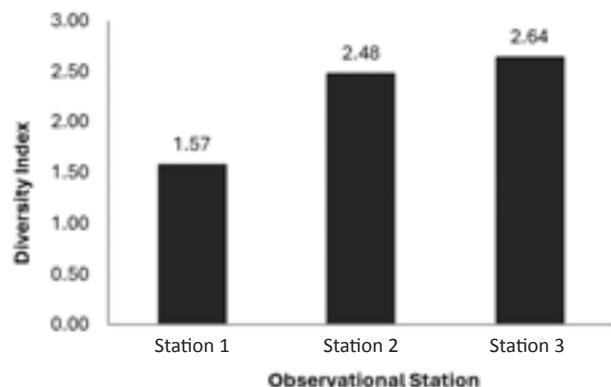


Figure 1. Shannon diversity index (H') in the Nantu-Bolihuto Wildlife Reserve.

Table 1. Identification of Lepidoptera species in the Nantu-Bolihuto Wildlife Reserve, Boalemo, Gorontalo Province.

Family	Species	Number of individuals			Total number of sampled individuals
		ST I	ST II	ST III	
Hesperiidae	<i>Erionota thrax</i> (Linnaeus, 1767)	-	57	-	57
	<i>Parnara bada</i> (Moore, 1878)	-	33	25	58
Lycaenidae	<i>Sithon nedymond</i> (Cramer, 1780)	-	-	50	50
Pieridae	<i>Cepora timnatha</i> (Hewitson, 1862)	31	31	44	106
	<i>Hebomoia glaucippe</i> (Linnaeus, 1758)	-	22	56	78
	<i>Appias nero</i> (Fabricius, 1793)	-	10	46	56
	<i>Appias zarinda</i> (Boisduval, 1836)	-	17	37	54
	<i>Catopsilia pomona</i> (Fabricius, 1775)	51	8	21	80
Papilionidae	<i>Graphium eurypylus</i> (Linnaeus, 1758)	-	-	35	35
	<i>Chilasa veiovis</i> (Hewitson, 1853)	-	-	32	32
Nymphalidae	<i>Parthenos sylvia</i> (Cramer, 1776)	-	-	37	37
	<i>Elymnias hypermnestra</i> (Linnaeus, 1763)	48	-	-	48
	<i>Idea blanchardii</i> Marchal, 1845	-	37	57	94
	<i>Cyrestis themire</i> Honrath, 1884	-	44	33	77
	<i>Faunis canens</i> Hübner, [1826]	23	-	-	23
	<i>Elymnias resplendens</i> (Martin, 1929)	-	81	76	157
	<i>Hypolimnas bolina</i> (Linnaeus, 1758)	33	-	-	33
	<i>Moduza lymire lymire</i> (Hewitson, 1859)	-	35	-	35
Uraniidae	<i>Acropteris ciniferaria</i> (Walker, 1866)	-	51	25	76
Geometridae	<i>Eumelea rosalia</i> (Stoll, 1781)	-	42	-	42
Erebidae	<i>Asura</i> sp.	-	19	22	41
Total individuals overall		186	487	596	1269

Note: The dash (-) indicates the absence of individuals recorded.

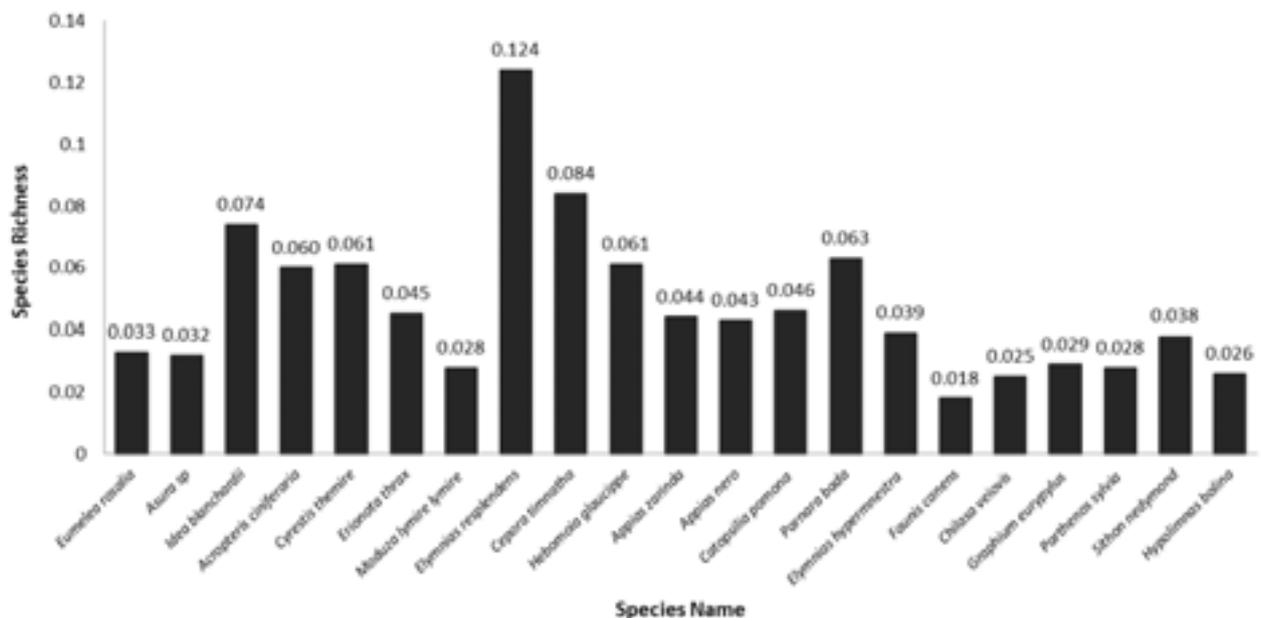


Figure 2. Species richness in the Nantu-Bolihuto Wildlife Reserve.

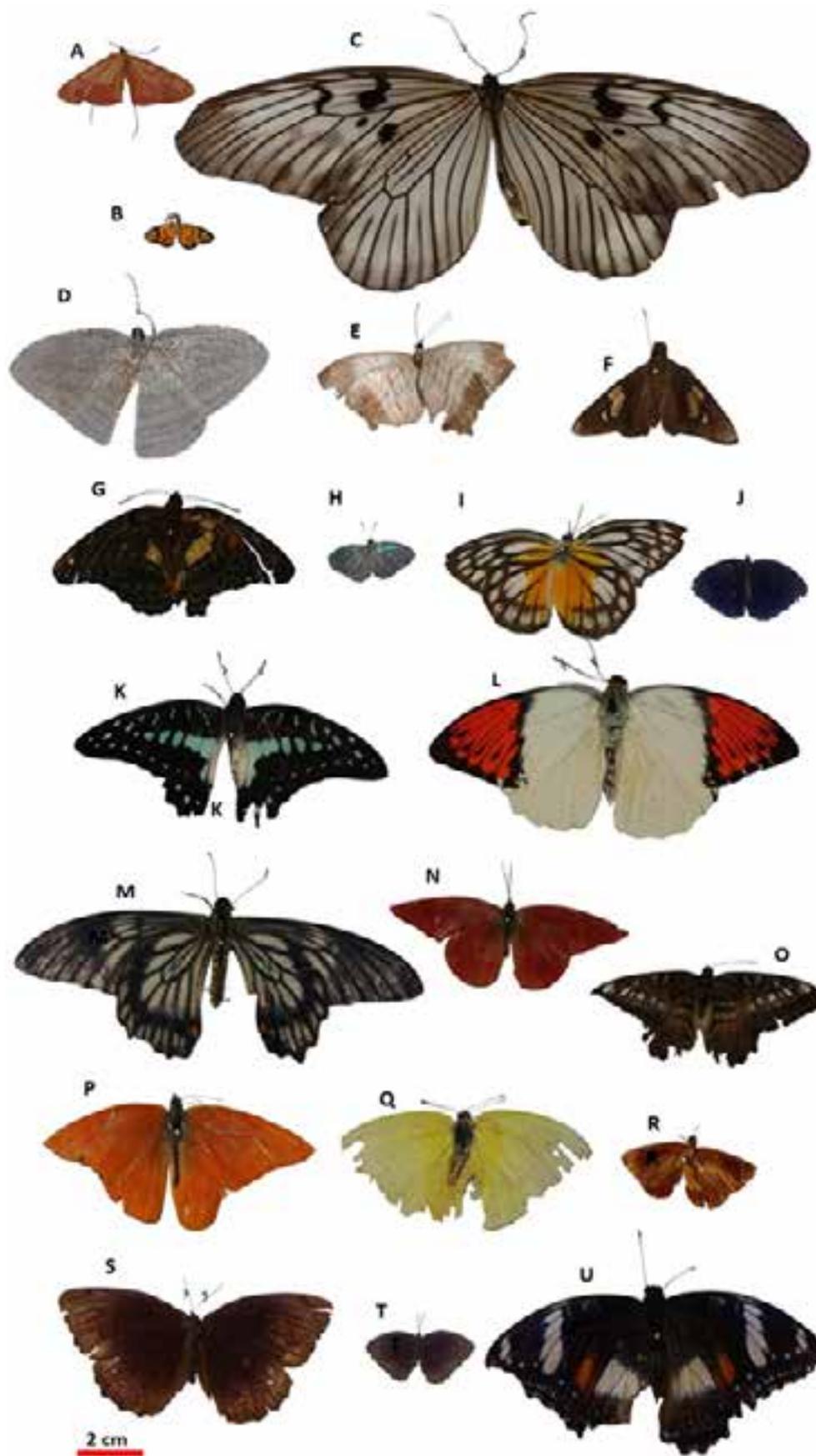


Image 2. Lepidoptera in the Nantu-Bolihuto Wildlife Reserve, Boalemo, Gorontalo Province: A—*Eumelea rosalia* (Stoll, [1781]) | B—*Asura* sp. | C—*Idea blanchardii* Marchal, 1845 | D—*Acropteris ciniferaria* (Walker, 1866) | E—*Cyrestis themire* Honrath, 1884 | F—*Erionota thrax* (Linnaeus, 1767) | G—*Moduza lymire lymire* Hewitson, 1859 | H—*Elymnias resplendens* Martin, 1929 | I—*Cepora timnatha* (Hewitson, 1862) | J—*Sithon nedymond* subsp. *isamarus* Fruhstorfer, 1912 | K—*Graphium euryppylus* (Linnaeus, 1758) | L—*Hebomoia glaucippe* (Linnaeus, 1758) | M—*Chilasa veiovis* (Hewitson, 1853) | N—*Appias zarinda* (Boisduval, 1836) | O—*Parthenos sylvia* (Cramer, [1776]) | P—*Appias nero* (Fabricius, 1793) | Q—*Catopsilia pomona* (Fabricius, 1775) | R—*Parnara bada* (Moore, 1878) | S—*Faunis canens* Hübner, [1826] | T—*Elymnias hypermnestra* (Linnaeus, 1763) | U—*Hypolimnias bolina* (Linnaeus, 1758).

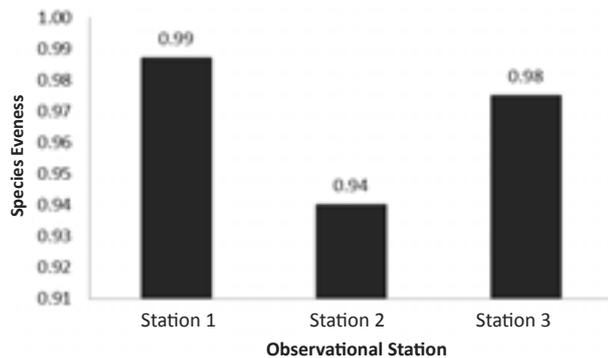


Figure 3. Species evenness in the Nantu-Bolihuto Wildlife Reserve.

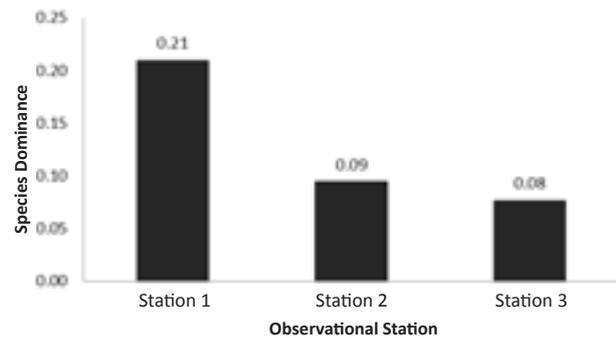


Figure 4. Species dominance in the Nantu-Bolihuto Wildlife Reserve.

abundance is *Elymnias resplendens* Martin, 1929. The *E. resplendens* is found at two research stations: station II in the Babirusa Wallow Area and station III in the waterfall area of the Nantu-Bolihuto Wildlife Reserve, with a Di value of 0.124. The species with the lowest abundance level is *Faunis canens* Hübner, [1826], with a Di value of 0.018.

According to Figure 3, the evenness index of Lepidoptera in the Nantu-Bolihuto Wildlife Reserve varies across the three stations. At station I, the value is $E = 0.99$; at station II, $E = 0.94$; and at station III, $E = 0.98$. Based on the evenness index criteria, the values at all three stations are considered relatively high, indicating a high level of evenness.

Based on the data analysis of the dominance index of Lepidoptera in the Nantu-Bolihuto Wildlife Reserve area (Figure 4), the values obtained for each station are as follows: Station I, the camp area, $D = 0.21$; Station II, the Babirusa Wallow area, $D = 0.09$; and Station III, the waterfall area, $D = 0.08$. According to the dominance index criteria, these values indicate a low dominance index.

The environmental parameters varied significantly across the stations, directly influencing Lepidoptera abundance (Table 2). Station I recorded the highest temperature (34 °C) and light intensity (5,501 lx), but the lowest humidity at 20%. While 20% is exceptionally low for a tropical forest, this value reflects the micro-climate of the open-canopy camp area, which is dominated by shrubs and grasses and located far from the river. This extreme condition creates the lowest abundance (186 individuals) recorded at this site. In contrast, Stations II and III exhibited more stable tropical forest conditions, with higher humidity levels (67% and 78%, respectively) and lower temperatures (29 °C). These conditions, found in the Babirusa wallow and waterfall areas, provide the necessary moisture and thermal buffering required for

Table 2. The abiotic environmental parameters at the research sites.

	Environmental factors	Station			Mean
		I	II	III	
1	Temperature (°C)	34	29	29	30.7
2	Light intensity (lx)	5,501	105	120	1,908.7
3	Humidity (%)	20	67	78	55

high species diversity and abundance.

DISCUSSION

The Nantu-Bolihuto Wildlife Reserve supports a diverse Lepidoptera community, evidenced by the 1,269 individuals across eight families. The presence of five butterfly and three moth families, particularly diurnal moths like *Eumelea rosalia* and *Erionota thrax*, suggests that the Reserve provides a broad range of ecological niches. Notably, this study recorded *Cyrestis themire*, which is currently assessed as 'Least Concern' (LC) according to the IUCN Red List (Müller & Tennent 2011). Combined with a moderate diversity index (H') ranging 1.57–2.64 across all stations, these findings reflect a balanced ecosystem capable of sustaining diverse tropical Lepidoptera populations. This moderate diversity indicates a stable community structure where resources are sufficient to prevent the total dominance of any single species, a condition further supported by the high evenness and low dominance indices recorded. As noted by Ahmed et al. (2022), such indices suggest a healthy, competitive environment where critical resources, including nectar and host plants, are distributed effectively across the landscape.

The variation in H' values is closely tied to the micro-climatic gradient of the stations. Station I's lower diversity (1.57) is a direct consequence of its extreme environmental conditions—high temperature (34 °C)

and intense solar radiation (5,501 lx). As explained by Liang et al. (2021), elevated temperatures and dry air accelerate the evaporation of body fluids and decrease nectar secretion in flowers. This forces butterflies to minimize activity to conserve energy and avoid desiccation, ultimately limiting species richness in open habitats. While butterflies generally survive within a range of 18–38 °C, the lack of canopy cover at Station I intensifies heat stress beyond the tolerance levels of many sensitive species. In contrast, the higher diversity recorded at Station III (2.64) is supported by the dense canopy and proximity to the waterfall, which provide a critical thermal buffer and high humidity (78%). According to Liao (2020), light intensity and the resulting heat energy are necessary for butterflies to maintain metabolic balance; however, the stable environment at Station III prevents the metabolic exhaustion associated with extreme heat. This creates an ideal refuge where moisture and temperature are balanced, facilitating a more diverse and active Lepidoptera community compared to the physiologically demanding conditions of the open-canopy camp area (Station I).

The abundance of specific species like *Elymnias resplendens* at Stations II and III highlights the importance of habitat preservation and water proximity. Butterflies are naturally drawn to damp areas (mud-puddling) for essential salts and minerals (Wilson et al. 2022). Conversely, the moth species *E. rosalia* was found only at station II, while *Asura* sp. and *A. ciniferaria* were found only at stations II and III during twilight hours. These moth species are most active during dusk and dawn (Pop et al. 2024).

Differences in the abundance of Lepidoptera species in the Nantu-Bolihuto Wildlife Reserve area can be attributed to variations in the types of plants that serve as food sources and the lack of plants that provide food for Lepidoptera species. The success of butterfly colonization depends on suitable habitats, particularly the availability of food sources (Tepa-Yotto et al. 2021). *Faunis canens* is the species with the lowest abundance value. This is because the *F. canens* is found only at station I, an area without a canopy where only shrubs are present (Image 1B). This is supported by Christharina & Abang (2022), who explained that, in general, the family Nymphalidae has a wide distribution and prefers places such as forests, open areas, and fields like stations II and III (Figure 1B). The combination of grassland vegetation, scrubland, and dominant trees in the Nantu-Bolihuto Wildlife Reserve provides essential shelter from predatory insects, ensure sufficient food availability, and provide environmental factors that support butterfly life.

The evenness index in the Nantu-Bolihuto Wildlife Reserve is categorized as high (Figure 3). This means that the number of individuals of each butterfly species is evenly distributed, with no dominant or sub-dominant species (Figure 4). The high evenness recorded indicates that despite these habitat variations, the species composition remains balanced, preventing ecological degradation and maintaining a robust food web. Pertiwi et al. (2020) explain that high evenness in a community indicates the ecosystem is in good condition, while low evenness suggests damage or degradation of ecosystem quality. By calculating the evenness index, it can be determined that Lepidoptera in the Nantu-Bolihuto Wildlife Reserve across various habitat types have an evenly distributed species composition and a healthy ecosystem. This is supported by Baderan et al. (2021) & Rahim et al. (2023), who explain that a community can be categorized as stable or as having evenly distributed species if the evenness index value approaches 1; and conversely, a lower evenness index indicates uneven species distribution. High indices of species diversity and evenness indicate a stable habitat and the availability of resources that support butterfly life. Butterflies have high mobility and adaptive abilities to environmental factors.

The dominance index of Lepidoptera was low at each research station (Figure 4), indicating that there are no dominant Lepidoptera species in the Nantu-Bolihuto Wildlife Reserve. According to Attiwilli et al. (2022), species richness significantly influences dominance values; specifically, lower species richness typically leads to a higher dominance index, whereas high richness tends to yield lower dominance. These results reflect a balanced distribution of individuals among species, which may intensify interspecific competition for limited floral resources, such as nectar, as influenced by the functional traits of the community. Overall, these findings suggest that the Nantu-Bolihuto Wildlife Reserve maintains a stable and diverse habitat that supports a wide array of Lepidoptera without the ecological pressure of a single dominant taxon.

REFERENCES

- Adom, M., K.O. Fening, M.K. Billah, D.D. Wilson, W. Hevi, V.A. Clotey, F. Ansah-Anprofi & A.Y. Bruce (2021). Pest status, bio-ecology and management of the false codling moth, *Thaumatotibia leucotreta* (Meyrick) (Lepidoptera: Tortricidae) and its implication for international trade. *Bulletin of Entomological Research* 111(1): 17–30. <https://doi.org/10.1017/s0007485320000358>
- Ahmed, S., S.K. Sarker, D.A. Friess, M. Kamruzzaman, M. Jacobs, M.A. Islam, M.A. Alam, M.J. Suvo, M.N.H. Sani, T. Dey, C.S. Naabeh

- & H. Pretzsch (2022). Salinity reduces site quality and mangrove forest functions. From monitoring to understanding. *Science of The Total Environment* 853(1): 158662. <https://doi.org/10.1016/j.scitotenv.2022.158662>
- Attiwilli, S., T. Karmakar, K. Isvaran & K. Kunte (2022). Habitat preference and functional traits influence responses of tropical butterflies to varied habitat disturbance. *International Journal of Tropical Insect Science* 42(1): 855–864. <https://doi.org/10.1007/s42690-021-00609-1>
- Baderan, D.W.K., S. Rahim, M.H. Angio & A.B. Salim (2021). Keanekaragaman, Kemerataan, dan Kekayaan Spesies Tumbuhan Dari Geosite Potensial Benteng Otanaha Sebagai Rintisan Pengembangan Geopark Provinsi Gorontalo. *Al-Kauniyah: Jurnal Biologi* 14(2): 264–274. <http://doi.org/10.15408/kauniyah.v14i2.16746>
- Bánki, O., Y. Roskov, M. Döring, G. Ower, D.R. Hernández Robles, C.A. Plata Corredor, T. Stjernegaard Jeppesen, A. Örn, T. Pape, D. Hobern, S. Garnett, H. Little, R.E. DeWalt, K. Ma, J. Miller, T. Orrell, R. Aalbu, J. Abbott, C. Abreu & P.A. Acero (2025). Catalogue of Life Checklist (Version 2025-12-20 XR). Catalogue of Life Foundation, Amsterdam, Netherlands. Database accessible at <https://www.catalogueoflife.org/> Accessed on 03.x.2025.
- Boukouvala, M.C., N.G. Kavallieratos, A. Skourti, X. Pons, C.L. Alonso, M. Eizaguirre, E.B. Fernandez, E.D. Solera, S. Fita, T. Bohinc, S. Trdan & C.G. Athanassiou (2022). *Lymantria dispar* (L.) (Lepidoptera: Erebidiae): current status of biology, ecology, and management in Europe with notes from North America. *Insects* 13(9): 854. <https://doi.org/10.3390/insects13090854>
- Braby, M.F. (2004). *The Complete Field Guide to Butterflies of Australia*. CSIRO Publishing, Collingwood, Australia, 339 pp.
- Caldas A. & R.K. Robbins (2003). Modified Pollard transects for assessing tropical butterfly abundance and diversity. *Biological Conservation* 110(2): 211–219. [https://doi.org/10.1016/S0006-3207\(02\)00190-8](https://doi.org/10.1016/S0006-3207(02)00190-8)
- Christharina, S.G. & F. Abang (2022). Roles of heterogeneous habitat for conservation of Nymphalidae in Sarawak (East Malaysia). *International Journal of Biology and Biomedical Engineering* 16: 252–260. <https://doi.org/10.46300/91011.2022.16.32>
- Hamer, K.C., J.K. Hill, L.A. Lace & A.M. Langan (1997). Ecological and biogeographical effects of forest disturbance on tropical butterflies of Sumba, Indonesia. *Journal of Biogeography* 24(1): 67–75. <https://doi.org/10.1111/j.1365-2699.1997.tb00051.x>
- Hamidun, M.S. & D.W.K. Baderan (2014). Analisis vegetasi hutan produksi terbatas boliyohuto provinsi Gorontalo. Gorontalo: Universitas Negeri Gorontalo. <https://www.academia.edu/download/68861692/Analisis-Vegetasi-Hutan-Produksi-Terbatas-Boliyohuto-Provinsi-Gorontalo-Penulis2.pdf>. Accessed on 03.v.2025.
- Hamidun, M.S., D.W.K. Baderan & M.L. Modjo (2016). Biodiversitas Suaka Margasatwa Nantu Sebagai Sumber Penghidupan Bagi Masyarakat Sekitar (Biodiversity of Nantu-Boliyohuto Wildlife Reserve As the Source of Livelihoods for Local Communities). *Seminar Nasional Biodiversitas* 5(2): 196–200
- Ho, H.C. & F. Altermatt (2024). Associating the structure of Lepidoptera-plant interaction networks across clades and life stages to environmental gradients. *Journal of Biogeography* 51(4): 725–738. <https://doi.org/10.1111/jbi.14776>
- Holloway, J.D. (1996). The Moths of Borneo: Family Geometridae, subfamilies Oenochrominae, Desmobastrinae and Geometrinae. *Malayan Nature Journal* 49: 147–326.
- Körösi, Á., M. Dolek, A. Nunner, A. Lang & F. Theves (2022). Pace of life and mobility as key factors to survive in farmland—Relationships between functional traits of diurnal Lepidoptera and landscape structure. *Agriculture, Ecosystems & Environment* 334: 107978. <https://doi.org/10.1016/j.agee.2022.107978>
- Kusuma, T.C., M. Hadi & J.W. Hidayat (2022). Struktur Komunitas Kupu-Kupu (Lepidoptera: Rhopalocera) di KHDTK Wanadipa Undip Kabupaten Semarang, Jawa Tengah. *Bioma : Berkala Ilmiah Biologi* 24(1): 90–95. <https://doi.org/10.14710/bioma.24.1.90-95>
- Laindi, M.R., F.H. Wartabone & I. Staddal (2021). Pemberdayaan Suku Polahi Melalui Konsep Agroforestri untuk Menjaga Kelestarian Suaka Margasatwa Nantu. *Jurnal Ilmiah Pangabdhi* 7(2): 94–98. <https://doi.org/10.21107/pangabdhi.v7i2.11486>
- Le, T.Q. & L.V. Vu (2024). Checklist of hawkmoths (Lepidoptera: Bombycoidea: Sphingidae) in the Central Highlands of Vietnam. *Journal of Threatened Taxa* 16(1): 24503–24528. <https://doi.org/10.11609/jott.8636.16.1.24503-24528>
- Lestari, D.F., R.D.A. Putri, M. Ridwan & A.D. Purwaningsih (2015). Keanekaragaman kupu-kupu (Insekta: Lepidoptera) di Wana Wisata Alas Bromo, BKPH Lawu Utara, Karanganyar, Jawa Tengah. *Seminar Nasional Masyarakat Biodiversitas Indonesia* 1(6): 1284–1288. <https://doi.org/10.13057/psnmbi/m010604>
- Liang, F., Z. Wang, K. He, S. Bai & T. Zhang (2021). Effects of brief exposure to high temperatures on the survival and fecundity of *Athetis lepigone* (Lepidoptera: Noctuidae). *Journal of Thermal Biology* 100: 103066. <https://doi.org/10.1016/j.jtherbio.2021.103066>
- Liao, H., C. Liu, T. Du & L. Shi (2020). Light Intensity Affects the Reproductive Success of *Danaus chrysippus* (Lepidoptera: Danaidae) by Influencing Flight Behavior. *Journal of Entomological Science* 55(2): 234–251. <https://doi.org/10.18474/0749-8004-55.2.234>
- Longcore T., Lam C.S. & J.P. Wilson (2004). Analysis of Butterfly Survey Data and Methodology from San Bruno Mountain Habitat Conservation Plan (1982–2000). 1. *Status and Trends*. University of Southern California GIS Research laboratory, Los Angeles, California, pp. 1–7.
- Ludwig, J.A. & J.F. Reynolds (1988). *Statistical Ecology: A Primer on Methods and Computing*. John & Wiley, New York.
- Ministry of Environment and Forestry of the Republic of Indonesia (2018). *Regulation of the Minister of Environment and Forestry of the Republic of Indonesia Number P.106/MENLHK/SETJEN/KUM.1/12/2018 concerning 1 the Second Amendment to the Regulation of the Minister of Environment and Forestry Number P.20/MENLHK/SETJEN/KUM.1/6/2018 concerning 2 the Types of Protected Plants and Animals*. Jakarta, Indonesia.
- Müller, C.J. & W.J. Tennent (2011). *Cyrestis themire*. The IUCN Red List of Threatened Species 2011: e.T160408A5366174. <https://doi.org/10.2305/IUCN.UK.2011-2.RLTS.T160408A5366174.en>. <https://www.iucnredlist.org/species/160408/5366174>. Accessed on 03.v.2025.
- Peggie, D. & M. Amir (2006). *Practical Guide to the Butterflies of Bogor Botanic Garden - Panduan Praktis Kupu-kupu di Kebun Raya Bogor*. Pusat Penelitian Biologi, LIPI Cibinong, Bogor dan Nagao Natural Environment Foundation, Tokyo.
- Peggie, D., S. Supadi, G. Guntoro, S. Sarino, F. Fatimah, R. Rachmatiyah & C. Haeuser (2022). *Papilio demoleus* L. and *Papilio polytes* L. (Lepidoptera: Papilionidae) reared on some host plants at Butterfly Research Facility, LIPI-Cibinong, West Java, Indonesia. *Treubia* 49(1): 41–56. <https://doi.org/10.14203/treubia.v49i1.4468>
- Pertiwi, R.A.P., S. Sugiyarto, A. Budiharjo & I.N. Nayasilana (2020). Diversity of butterflies (Lepidoptera) in Mount Bromo forest area with special purpose (Fasp), Karanganyar, Central Java. *Zoo Indonesia* 29(2). <https://doi.org/10.52508/zi.v29i2.3993>
- Pop, P., N. Pattanaik, K.S. Barwal, H.P. Singh, P. Pandey, S. Sondhi & R. Singh (2024). A checklist of moths in Bilaspur district, Himachal Pradesh, in the western Himalayan foothills, India. *Entomon* 49(3): 399–416.
- Pitkin, L. M. (2002). Neotropical ennomine moths: a review of the genera (Lepidoptera: Geometridae). *Zoological Journal of the Linnean Society* 135(2–3): 121–401. <https://doi.org/10.1046/j.1096-3642.2002.00012.x>
- Rahim, S., D.W.K. Baderan, M.S. Hamidun, A. Hasim, W.E.S. Anwar, M.H. Angio & S. Sunardi (2023). Diversity, distribution and conservation status of mangrove species in Pulias Bay, Indonesia. *Biosystems Diversity* 31(3): 276–281. <https://doi.org/10.15421/012331>
- Savela, M. (2025). *Lepidoptera and some other life forms*. Funet (Finnish University and Research Network). Database <https://www.nic.funet.fi/pub/sci/bio/life/intro.html>. Accessed on 03.x.2025.
- Scherrer, S., V.G. Ferro, M.N. Ramos & I.R. Diniz (2013). Species

- composition and temporal activity of Arctiinae (Lepidoptera: Erebidae) in two cerrado vegetation types. *Zoologia* 30(2): 200–210. <http://doi.org/10.1590/S1984-46702013000200010>
- Scoble, M.J. (1999).** *Geometrid Moths of the World: a catalogue (Lepidoptera, Geometridae), Volume 1 & 2.* CSIRO Publishing and Apollo Books, Australia, 1200 pp.
- Shannon, C.E. & W. Weaver (1964).** *The Mathematical Theory of Communication.* The University of Illinois Press, Urbana, United States of America. pp. 117–127
- Tepa-Yotto, G.T., H.E. Tonnang, G. Goergen, S. Subramanian, E. Kimathi, E.M. Abdel-Rahman & M.G. Sæthre (2021).** Global habitat suitability of Spodoptera frugiperda (JE Smith)(Lepidoptera, Noctuidae): key parasitoids considered for its biological control. *Insects* 12(4): 273. <https://doi.org/10.3390/insects12040273>
- Tsukada, E. & Y. Nishiyama (1982).** *Butterflies of the South East Asian Islands, Volume I, Papilionidae.* Plapac Company, Tokyo.
- Tyler, T. (2020).** Relationship between moth (night active Lepidoptera) diversity and vegetation characteristics in southern Sweden. *Journal of Insect Conservation* 24: 1005–1015. <https://doi.org/10.1007/s10841-020-00270-y>
- Wilson, B.E., L.D. Salgado & J.M. Villegas (2022).** Optimizing chemical control for *Diatraea saccharalis* (Lepidoptera: Crambidae) in sugarcane. *Crop Protection* 152: 105843. <https://doi.org/10.1016/j.cropro.2021.105843>





Foraging niche segregation among woodpeckers in the oak-pine forest of Kumaon Himalaya, Uttarakhand, India

Rafat Jahan¹ , Satish Kumar²  & Kaleem Ahmed³ 

¹⁻³ Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.
¹rftazhar@gmail.com, ²satishkumar.amu@gmail.com, ³kaleemdar@gmail.com (corresponding author)

Abstract: Understanding how species that share the same habitat coexist can reveal how niche segregation helps reduce competition and structure communities. This study examines foraging niche segregation among six woodpecker species: Brown-fronted Woodpecker *Dendrocoptes auriceps*, Himalayan Woodpecker *Dendrocopos himalayensis*, Grey-headed Woodpecker *Picus canus*, Scaly-bellied Woodpecker *Picus squamatus*, Greater Yellownape *Chrysophlegma flavinucha*, and Lesser Yellownape *Picus chlorophus* in the oak-pine forests of Ranikhet, Kumaon Himalaya, Uttarakhand. Opportunistic observations were conducted to determine key foraging niche dimensions, including foraging tree diameter, foraging height, substrate type, vertical position, and the condition of foraging trees and substrate. The analysis indicates that these woodpecker species exhibit distinct foraging preferences concerning substrate use, foraging height, and vertical stratification, while they did not seem to respond to the presence of dead substrate. Notably, the Grey-headed and Scaly-bellied Woodpeckers, unlike the other species that primarily forage on trees, exhibited a preference for lower foraging heights and were frequently observed foraging on the ground.

Keywords: Competition, deadwood conservation, foraging behavior, picidae, snags, substrate condition, sympatry, vertical stratification, woodpeckers.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

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

Citation: Jahan, R., S. Kumar & K. Ahmed (2026). Foraging niche segregation among woodpeckers in the oak-pine forest of Kumaon Himalaya, Uttarakhand, India. *Journal of Threatened Taxa* 18(2): 28317–28328. <https://doi.org/10.11609/jott.9693.18.2.28317-28328>

Copyright: © Jahan et al. 2026. 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: Ms. Rahat Jahan was awarded Junior Research Fellowship (JRF) and subsequently Senior Research fellowship (SRF) by the University Grants Commission to conduct research.

Competing interests: The authors declare no competing interests.

Author details: RAFAT JAHAN is a UGC NET-JRF fellow in the Department of Wildlife Sciences at Aligarh Muslim University. She is pursuing her doctoral research on woodpeckers in the Kumaon Himalaya focusing on their ecology and behavior. Her thesis investigates the ecological roles and behavioral adaptations of woodpeckers in this region. SATISH KUMAR is a professor at Aligarh Muslim University and Chairperson of the Department of Wildlife Sciences. His research specializes in large carnivore ecology, with a focus on predator-prey relationships involving the Grey Wolf, Blackbuck and livestock studied through radio-telemetry. He has also investigated the migratory behavior of Bar-headed Geese between their wintering and breeding ranges using satellite telemetry. Over the years, he has mentored students on a wide range of topics in wildlife science and conservation. DR. KALEEM AHMED is an assistant professor in the Department of Wildlife Sciences at Aligarh Muslim University. His research spans diverse areas of wildlife ecology, with a current focus on leopards in conflict zones of western Uttar Pradesh and the impacts of heat stress on birds using remote sensing and GIS technology. He is also engaged in studies on avian ecology in the Himalayan region.

Author contributions: RA: field work, manuscript draft. SK: conceptualization, methodology, supervision and editing of manuscript. KA: conceptualization, supervision, evaluation, editing and proof reading.

Acknowledgements: The first author would like to thank the chairperson, Department of Wildlife Sciences, Aligarh Muslim University, for allowing her to stay at the field station, Ardee Estate Bungalow, while conducting research in the Ranikhet Reserve Forest. R.J. also expresses her heartfelt appreciation to Mr. Aamir Azhar and Mr. Avinash for their invaluable contributions. She extends gratitude to the local communities throughout the field sites for their cooperation and help during the study.



INTRODUCTION

Banj Oak *Quercus leucotrichophora* and Chir Pine *Pinus roxburghii* forests occupy a distinct mid-elevation vegetation zone (1500–2200 m) in the western Himalaya. In contrast to Chir Pine forests, which are rather dry and have a simpler structure, oak forests, with their damp microclimate, dense understory, epiphyte-rich vegetation, and cavity-bearing trees, are more complex. Together, these forests form a mosaic crucial for sustaining avian communities, including several woodpecker species (Shahabuddin et al. 2017). Understanding the segregation of woodpeckers within this oak-pine forest is key to explaining how they coexist in a landscape like Ranikhet, since the woodpeckers are primary cavity excavators and resource partitioners.

The current ecological study on woodpeckers focuses on the mechanism of species coexistence within communities. Coexistence becomes much more challenging in the case of sympatric species, which are ecologically and morphologically similar (Johnson & Bronstein 2019). The theoretical basis for understanding species coexistence within ecological communities is provided by the ecological niche idea as an n-dimensional hypervolume that includes the resources and environmental conditions that allow a species to persist (Hutchinson 1957). Gause (1934) was the first to experimentally show the competitive exclusion principle, which states that two species with the same ecological requirements cannot coexist indefinitely because one will eventually outcompete the other for shared limiting resources. These ideas have been improved by modern coexistence theory, which finds that stable species coexistence happens when niche differences are sufficient to offset any inherent fitness differences between competitors (Chesson 2000).

Niche partitioning (or niche segregation) is the main stabilizing mechanism that allows biodiversity to be maintained in natural communities by minimizing direct competition between coexisting species through differential resource utilization, spatial or temporal habitat use, or through other ecological dimensions (MacArthur & Levins 1967). The niche theory of competition assumes that exploitation of resources, prey species, food, or habitat type is the primary determinant of ecological segregation. It predicts that coexisting species should differ in ecological, morphological, or behavioural characteristics to minimize competition (Zeng & Lu 2009). To address this pressing issue in ecology, many ecologists have suggested the importance of niche segregation as a significant factor in reducing

interspecific competition (Gamboa & Brown 1976; Bull et al. 1986). It has been demonstrated over time by field and laboratory observations, mathematical models, and the segregation of shared resources that coexisting species reduce the consequences of interspecific competition.

The concepts of sympatry, resource partitioning, and coexistence have also been studied extensively in various woodpecker species (Williams 1975; Short 1978; Torok 1990). They may live in a wide range of habitat types due to their morphological variation in size, and segregation by size may also be a crucial component in sympatric species coexistence (Winkler & Christie 2002). Tropical rainforests harbour the most significant number of woodpeckers. The most diverse forests are found in southeastern Asia and South America, where up to 13 species can coexist in sympatric communities within 100 ha or less. Woodpeckers are highly specialized in more or less similar ways, and it could be challenging to separate their habitat (Short 1978).

Even so, as many as 15 woodpecker species were observed coexisting in sympatry in the deciduous Sal forests of sub-Himalayan regions (Kumar et al. 2020). They segregated their foraging niche based on tree size, foraging height, utilization of live and dead trees, borer-infested vegetation, open spaces, and canopy cover. Santharam (1995) studied how eight woodpecker species in the Western Ghats segregate foraging niches, and found evidence of size-related preference in substrate sizes. However, with a few notable exceptions (Mikusiński 2006), the ecology of woodpecker foraging has not received much attention in tropical and subtropical regions with a high woodpecker diversity.

Recent studies highlight how resource partitioning enables woodpecker coexistence in forested landscapes. Si et al. (2023) found that sympatric woodpeckers in northeastern China segregated their niches according to substrate type, tree condition, DBH, and foraging height, with larger species preferring snags and trunks while smaller species used canopy branches. Similarly, Pradhan et al. (2025) discovered that woodpeckers in the non-protected forest of the eastern Himalaya showed elevation-dependent changes in foraging strategies, vertical stratification, and body size-driven segregation, with tropical forests supporting higher diversity. Both studies emphasize that in order to sustain diverse woodpecker communities, structural heterogeneity is essential, including the presence of large old huge trees as well as snags.

The present study was conducted to investigate how woodpeckers segregate within the oak-pine forest

of Ranikhet, which is crucial to understanding their coexistence in this landscape.

METHODS

Study area

The research was carried out in Ranikhet Cantonment Forest. The study area is situated in the Uttarakhand Pali sub-division of the Almora District, falling within the boundaries of Ranikhet Cantonment. Three distinct areas make up the Cantonment: Chaubatia (2,125 m), Deolikhet (1,823 m), and Alma Barrack (1,818 m). The majority of the area near Ranikhet is a protected reserve forest covering a stretch of ridges with rounded or flat tops, subsidiary spurs, and slopes with a mild to moderate gradient. Deep, well-drained soils have developed as a result of the moderate slopes. The terrain is undulating and crisscrossed by small streams (Mani 1981).

The Ardee Estate Bungalow, a guest house affiliated with Aligarh Muslim University, is a well-known property

in Ranikhet, Uttarakhand, that provides academic visitors with a pristine environment dominated by oak-pine forests. The Ardee Estate was designated as the central point of the study area, encompassing a 3-km radius. This area was selected as a reasonable spatial limit for conducting intensive research. Using Google Earth Pro, the study area was precisely mapped, and the boundaries of the study site were drawn (Image 1).

Data collection

Field observations were carried out over a period of 16 months (November 2022–May 2024), except for the monsoon months (July 2023–September 2023), by the first author. Birds were located by searching in different patches of Oak and Chir-Pine forests, usually an hour after sunrise, and continued until sunset. Opportunistic observations were also recorded during the study. While observations were conducted throughout the day, most were taken in the early morning or late afternoon hours, when foraging activity was at its highest. During the study period, approximately 240 cumulative field

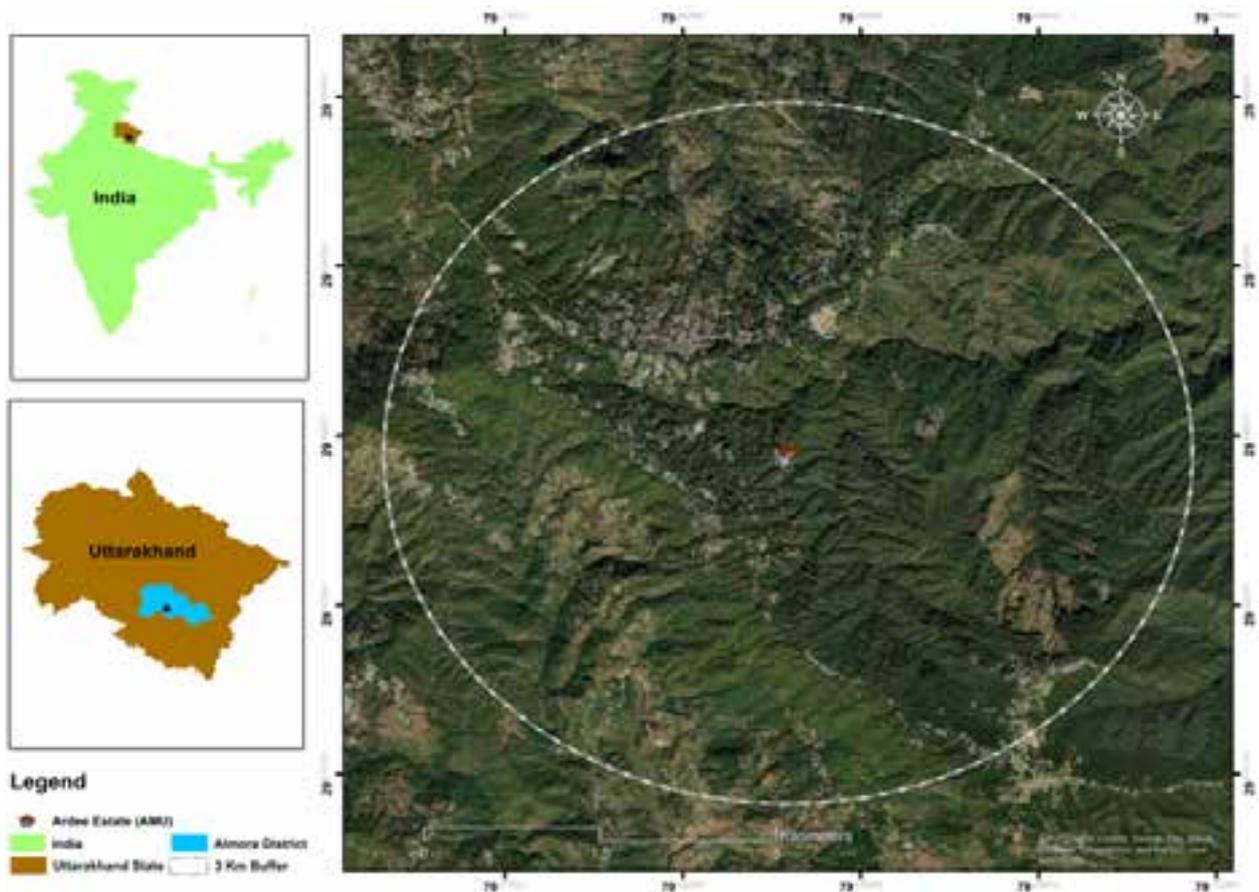


Image 1. Map showing the location of the study area.

days were spent in the study area, with an estimated 1,440 h of observation time. When a woodpecker was detected, records were made of the species, foraging behavior, foraging time, and the characteristics of the trees it foraged on. Repeated observations of the same individual were avoided to ensure sample independence. A woodpecker was only included in a second observation if it had moved at least 100–150 m from its original location. A minimum viewing distance of 10 m was maintained to avoid disturbance to woodpeckers.

Foraging behavior parameters

For every foraging observation, the following parameters were noted: foraging behavior (see below), foraging height, and substrate (ground, tree or tree branch). The following criteria were used to distinguish the foraging behavior (Remsen & Robinson 1990): (1) pecking: pecking at a branch or tree trunk where wood chips or tiny pieces of bark fall; (2) excavating: using its beak to make a hole so that big wood and bark fragments can fall from it; (3) probing: searching for food by probing and looking through any gaps or sutures in a tree; (4) gleaning: searching over trunk and limb surfaces; (5) flycatching/eating: the pursuit of insects in flight; and (6) ground foraging.

Foraging tree attributes

The attributes of the trees included the species of tree being foraged upon, girth at breast height (GBH), the height of the tree (measured using Nikon Forestry Pro II laser rangefinder/hypsometer), the tree canopy cover (measured by gridded mirror method), and substrate and tree condition. The tree condition was classified as: (1) live: standing and growing trees, (2) dead: trees standing in the forest with branches intact but otherwise dead, (3) snag: trees standing in the forest with boles that were completely dead. However, dead trees and snags were clubbed together and designated as dead. The substrate condition was thus classified as: (1) Live, (2) Dead (~75% of the substrate in use was completely dead).

Niche overlap

Niche overlap among the six woodpecker species was measured using Pianka's index in EcoSim 7.0 software (EcoSimPro/PROOSIS 2024, Version 7.0). The Pianka index measures the degree to which two different species overlap in their use of similar resources and is estimated by using the formula:

$$O_{jk} = \frac{\sum_i p_{ij} p_{ik}}{\sqrt{\sum_i p_{ij}^2 \sum_i p_{ik}^2}}$$

where p_{ij} and p_{ik} represent the proportional use of resource i by species j and k , respectively. The index ranges from 0 (no overlap) to 1 (complete overlap). Using the RA3 algorithm, which maintains the niche breadth of each species while reshuffling resource use, EcoSim randomly generated 1000 iterations of the resource use matrix to see if observed overlaps differed from random expectations. Then, the observed values were compared to null distributions to determine whether there was a significantly higher overlap (shared resource use) or a smaller overlap (niche segregation).

Correlation between woodpecker morphology and foraging variables

To know whether woodpeckers had a tendency to forage on tree diameters based on their body weights, the correlation between the mean DBH of trees used for foraging by each species and their corresponding body weights were calculated. Likewise, a correlation between body weight and mean foraging height was also assessed. Body weight of woodpeckers was obtained from Winkler et al. (1995).

Data analysis

Analysis was done for those species for which at least ten observations were available. The continuous data were evaluated using the Kruskal-Wallis test (such as foraging tree diameter and its height). On the other hand, categorical variables (i.e., vertical position, foraging behavior, tree and substrate condition) were evaluated using chi-square tests. Two steps were used to investigate the segregation of foraging niches along individual dimensions. First, it was evaluated whether there were differences among species in each of the dimensions related to foraging. A second-level analysis of pairwise species comparison was conducted if differences were statistically significant, using the post-hoc Dunn's test (for continuous variables) and chi-square test (for categorical variables) with Bonferroni adjustments for multiple comparisons.

R software (R Core Team 2024, version 4.4.1) in Rstudio (version 2024.12.1 +563) was used for all the graphical representation and statistical analysis using the following packages: ggplot2 (3.5.1) (Wicham 2016), vegan (2.6-8) (Oksanen et al. 2024). The EcoSim 7.0 software used Pianka's indices to measure the niche overlap.

RESULTS

A total of 1,006 foraging observations on six species of woodpeckers were collected, including 387 for Brown-fronted Woodpeckers *Dendrocoptes auriceps*, 233 for Grey-headed Woodpeckers *Picus canus*, 182 for Greater Yellownape *Chrysophlegma flavinucha*, 142 for Himalayan Woodpeckers *Dendrocopos himalayensis*, 32 for Scaly-bellied Woodpeckers *Picus squamatus* and 30 for Lesser Yellownape *Picus chlorophus* (Table 1). Four additional species (i.e., Speckled Piculet *Picumnus innominatus*, Rufous-bellied Woodpecker *Dendrocopos hyperythrus*, Fulvous-breasted Woodpecker *Dendrocopos macei*, and Greater Flameback *Chrysocolaptes guttacrastatus*) were also sighted. However, they were not included in the analysis due to a low sample size (< 10).

Foraging behavior differed among six woodpecker species

The six woodpecker species differed significantly in their foraging behavior ($\chi^2 = 424.3$; $df = 25$; $p < 0.001$). Both the Brown-fronted and Himalayan Woodpeckers exhibited various foraging behaviours. Pecking was the most preferred (58.4% and 54.9% of foraging observations, respectively), followed by probing (18.1% and 16.9%, respectively), gleaning (15.5% and 21.1%, respectively) and excavating (15.5% and 7%, respectively). Ground foraging was only observed in Grey-headed and Scaly-bellied Woodpeckers (45.5% and 40.6%, respectively). All pairwise species comparisons of foraging behaviour showed significant differences, except for the Himalayan Woodpecker & Lesser Yellownape, the Grey-headed Woodpecker & Scaly-bellied, and Brown-fronted Woodpecker & Greater Yellownape (Table 2). Pecking was the most common

foraging behaviour exhibited by all the woodpeckers except the Grey-headed Woodpecker (Figure 1).

Species pairs differed significantly in vertical positioning with respect to strata, i.e., portions of a tree utilized for foraging ($\chi^2 = 563.69$; $df = 25$; $p < 0.001$). Compared to the Grey-headed Woodpecker and Lesser Yellownape, the other four species used the trunk more often (Brown-fronted Woodpecker, 70%; Himalayan Woodpecker, 68.3%; Scaly-bellied Woodpecker, 43.7%; Greater Yellownape, 47.3%). The Grey-headed Woodpecker was predominantly observed foraging on the ground (45.5%), whereas the Lesser Yellownape showed greater use of the lower canopy (60%). The Grey-headed and Scaly-bellied Woodpecker species pairs did not differ significantly, while the other pairs did (Table 3).

Foraging tree attributes differences among six woodpecker species

Among the six woodpecker species, significant differences were observed in the selection of foraging tree species ($\chi^2 = 674.74$, $df = 50$, $p < 0.001$). The Grey-headed and Scaly-bellied Woodpeckers primarily foraged on the ground (45.5% & 40.6%, respectively) but also utilized tree species such as pine (27.5% & 37.5%, respectively), oak (13.3% & 0%, respectively), Kaafal *Myrica esculenta* (5.2% and 3.1%, respectively), and Deodar *Cedrus deodara* (3.9% and 18.8%, respectively). The Brown-fronted Woodpecker exhibited a strong preference for pine trees *Pinus roxburghii*, with 90.2% of its foraging activity occurring on this species. Similarly, the Himalayan Woodpecker and Greater Yellownape primarily foraged on pine trees (57% and 55%, respectively), followed by oak trees (24.7% & 21.4%, respectively), with occasional use of other species such as Kaafal, rhododendron *Rhododendron arboreum*,

Table 1. Size categories and species codes considered for this study. Species are arranged from smallest to largest (Body weights taken from Winkler et al. 1995).

Species	Code	Size category	Foraging observations (No.)	Body weight (g)
Brown-fronted Woodpecker <i>Dendrocoptes auriceps</i>	DEAU	Small	387	44.5
Himalayan Woodpecker <i>Dendrocopos himalayensis</i>	DEHI	Medium	142	73
Lesser Yellownape <i>Picus chlorophus</i>	PICH	Medium	30	79
Grey-headed Woodpecker <i>Picus canus</i>	PICA	Large	233	152.5
Greater Yellownape <i>Chrysophlegma (Picus) flavinucha</i>	PIFL	Large	182	181.5
Scaly-bellied Woodpecker <i>Picus squamatus</i>	PISQ	Large	32	182

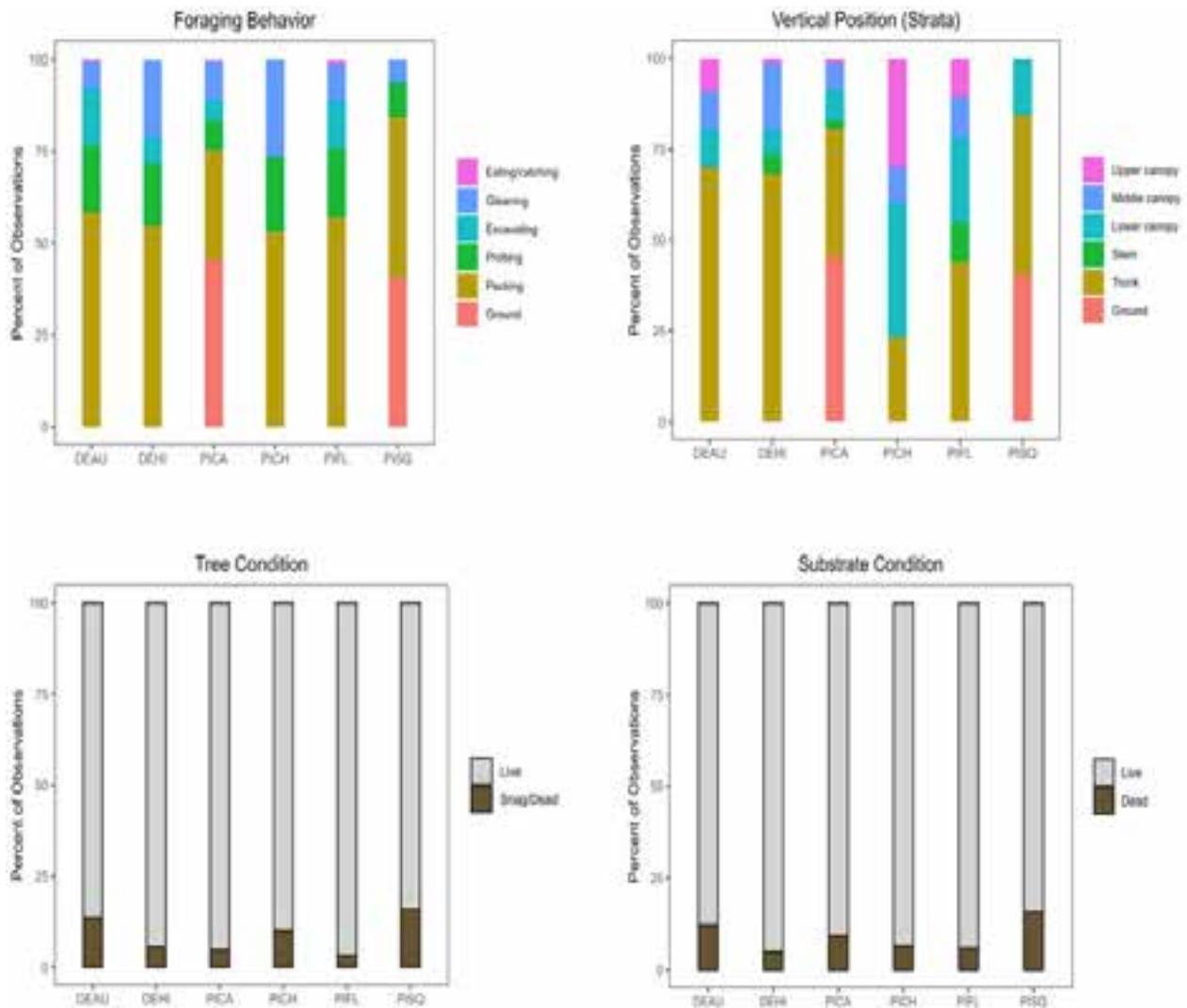


Figure 1. Frequency of foraging observation of six woodpecker species, categorized by foraging behavior (top left), vertical position (strata) (top right), tree condition (bottom left), and substrate condition (bottom right). Refer Table 1 for species codes.

Table 2. Differences in foraging behavior between species pairs (below diagonal). The table shows the chi-squared test p-value. Significant differences were at $\alpha = 0.05$. Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU						
DEHI	<0.001					
PICA	<0.001	<0.001				
PISQ	<0.001	<0.001	0.495			
PIFL	0.655	0.036	<0.001	<0.001		
PICH	<0.001	0.457	<0.001	<0.001	0.050	

and eucalyptus *Eucalyptus* spp.. There were significant differences in the selection of foraging tree species among all species pairs (Table 4, above diagonal).

There were significant differences among the six

woodpecker species in their use of live and dead (snag) trees for foraging ($\chi^2 = 35.487$, $df = 10$, $p < 0.001$). While all species primarily foraged on live trees, the Brown-fronted Woodpecker and Scaly-bellied Woodpecker

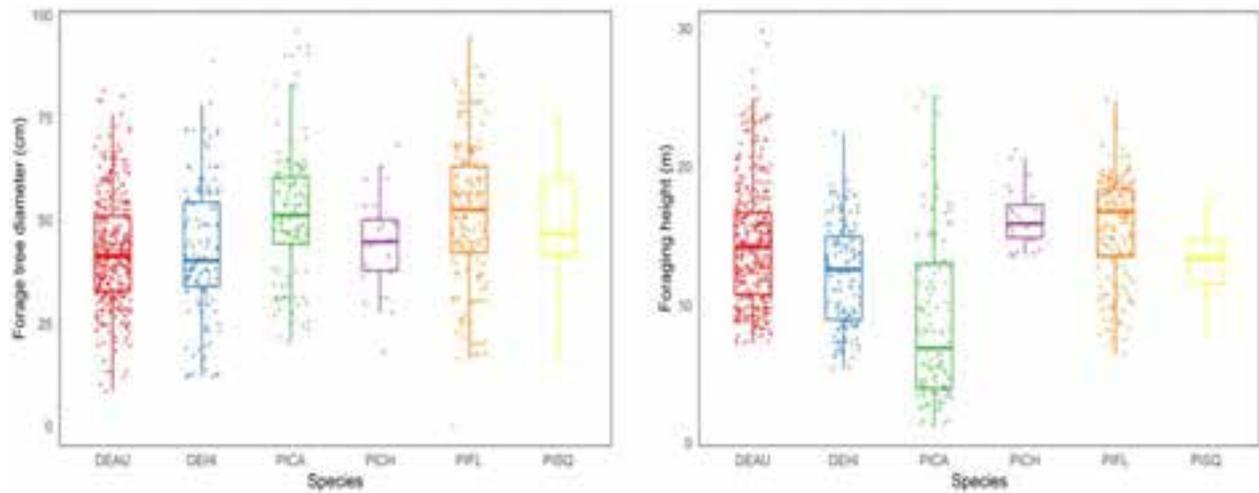


Figure 2. Comparison of forage tree diameter (cm) and foraging height (m) among six woodpecker species. Boxplots display observed values and distribution ranges, excluding outliers, using dots and whiskers. Horizontal lines represent medians, while boxes indicate the interquartile range (middle 50% of values). Refer Table 1 for species codes.

Table 3. Differences in vertical position(strata) between species pairs (below diagonal). The table shows the chi-squared test p-value. Significant differences were at $\alpha = 0.05$. Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU						
DEHI	<0.001					
PICA	<0.001	<0.001				
PISQ	<0.001	<0.001	0.344			
PIFL	<0.001	<0.001	<0.001	<0.001		
PICH	<0.001	<0.001	<0.001	<0.001	0.013	

Table 4. Differences in the foraging tree condition (below diagonal) and foraging tree species (above diagonal) between species pairs. The table shows the chi-squared test p-value. Significant differences were considered at $\alpha = 0.05$. Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU		<0.001	<0.001	<0.001	<0.001	<0.001
DEHI	0.005		<0.001	<0.001	<0.001	<0.001
PICA	0.207	0.095		0.021	<0.001	<0.001
PISQ	0.948	0.056	0.123		<0.001	<0.001
PIFL	<0.001	0.176	0.652	0.044		<0.001
PICH	0.669	0.363	0.009	0.172	0.009	

used snags/dead trees more for foraging than others, accounting for 13.7% and 15.8% of their foraging activity, respectively (Figure 1, bottom left). Significant differences in tree usage were observed between the Brown-fronted and Greater Yellownappe, as well as between the Brown-fronted and Himalayan Woodpecker. Foraging tree usage did not differ significantly among

other species pairs (Table 4, below diagonal).

Woodpeckers utilized forage trees with GBH ranging 8.6–96.18 cm. The average GBH of trees used for foraging varied among species, with the Brown-fronted Woodpecker *Dendrocytes auriceps* foraging on trees with an average GBH of 42.52 cm, while the Grey-headed Woodpecker *Picus canus* selected trees with an average

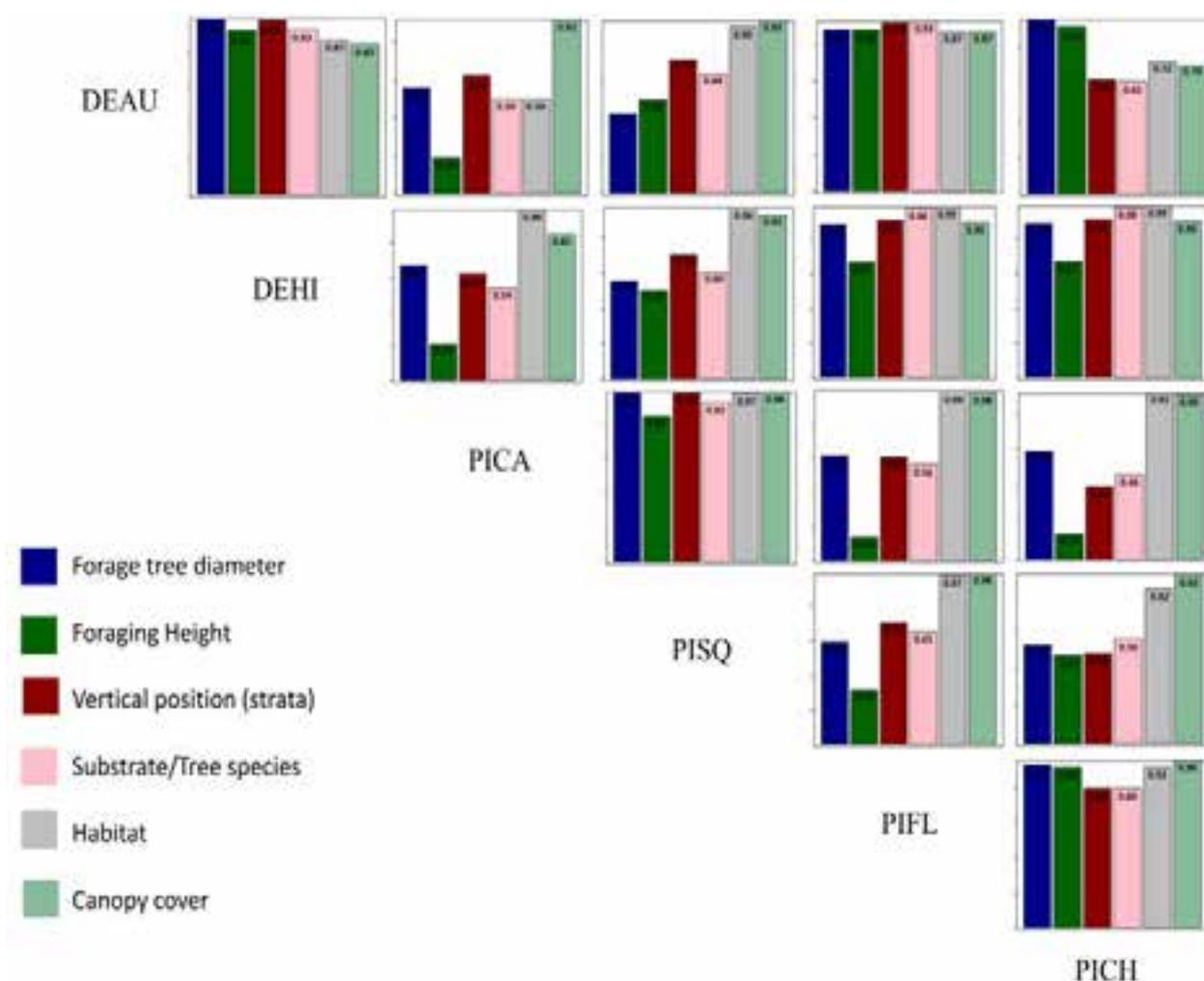


Figure 3. Overlap in foraging niches between woodpecker species pairs for individual foraging dimensions. The y-axis scale represents overlap values, ranging from 0 (no overlap) to 1 (complete overlap). The x-axis scale represents the individual foraging dimension shown in legends. Refer Table 1 for species codes.

GBH of 52.10 cm (Figure 2).

The diameter of the trees used for foraging differed significantly between the species ($H = 71.511$, $df = 5$, $p < 0.001$). When comparing species pairs, it was observed that larger-bodied species (Grey-headed Woodpecker & Greater Yellownape) picked larger trees for foraging. In contrast, smaller woodpeckers (Brown-fronted Woodpeckers) chose smaller tree diameters. The preference of the medium-sized woodpecker (Himalayan Woodpecker) for foraging tree diameter was similar to that of the smaller species (Brown-fronted Woodpecker). Although having a large size, Scaly-bellied Woodpecker did not significantly differ from any other woodpecker species in its choice of foraging tree diameter (Figure 2, left; Table 5, below diagonal).

All woodpeckers were found to be foraging from the ground to a height of around 30 m in this study. The

height at which each species foraged differed significantly ($H = 150.07$, $df = 5$, $p < 0.001$). Often observed on the ground, Grey-headed Woodpeckers foraged at a much lower height (maximum 15 m) (Figure 2, right) than other woodpecker species. Grey-headed Woodpeckers and Lesser Yellownape chose considerably different foraging heights from other species, while comparing in between-species (Table 5, above diagonal).

Niche overlap

Niche overlap among species was assessed by pooling all measured variables ($N = 36$). The Grey-headed Woodpecker had the minimum overlap with other species in its overall foraging niche. Larger woodpecker species, particularly the Grey-headed and Scaly-bellied Woodpeckers, generally showed lower overlap in their selection of foraging tree diameter than

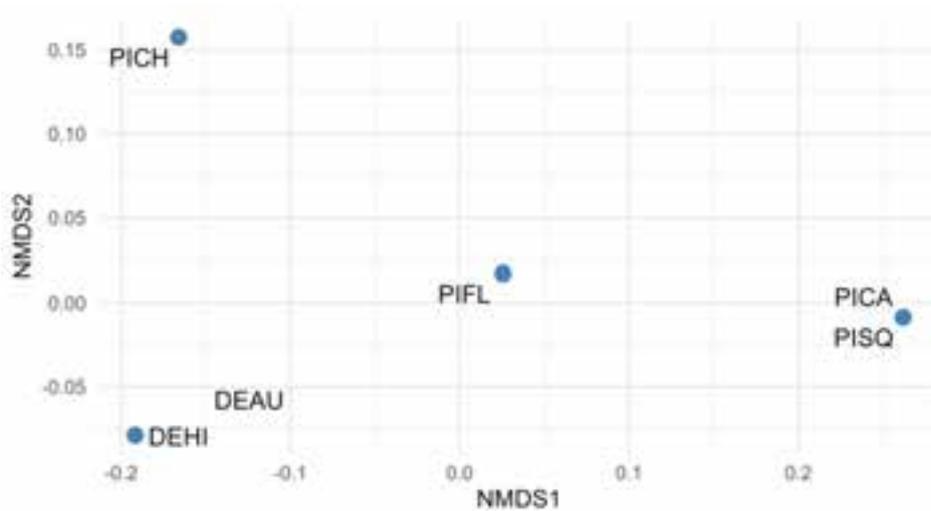


Figure 4. NMDS ordination of average foraging niche dimensions of six woodpecker species. Refer Table 1 for species codes.

Table 5. Summary of post-hoc Dunn's test for differences between species pairs in foraging height (above diagonal) and forage tree diameter (below diagonal). The table shows the p-value with Bonferroni corrections for multiple comparisons. Significant differences were at $\alpha = 0.05$. Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU		<0.001	<0.001	1.000	0.013	0.028
DEHI	1.000		<0.001	1.000	<0.001	<0.001
PICA	<0.001	0.048		0.011	<0.001	<0.001
PISQ	1.000	1.000	1.000		1.000	0.264
PIFL	<0.001	0.016	1.000	1.000		1.000
PICH	1.000	1.000	1.000	1.000	1.000	

the smaller species. Foraging height appeared to be a key distinguishing factor among woodpecker species, as overlap values for this dimension were often low. Most other species showed moderate overlap with Brown-fronted Woodpeckers and Lesser Yellownape regarding their vertical position (strata). High overlap values in a habitat type and canopy cover suggested limited species segregation along these dimensions. Foraging niche similarities between Grey-headed and Scaly-bellied Woodpeckers were highest (0.94 overlap), whereas the minimum niche overlap was found between Grey-headed Woodpecker and Lesser Yellownape (0.57 overlap) (Table 6).

The Lesser Yellownape demonstrated the most distinct foraging niches within the community by having significantly less overlap with other species. Similarly, the Greater Yellownape also showed comparatively less overlap with other woodpecker species. However, moderately high overlaps were found between the Grey-headed and Scaly-bellied Woodpeckers, as well

as between the Brown-fronted and the Himalayan Woodpecker (Figure 3).

NMDS ordination plot revealed clear separation in foraging niches among six woodpecker species (Figure 4). Species such as Grey-headed and Scaly-bellied Woodpeckers clustered closely and showed similar foraging strategies. The Himalayan Woodpecker also showed similar foraging niches, while Lesser Yellownape occupied a more distinct position on the ordination plot, indicating distinct niche segregation.

Relationship between woodpecker morphology and foraging variables

There was a significant correlation ($r = 0.84$, $p < 0.03$) found between the body weights of woodpecker species and the mean DBH of trees used for foraging (Figure 5). No significant relationship was found between the mean foraging height of trees used by woodpecker species and their body weight.

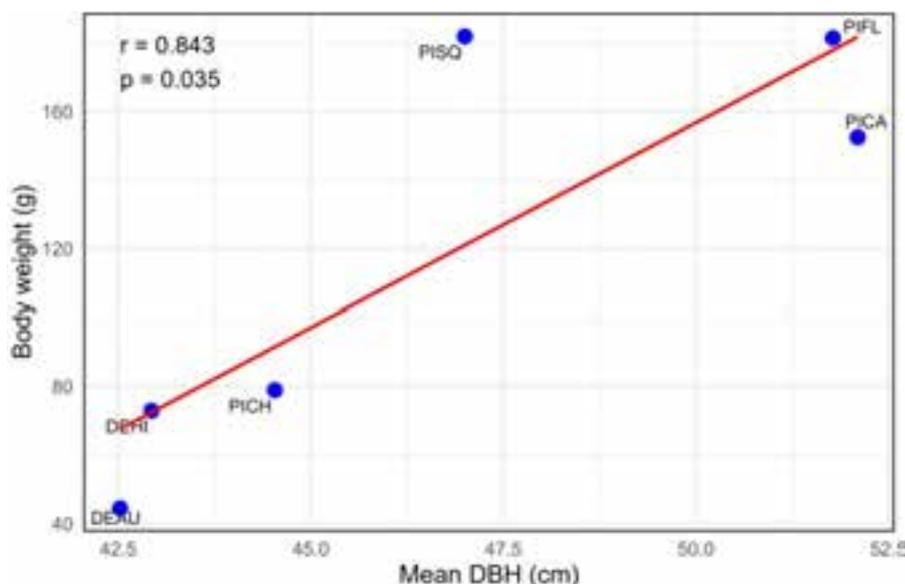


Figure 5. Relationship between Mean DBH and Body weight of six woodpecker species. Refer Table 1 for species codes.

Table 6. Species pair-wise comparison of overall Pianka's niche overlap (N = 36, represents all measured foraging variables pooled together). Refer Table 1 for species codes.

	DEAU	DEHI	PICA	PISQ	PIFL	PICH
DEAU		0.92	0.61	0.70	0.88	0.71
DEHI			0.64	0.71	0.89	0.77
PICA				0.94	0.64	0.57
PISQ					0.71	0.63
PIFL						0.89
PICH						

DISCUSSION

The observations indicate that foraging behaviour and tree attributes significantly differed among woodpecker species. They distinguish their foraging niches from each other by having different vertical positioning and varying preferences for substrates. Other investigations have shown that picids exhibit selectivity in the diameter of foraging trees. The Lesser Spotted Woodpecker *Dryobates minor* in Italy chose trees with smaller diameters than the Great Spotted Woodpecker *Dendrocopos major* (Laiolo et al. 2003). The Downy Woodpecker *Dryobates pubescens* in north America foraged on smaller diameter substrates (Conner et al. 1994), while the Middle-spotted Woodpecker *Dendrocytes medius* in northern Switzerland (Pasinelli & Hegelbach 1997; Robles et al. 2007), and the Pileated Woodpecker *Dryocopus pileatus* in east-central Louisiana

(Newell et al. 2009) had a preference for larger trees.

The woodpecker community in the Western Ghats shows a preference for large-diameter trees, establishing the fundamental relationship between woodpecker body size and resource use (Santharam 1995). These patterns were confirmed among ten sub-Himalayan woodpecker species, reinforcing the relationship between body size and tree diameter preference (Kumar et al. 2020), while Pradhan et al. (2025) demonstrated similar body size-tree diameter relationships across elevation gradients in eastern Himalayan forests.

Similarly, research conducted in the Americas revealed that Red-cockaded Woodpecker (*Dryobates borealis*) (Engstrom & Sanders 1997), Magellanic Woodpecker *Campephilus magellanicus* (Vergara & Schlatter 2004), and American Three-toed Woodpecker *Picoides dorsalis* (Gagne et al. 2007) significantly utilized larger trees with their availability. The idea that

larger species will use resources more effectively is predicted by optimal foraging theory (Campbell 1987), and this understanding has been supported by these investigations as well as the current study.

Body size influenced the selection of tree size for foraging by woodpeckers, and this pattern could possibly reflect their biochemical capabilities and limitations, which are functions of body mass (Kumar et al. 2020). Foraging height did not exhibit any size-related patterns (Lammertink 2007). Despite being a large species, the Greater Yellownape foraged higher than other species, much like the medium-sized Lesser Yellownape.

The foraging height and vertical position were crucial in differentiating woodpeckers in the current study. The vertical position was somewhat associated with segregation along foraging height. Similarly, segregating woodpecker species based on foraging height was crucial in North America (Williams 1975; Conner et al. 1994), Southeast Asia (Short 1978; Styring & Zakaria 2004; Lammertink 2007), and Europe (Török 1990; Böhm & Kalko 2009). Vertical stratification was identified as a key mechanism enabling coexistence among sub-Himalayan woodpeckers (Kumar et al. 2020), while Pradhan et al. (2025) documented species-specific foraging height preferences that varied across tropical, subtropical, and temperate forest zones in the eastern Himalaya.

Recent comparative studies have further expanded our understanding of these patterns. It has been observed by Si et al. (2023) in northeastern China that vertical stratification in foraging positions is a key factor in segregating foraging among woodpecker species, suggesting that woodpeckers find and occupy specific niches within forests to avoid resource-based competition. This finding is consistent with patterns observed in various Indian studies, suggesting that vertical niche partitioning serves as a widespread mechanism facilitating woodpecker coexistence.

In terms of substrate condition preferences, the findings of this study are consistent with other investigations (Santharam 1995; Kumar et al. 2020; Pradhan et al. 2025), who similarly discovered no interspecific variations in the utilization of substrate conditions for foraging in the Western Ghats, sub-Himalayan and eastern Himalayan woodpecker communities, respectively. Deadwood has been recognized as an essential resource for numerous woodpecker species (Winkler et al. 1995). Nonetheless, since this study found no distinct differences across species regarding substrate conditions, dead substrates may thus be uniformly crucial to all species. In non-protected forests, anthropogenic removal of snags for

firewood (Pradhan et al. 2025) may limit this resource, thereby emphasizing the importance of deadwood conservation for maintaining foraging niches. Pradhan et al. (2025) discovered that woodpeckers were more frequently observed foraging on live trees than on snags/dead trees, which is consistent with the findings of this study regarding tree condition preferences. Across all forest types, woodpeckers showed a strong preference for snags and unhealthy trees, which highlights the significance of snags and deadwood for woodpecker foraging (Winkler et al. 1995; Smith 2007; Kumar et al. 2020; Si et al. 2023). This may be attributed to the relatively limited availability of snags in our study area. It has been documented that the snags are commonly used as firewood in non-protected forests, and local communities frequently remove them (Pradhan et al. 2023).

This study shows that the woodpecker species that overlap in one foraging niche dimension may often segregate along multiple other ecological dimensions. Also, the results suggest that niche segregation plays a key role in the stable coexistence of woodpecker species at Ranikhet, Kumaon Himalaya, Uttarakhand. This finding is also consistent with the broader framework established by research findings on the Indian woodpecker community, such as Santharam (1995), who first described multi-dimensional niche partitioning in woodpeckers in the Western Ghats, Kumar et al. (2020) in north-western forests of the Himalaya, and Pradhan et al. (2025) across elevation gradients in the eastern Himalaya.

The availability of resources, such as dietary preferences, roost and nest sites, or interactions with other species, may be key factors for this segregation. Further data collection is required to understand these mechanisms and direct conservation efforts to maintain woodpecker diversity and forest structure, including snag/deadwood and trees of different diameters.

REFERENCES

- Böhm, S.M. & E.K. Kalko (2009). Patterns of resource use in an assemblage of birds in the canopy of a temperate alluvial forest. *Journal of Ornithology* 150: 799–814. <https://doi.org/10.1007/s10336-009-0401-7>
- Bull, E.L., S.R. Peterson & J.W. Thomas (1986). *Resource partitioning among woodpeckers in northeastern Oregon*. United States Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 19 pp. <https://doi.org/10.2737/PNW-RN-444>
- Chesson, P. (2000). Mechanisms of maintenance of species diversity. *Annual Review of Ecology and Systematics* 31: 343–366. <https://doi.org/10.1146/annurev.ecolsys.31.1.343>

- Conner, R.N., S.D. Jones & G.D. Jones (1994). Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. *The Wilson Bulletin* 242–257.
- EcoSimPro/PROOSIS Version 7.0 (2024). Modelling and Simulation Software for Dynamic Systems. Madrid, Spain. Available at: ecosimpro.com
- Engstrom, R.T. & F.J. Sanders (1997). Red-cockaded woodpecker foraging ecology in an old-growth longleaf pine forest. *The Wilson Bulletin* 203–217.
- Gagné, C., L. Imbeau & P. Drapeau (2007). Anthropogenic edges: their influence on the American Three-toed Woodpecker *Picoides dorsalis* foraging behaviour in managed boreal forests of Quebec. *Forest Ecology and Management* 252(1–3): 191–200. <https://doi.org/10.1016/j.foreco.2007.06.039>
- Gamboia, G.J. & K.M. Brown (1976). Comparative foraging behavior of six sympatric woodpecker species. *In Proceedings of the Iowa Academy of Science* 82: 179–181.
- Gause, G. (1934). *The Struggle for Existence*. Haefner, New York, 188 pp.
- Hutchinson, G. E. (1957). Concluding remarks. *Cold Spring Harbor Symposia on Quantitative Biology* 22: 415–427.
- Johnson, C.A. & J.L. Bronstein (2019). Coexistence and competitive exclusion in mutualism. *Ecology* 100(6): e02708. <https://doi.org/10.1002/ecy.2708>
- Kumar, R., G. Shahabuddin & A. Kumar (2014). Habitat determinants of woodpecker abundance and species richness in sub-Himalayan dipterocarp forests of north-west India. *Acta ornithologica* 49(2): 243–256. <https://doi.org/10.3161/173484714X687136>
- Kumar, R., G. Shahabuddin & A. Kumar (2020). Foraging niche differentiation among sympatric woodpecker species in forests of north-western India. *Acta Ornithologica* 55(1): 88–100. <https://doi.org/10.3161/00016454AO2020.55.1.009>
- Laiolo, P., E. Caprio & A. Rolando (2003). Effects of logging and non-native tree proliferation on the birds overwintering in the upland forests of north-western Italy. *Forest Ecology and Management* 179: 441–454. [https://doi.org/10.1016/S0378-1127\(02\)00542-X](https://doi.org/10.1016/S0378-1127(02)00542-X)
- Lammertink, J.M. (2007). Community ecology and logging responses of Southeast Asian woodpeckers (Picidae, Aves). PhD Thesis, Department of Biological Sciences, Universiteit van Amsterdam.
- MacArthur, R.H. & R. Levins (1967). The limiting similarity, convergence, and divergence of coexisting species. *American Naturalist* 101(921): 377–385.
- Mani, A.N.N.A. (1981). The climate of the Himalaya. *The Himalaya: Aspects of Changes* 3:15.
- Mikusiński, G. (2006). Woodpeckers: distribution, conservation, and research in aglobal perspective. *Annales Zoologici Fennici* 43(2): 86–95.
- Newell, P., S. King & M. Kaller (2009). Foraging behavior of Pileated Woodpeckers in partial cut and uncut bottomland hardwood forest. *Forest Ecology and Management* 258(7): 1456–1464. <https://doi.org/10.1016/j.foreco.2009.06.053>
- Oksanen, J., G. Simpson, F. Blanchet et al. (2024). vegan: Community Ecology Package. R Package Version 2.6-6.1. <https://CRAN.R-project.org/package=vegan>
- Pasinelli, G. & J. Hegelbach (1997). Characteristics of trees preferred by foraging middle spotted woodpecker *Dendrocopos medius* in northern Switzerland. *Ardea* 85(2): 203–209.
- Pradhan, A. & S. Khaling (2023). Community priorities, values, and perceptions associated with ecosystem services provided by the socio-ecological landscapes of Darjeeling-Sikkim Himalaya. *Regional Environmental Change* 23(1): 36. <https://doi.org/10.1007/s10113-023-02028-z>
- Pradhan, A., S. Khaling, & G.K. Saha (2025). Exploring foraging niche dynamics of woodpeckers in the non-protected forests of eastern Himalaya. *Ornithology Research* 33(1): 1–19. <https://doi.org/10.1007/s43388-025-00227-2>
- R Core Team (2024). R: A language and environment for statistical computing. Version 4.4.1. R Foundation for Statistical Computing, Vienna, Austria. URL: <https://www.r-project.org/>
- Remsen, J.V. & S.K. Robinson (1990). A classification scheme for foraging behavior of birds in terrestrial habitats. *Studies in Avian Biology* 13(1): 144–160.
- Robles, H., C. Ciudad, R. Vera, P.P. Olea, F.J. Purroy & E. Matthysen (2007). Sylvopastoral management and conservation of the middle-spotted woodpecker at the south western edge of its distribution range. *Forest Ecology and Management* 242: 343–352. <https://doi.org/10.1016/j.foreco.2007.01.052>
- Santharam, V. (1995). Ecology of sympatric woodpecker species of Western Ghats, India. PhD Thesis. Pondicherry University.
- Shahabuddin, G., R. Goswami & M. Gupta (2017). An annotated checklist of the birds of Banj Oak-Chir Pine forests in Kumaon, Uttarakhand. *Indian Birds* 13(2): 29–36.
- Short, L.L. (1978). Sympatry in woodpeckers of lowland Malayan Forest. *Biotropica* pp. 122–133.
- Si, Y., D. Meng, H. Zhong, Z. Zhu, H. Zou & K. Rong (2023). Foraging niche differentiation of five woodpecker species in the primitive broadleaved Korean pine forests of northeast China. *Forests* 14(11): 2166. <https://doi.org/10.3390/f14112166>
- Styring, A.R. & M.Z. bin Hussin (2004). Effects of logging on woodpeckers in a Malaysian rain forest: the relationship between resource availability and woodpecker abundance. *Journal of Tropical Ecology* 20(5): 495–504. <https://doi.org/10.1017/S0266467404001580>
- Török, J. (1990). Resource partitioning among three woodpecker species *Dendrocopos* spp. during the breeding season. *Ecography* 13(4): 257–264. <https://doi.org/10.1111/j.1600-0587.1990.tb00617.x>
- Vergara, P. & R.P. Schlatter (2004). Magellanic Woodpecker (*Campephilus magellanicus*) abundance and foraging in Tierra del Fuego, Chile. *Journal of Ornithology* 145: 343–351. <https://doi.org/10.1007/s10336-004-0052-7>
- Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York. ISBN 978-3-319-24277-4. <https://ggplot2.tidyverse.org>
- Williams, J.B. (1975). Habitat utilization by four species of woodpeckers in a central Illinois woodland. *American Midland Naturalist* 354–367. <https://doi.org/10.2307/2424168>
- Winkler, H., D.A. Christie & D. Nurney (1995). *Woodpeckers: An Identification Guide to the Woodpeckers of the World*. 1st ed. Houghton Mifflin Company, New York.
- Winkler, H. & D.A. Christie (2002). Family Picidae (Woodpeckers), pp. 296–555. In: In: del Hoyo, J., A. Elliot & J. Sargatal (eds.) *Handbook of the Birds of the World - 7: Jacamers to Woodpeckers*. Lynx Edicions, 613pp.
- Zeng, X. & X. Lu (2009). Interspecific dominance and asymmetric competition with respect to nesting habitats between two snowfinch species in a high-altitude extreme environment. *Ecological Research* 24: 607–616. <https://doi.org/10.1007/s11284-008-0530-0>



Local knowledge, attitudes, and perceptions of ecosystem services and disservices provided by the Painted Stork *Mycteria leucocephala* Pennant, 1769 (Aves: Ciconiidae) in northern India: insights for conservation

Yashmita-Ulman¹  & Manoj Singh² 

¹ Department of Silviculture & Agroforestry, College of Horticulture & Forestry, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh 224229, India.

² Department of Zoology, Kalinga University, Naya Raipur, Chhattisgarh 492012, India.

¹ yashmita-agf@nduat.org, ² manoj.singh@kalingauniversity.ac.in (corresponding author)

Abstract: Understanding the knowledge, attitudes and perceptions of the local communities towards the target species before implementing any awareness-based programmes is essential for the success and long-term protection of the species. No studies have yet been conducted on local knowledge, attitudes, perceptions of ecosystem services and disservices, threats and possible recommendations for conservation of the Painted Stork *Mycteria leucocephala* in northern India. To fill this gap, a study was conducted in August–September 2024 in villages of Etawah District, Uttar Pradesh, India, where Painted Stork builds nests in farmland in human-dominated areas. The study employed a questionnaire survey, containing both closed and open-ended questions, administered to 200 respondents. All the respondents identified the species, and a majority knew its local name, breeding ecology, foraging ecology, and population trend. A majority of the people (52%) liked the species, supported conservation of the species (51%), felt the need for awareness programmes (52%), and were ready to participate in nest monitoring training (47%) & awareness programmes (58%). At the same time, a majority of the people were reluctant to report hunting (48%), reluctant to take the injured birds to veterinary doctors (46%), and lacked knowledge on the bird's conservation status (64%). People perceived 12 ecosystem services and five ecosystem disservices provided by Painted Stork, with pest control (50%) being the highest cited service and crop destruction (72%) the most cited disservice. According to the respondents, the highest threat to the species is wetland loss (59%). A majority recommended that conservation efforts should focus on organizing awareness programmes (52%) and implementing wetland management and conservation (50%). Furthermore, respondents believed the community should take the initiative in these efforts (48%). This study emphasizes intensified awareness programs, wetland conservation and management and protection of nesting trees, among other measures, to ensure the conservation of this species outside protected areas. It provides the essential baseline for conservationists, researchers, and policy makers to design effective conservation and management strategies involving local communities and policies for research and conservation of Painted Stork.

Keywords: Etawah, Farhadpura, human-dominated landscapes, nesting trees, questionnaire surveys, recommendations, socio-demography characteristics, threats, Usrai, Uttar Pradesh.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

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

Citation: Yashmita-Ulman & M. Singh (2026). Local knowledge, attitudes, and perceptions of ecosystem services and disservices provided by the Painted Stork *Mycteria leucocephala* Pennant, 1769 (Aves: Ciconiidae) in northern India: insights for conservation. *Journal of Threatened Taxa* 18(2): 28329–28342. <https://doi.org/10.11609/jott.10272.18.2.28329-28342>

Copyright: © Yashmita-Ulman & Singh 2026. 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: This study was carried out through funding provided by the Wildlife Trust of India and Fondation Segre.

Competing interests: The authors declare no competing interests.

Author details: DR. YASHMITA-ULMAN, assistant professor in the Department of Silviculture & Agroforestry, ANDUAT, Ayodhya, Uttar Pradesh. She specialises in the field areas of agroforestry and wildlife conservation and management. DR. MANOJ SINGH, assistant professor in the Department of Zoology, Kalinga University, Naya Raipur, Chhattisgarh. He is specialized in bird acoustics and wildlife conservation.

Author contributions: Y-U conceived and designed the study, conducted fieldwork, and wrote the final draft of the manuscript. MS performed the field work, compiled the data and analyzed the data. Both authors read and approved the final manuscript.

Hindi abstract: See end of this article.

Acknowledgements: We thank the funding agencies, Wildlife Trust of India and Fondation Segre, and the villagers for their permission and constant support in conducting this survey.



INTRODUCTION

Anthropogenic factors such as deforestation, urbanization, encroachment, human-wildlife negative interactions have driven the species to the brink of extinction and led to wildlife population declines (Taylor-Brown et al. 2019; Lewis et al. 2021; Lees et al. 2022). The scientific community has tried to invent many different possibilities, such as creating wildlife sanctuaries (Gorbunov et al. 2019; Volenec & Dobson 2020), restoration of degraded areas (Possingham et al. 2015; Volis 2019), and ex situ conservation (Canessa et al. 2015). But focusing on these techniques is not sufficient, as many of the threatened species are found in human-dominated landscapes (Bracebridge et al. 2013; Yashmita-Ulman et al. 2018; 2021a,b; Ceballos et al. 2019). The co-existence of people with wildlife is ultimately seen as a necessity to achieve wildlife conservation (Chakanyuka & Utete 2022), emphasizing the importance of the community's ecological knowledge and attitudes towards wildlife conservation (Gupta et al. 2023; Manigandan et al. 2024).

As locals interact with native species routinely, they have a good insight (Romero-Bautista et al. 2020) into the aspects of species distribution, breeding, diet, associated problems, services and threats (Gaston et al. 2018; Kross et al. 2018) as is the case with the Painted Stork *Mycteria leucocephala*, which is commonly seen foraging and building nesting colonies in the wetlands (Yashmita-Ulman 2022, 2023; Yashmita-Ulman & Singh 2022, 2025) and agricultural fields (Yashmita-Ulman & Singh 2021) in Uttar Pradesh. Understanding the local knowledge and involving the communities in the decision-making process can make them actively participate in conservation programmes. This can lead to the effective design of species conservation management strategies (Katuwal et al. 2021; Messina et al. 2023). Benefit sharing related to conservation-related activities can inculcate positive attitudes towards the species (Bajracharya et al. 2007), whereas events such as crop-raiding, livestock depredation, which are the costs related to conservation, develop negative attitudes towards the species (Mehta & Heinen 2001; Walpole & Goodwin 2001; Yashmita-Ulman et al. 2020). Evidence shows that communities hold negative attitudes towards birds such as Sarus Crane (Nevard et al. 2019), raptors (Dabone et al. 2022), Black-necked Crane (Zhong et al. 2023), for crop damage, making noise (Leong et al. 2020), and spreading disease (Green & Elmberg 2014). Certain communities also appreciate birds for their ecosystem services, such as decorative value (Baya Weaver, Yashmita-Ulman et al.

2017), scavenging (vultures, Morales-Reyes et al. 2018), pest-control (owls, Iniguez-Gallardo et al. 2024), aesthetic value (Sarus crane, Bhattarai et al. 2025), and revere them for their cultural values (Hooded vultures, Dabone et al. 2022). Therefore, the attitudes of the community towards the species need to be understood as these play an important role in the acceptance or rejection of conservation-related activities and management practices (Winter et al. 2005; Byju et al. 2024). The attitude of people towards a species is influenced by factors such as age, caste, gender, size of landholding, education, religion, and distance from forests (Arjunan et al. 2006; Ntuli et al. 2019). These attitudes can also be changed through organizing effective conservation programmes based on the prior understanding of the knowledge and attitudes of the community towards the species. For effective implementation of any community-based conservation activity, the first step is to understand the local knowledge, perceptions and attitudes of the local people towards the species in question.

The Painted Stork, locally known as Dhek, is an ibis-like stork with a long, tapering and drooping bill, 93–102 cm in length, and it weighs around 2–3.5 kg. It is distributed across southwestern Pakistan, India, and Sri Lanka, and into Indochina and southern China. It is found in shallow freshwater ecosystems such as lakes, marshlands, rivers, paddy fields, and wetlands (Cornell Lab of Ornithology 2025). It is a locally migratory species in Uttar Pradesh, and its breeding season lasts from August/September to February. The global population was estimated to be around 25,000 birds in 1994 (Cornell Lab of Ornithology 2025). The bird species has been upgraded to Schedule II, Part B of the Wildlife (Protection) Amendment Act, 2022 (WPAA 2022) from Schedule IV of the Wildlife (Protection) Act, 1972 (WPA 1972). Though the IUCN status of this bird is 'Least Concern' (IUCN 2025), it locally faces the threat of hunting, habitat loss, and degradation (Cornell Lab of Ornithology 2025). This species is mainly hunted for its meat and eggs (Cornell Lab of Ornithology 2025) as it forms a cheap source of protein for the local communities. In Uttar Pradesh, the Painted Stork prefers wetlands and agricultural fields for nesting (Tiwarly et al. 2014) and foraging, which are present in human-dominated landscapes, not under the direct control of the forest department but under the community governance, increasing the chances of hunting and habitat destruction that go unreported. The most effective way to protect this species and its nesting sites is to integrate its conservation and management with local communities and their livelihoods.

Many studies have been conducted in different

countries across the world that document the local knowledge and attitudes of people towards bird species conservation (Jacobson et al. 2003; Mmassy & Roskaft 2013; Cortes-Avizanda et al. 2018; Gaston et al. 2018; Kross et al. 2018; Katuwal et al. 2021, 2024; Zhong et al. 2023). In India, a handful of such studies exist on wildlife (Mir et al. 2015; Talukdar & Gupta 2018; Karanth et al. 2019; Gupta et al. 2023; Bhaskaran & Nilon 2025), and birds in particular (Acharya et al. 2009; Aiyadurai & Banerjee 2020; Aiyadurai et al. 2023; Tiwari et al. 2023; Das et al. 2025), but there are none specifically on Painted Stork. Considering the knowledge gap on the subject and the species, this study aims to assess: 1) people's ecological knowledge on Painted Stork, 2) their attitudes towards the species, 3) people's perception of threats faced by the species, 4) perceptions on ecological services and disservices provided by the Painted Stork, and 5) possible recommendations to conserve the species as suggested by the community.

MATERIALS AND METHODS

Study area

The field sites for this study are centred around the villages of Farhadpura (26.888° N & 79.161° E) and Usrai (Usrahar) (26.919° N & 79.034° E) (Figure 1), both situated within the Barhpura Block of the Etawah District in southwestern Uttar Pradesh. These localities are part of the Ganga-Yamuna Doab—a region defined by its position between the two major rivers, the Yamuna and its main tributary, the Chambal (KVK 2025). The district covers an area of approximately 2,311 km², with the district headquarters in Etawah Town (GoUP 2025). The district experiences a sub-humid climate, with an average annual rainfall of about 792 mm, most of which falls between June and September during the southwest monsoon (KVK 2025). Temperatures peak in May, reaching daily maxima averaging up to 42 °C. Much of the area is agricultural, dominated by wheat, rice, and sugarcane crops (KVK 2025), but remnant patches of natural vegetation—especially along water bodies, agricultural fields and communal/village lands—serve as critical nesting sites for waterbirds. The Sarsai Nawar Wetland, recognized as a Ramsar site, lies in proximity and underlines the conservation importance of this region for waterbirds.

The Painted Stork is a colonial nester. In both the villages, these birds build nests on the trees of *Terminalia arjuna* and *Ficus religiosa* found in agricultural fields (Image 1).

Method

The questionnaire surveys were carried out for two months, August–September 2024. Before starting with the formal data collection, an introductory informal group discussion was conducted with the residents of both the villages with the help of the village headman or gaon pradhan. Then, a preliminary pilot survey was carried out by interviewing 40 respondents, based on which a few improvements were made in the questionnaires. The respondents were also asked to list the benefits and problems caused by the Painted Stork. Based on these answers, a list of 12 ecosystem services and five ecosystem disservices were included in the final questionnaires. The ecosystem services were further classified into three sections, namely, regulation & maintenance, cultural, and provisioning services (Zhong et al. 2023). The improvised questionnaire had a set of closed and open-ended questions (See supplementary file S1) administered to 100 randomly selected respondents (as the nesting trees were in or around agricultural fields) from each village, making a total of 200 respondents. The questions asked were pertaining to 1) knowledge on Painted Stork (species identification, local name, habitat, nesting trees, breeding season, foraging locations, diet, population fluctuations over the years, conservation status of species), 2) attitudes towards Painted Stork (thought of it as a harmful species, whether they liked the species, supported its conservation, whether they cut its nesting trees, opinions on need for awareness programmes, willingness to participate in nest monitoring training programmes and awareness programmes, report hunting, take injured birds to veterinary doctor), 3) threats faced as perceived by people, 4) recommendations to conserve the species as suggested by people, and 5) perceptions of ecosystem services and disservices provided by the species (respondents were asked to choose between the 12 ecosystem services namely pest control, eats snakes and nutrient cycling under regulation and maintenance ecosystem service, medicinal value and meat value under provisioning ecosystem service, sense of pride, existence value, aesthetic value, conservation value, conservation flagship, educational value and ecotourism under cultural ecosystem service and five ecosystem disservices namely destroys crops, eat fishes, makes noise, makes area dirty and spreads diseases). To establish whether the participants could identify the species and its local name, a photo-elicitation approach was used during the surveys. Before the start of every interview, the verbal consent of the respondents was taken, and they were informed that the data would be used only for research purposes. The interviews were

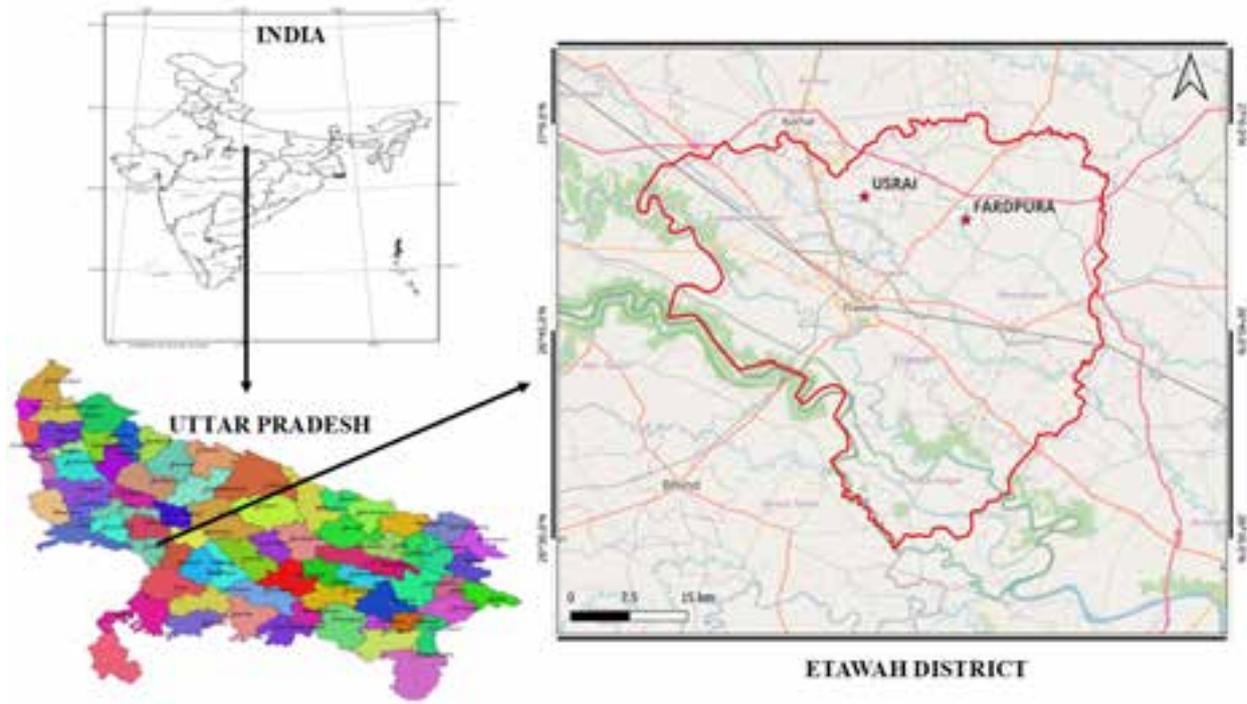


Figure 1. Map of the study area.



Image 1. Nesting locations showing nesting trees and nests of Painted Stork in Usrai and Farhadpura villages of Etawah District, Uttar Pradesh. © Manoj Singh & Rajesh Kumar.

conducted in the local Hindi language using simple local terms. Each interview took approximately 40 minutes to complete. For data analysis, the respondent's knowledge about the species was evaluated by marking one point for each correctly answered question and zero points for each wrong answer.

RESULTS AND DISCUSSION

Socio-demographic characteristics of respondents

Out of the 200 respondents, 66% (n = 132) were male, and 34% (n = 68) were female (Table 1). The respondents' ages ranged from 16–85 years, with the majority falling within the age range of 25–54 (Table 1). The majority of the respondents were engaged in agriculture and received secondary level education till 12th class (Table 1).

Respondent's ecological knowledge about the species

All the respondents were able to identify the Painted Stork, and more than half knew its local name (Figure 2). While most respondents could not correctly identify the bird's habitats, they were knowledgeable about the breeding season and preferred nesting trees of the species. The respondents mentioned that the Painted Storks arrive during the Diwali season (i.e., September/October) and avoid nesting on sacred Peepal *Ficus religiosa* trees used for prayer. Most of the respondents knew that wetlands and agricultural lands were the species' most preferred foraging sites, and that the species fed on fish, snakes, crustaceans, snails, shrimps, crabs, insects, and frogs. The familiarity of the local people with this species might be because the Painted Stork has an attractive appearance, a huge body and builds nests in and around farmlands and wetlands, close to human habitations. Similarly, many other studies have reported that people possess good knowledge of birds around them (Mmassy & Roskaft 2013; Katuwal et al. 2024; Das et al. 2025; Nima et al. 2025). The findings also report declines in the population of species (Figure 2), which might be due to the comparison with their past experiences. Interestingly, the population trend of this species shows that its population is increasing (BirdLife International 2025), suggesting a local decline in the species population. The majority of the people were unaware of the conservation status of the species and did not know its habitat (Figure 2), which also shows the knowledge gap. Some studies have reported that educated people have greater awareness of the conservation status of birds and their habitat (Ortega-Lasuen et al. 2023; Katuwal et al. 2024).

Respondent's attitudes towards the species

Amongst the respondents, 44% (n = 87) perceived the Painted Stork as a harmful species (Figure 3), primarily because its excreta fell on and destroyed crops. The majority of villagers supported species conservation and cherished the birds (Figure 3), as they were accustomed to living with them like family members and appreciated their elegant appearance. Furthermore, the respondents agreed that awareness programmes were necessary and expressed readiness to participate in nest monitoring and awareness programmes (Figure 3), consistent with findings from a study on the Sarus Crane in Nepal (Bhattarai et al. 2025). Nearly an equal number of people agreed and disagreed about taking injured birds to the veterinarians, with many refusing to report hunting (Figure 3). This reluctance likely stems from a desire to avoid legal repercussions. Consequently, hunting in villages remains underreported, causing this threat to rise slowly.

Perceived threats to the species

According to the opinion of the respondents, the highest threat faced by the Painted Stork is wetland loss and hunting (Figure 4). Similar threats have been reported by Herzon & Mikk (2007), Stanton et al. (2018) and Katuwal et al. (2021). Villagers confirmed that most wetlands were encroached upon for agricultural expansion and that this species was hunted for meat. During our field visits, some people were seen pelting stones at the chicks

Table 1. Socio-demography of the respondents who participated in the interviews.

Variables	Categories	Number (N)	Percentage (%)
Gender	Male	132	66
	Female	68	34
Age	Early working age (16–24)	37	18
	Prime working age (25–54)	78	39
	Mature working age (55–64)	61	31
	Elderly age group (> 65)	24	12
Educational Attainment	Illiterate (no formal education)	29	15
	Primary level (< 8 class)	46	23
	Secondary level (9–12 class)	74	37
Occupation	Bachelor & above	51	25
	Agriculture	113	57
	Business	34	17
	Government job	20	10
	Private job	29	14
	Others	4	2

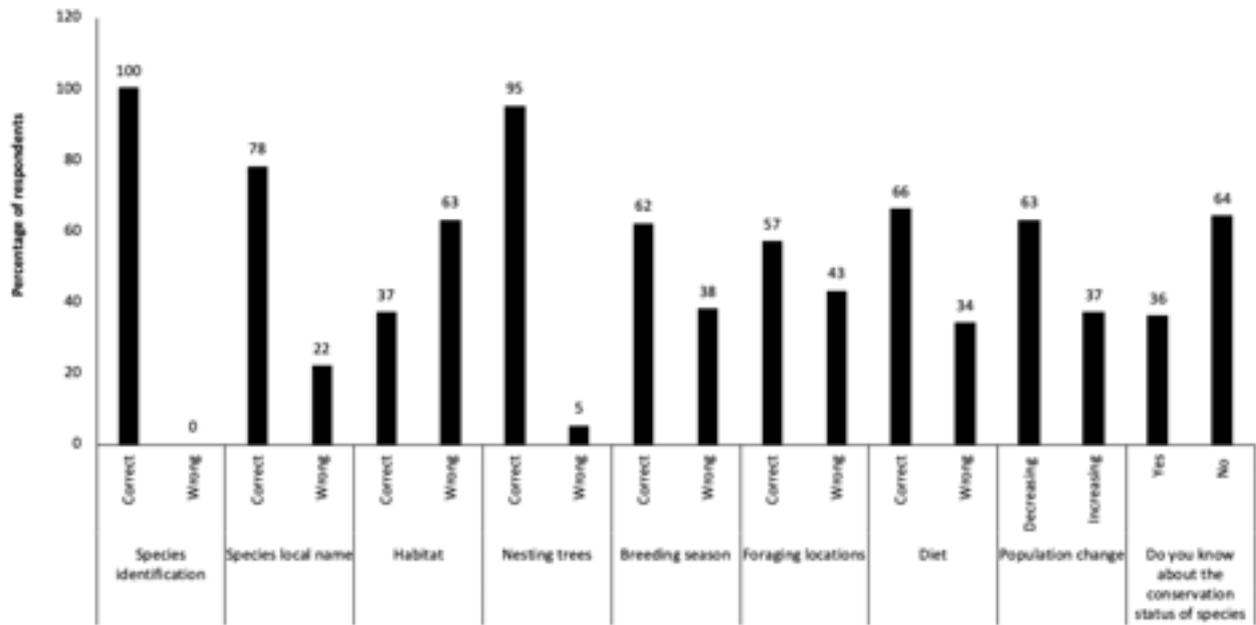


Figure 2. Respondent’s knowledge on the Painted Stork.

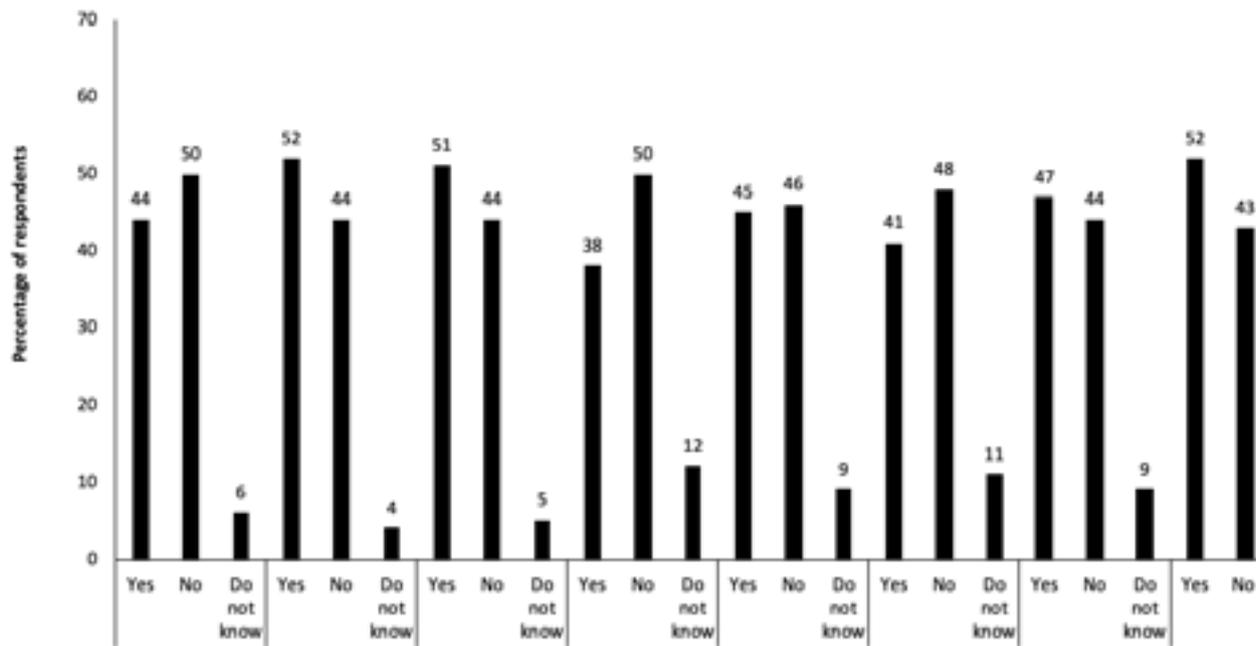


Figure 3. Respondents attitudes towards Painted Stork.

in the nest. There are reports that confirm this species is hunted for food (BirdLife International 2025). Although we observed one instance where a tree was cut down to avoid nesting, while a few villagers confirmed this during surveys, the majority denied it.

Perceived ecosystem services and disservices

In all, the respondents recognised 12 ecosystem services (three regulation and maintenance ecosystem services, two provisioning ecosystem service and seven cultural ecosystem services) and five ecosystem disservices (Figures 5 & 6). The most-cited regulation and maintenance ecosystem service was pest control;

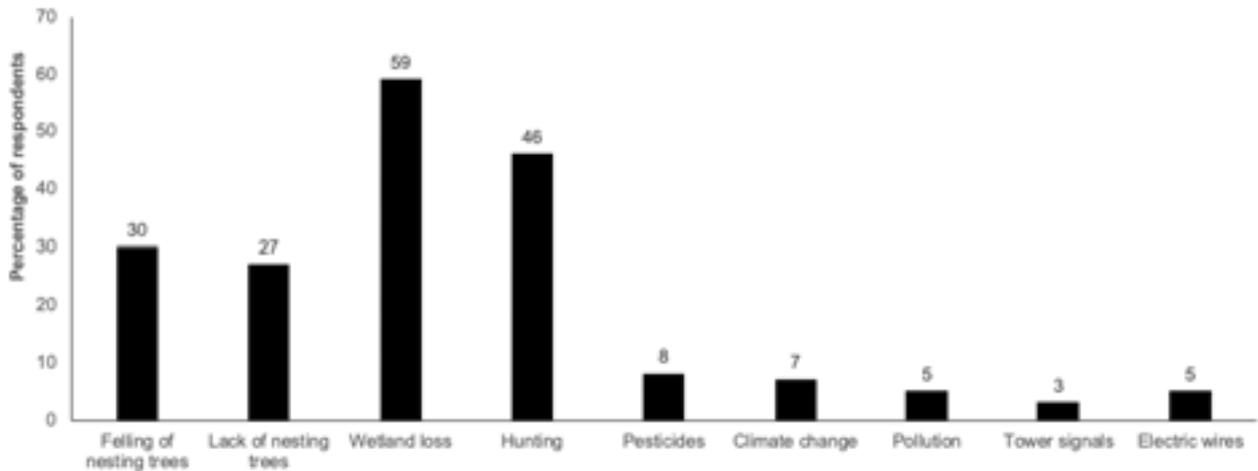


Figure 4. Threats faced by Painted Stork as perceived by the respondents.

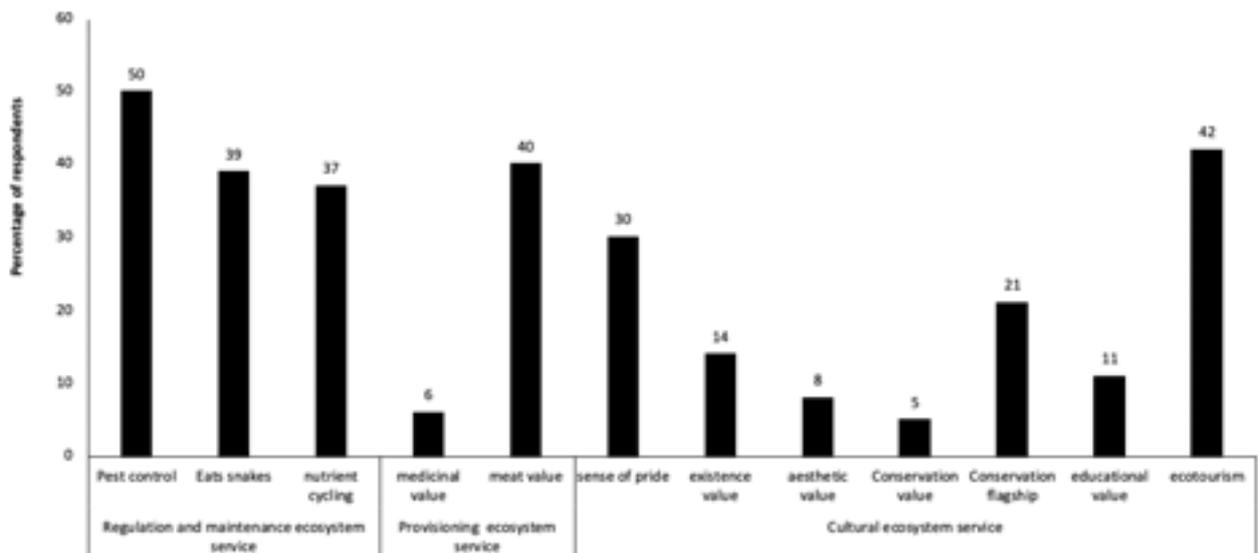


Figure 5. Perceived ecosystem services provided by Painted Stork.

the most-cited provisioning ecosystem service was meat value, and the most-cited cultural ecosystem service was ecotourism (Figure 5). Because the diet of the Painted Stork consists of agricultural pests – including insects, snails (Ali & Ripley 1987; Parasharya & Naik 1990; Sridhar et al. 2002; Urfi 2002), and snakes (Urfi 1988) – humans might appreciate this bird's role as a natural predator. The positive attitude towards this species might also have been developed as people acknowledged the ecosystem services provided by the Painted Stork (Whelan et al. 2008; Mariyappan et al. 2023). The most-cited ecosystem disservices were crop destruction and fish predation (Figure 6). Bird excreta that drop on nesting trees and crops below (observed by Yashmita-Ulman) form a white layer on leaves, disrupting photosynthesis and reducing

crop yield. Since the species is primarily piscivorous (Urfi 2011), this predation on fish—a food source for local people—results in human-wildlife negative interactions. The number of services and disservices mentioned by each respondent ranged 1–3, with the majority citing one ecosystem service in each category (Figures 7, 8, & 9) and two ecosystem disservices (Figure 10).

Conservation implications

The majority of respondents suggested conservation measures such as organizing awareness programs, wetland management and conservation, establishment of protected areas, and hunting control (Figure 11). The respondents strongly believed that the community should take the initiative for species conservation,

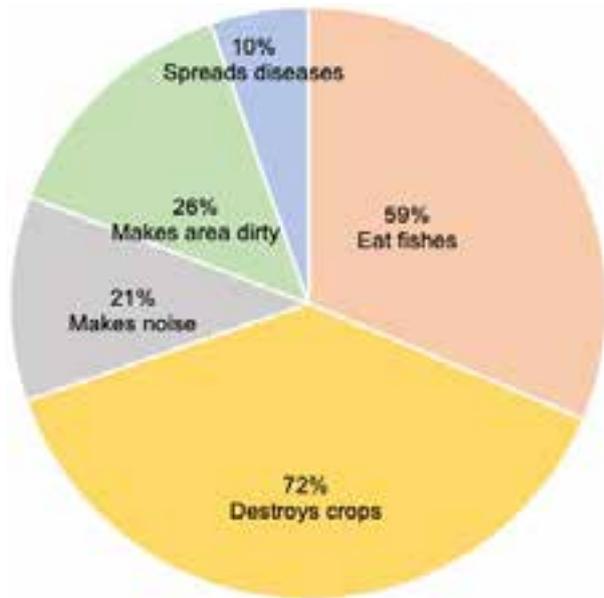


Figure 6. Perceived ecosystem disservices provided by Painted Stork.

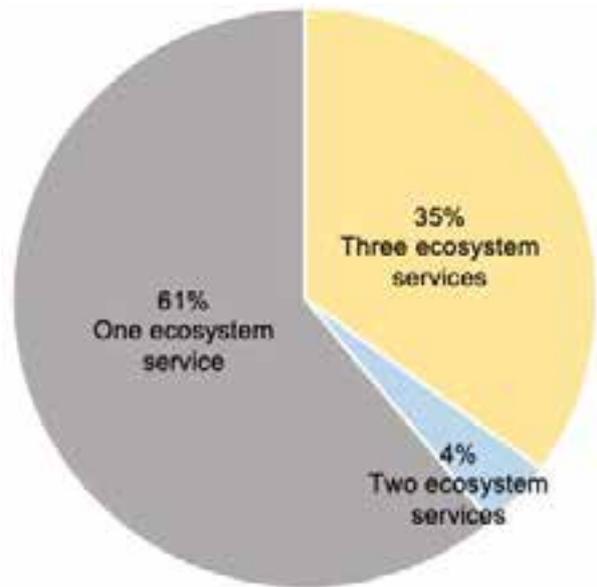


Figure 7. Number of regulation and maintenance ecosystem services provided by Painted Stork as perceived by respondents.

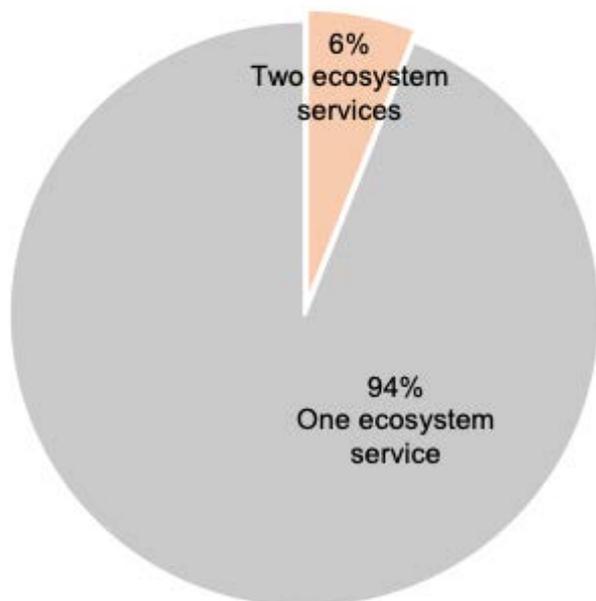


Figure 8. Number of provisioning ecosystem services provided by Painted Stork as perceived by respondents.

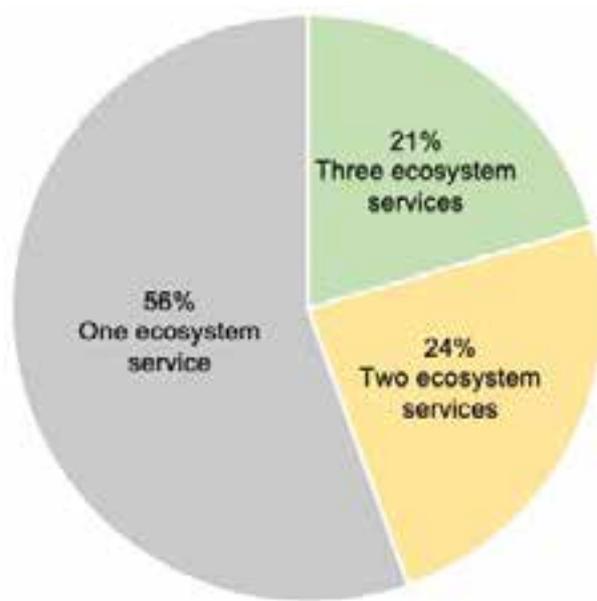


Figure 9. Number of cultural ecosystem services provided by Painted Stork as perceived by respondents.

consistent with findings from the study on Sarus Crane in Nepal (Bhattarai et al. 2025).

CONCLUSION

The ecological knowledge, attitudes, and conservation recommendations of the local people revealed through

this study increase the chances of positive impacts from awareness activities in this area. This positive mindset is necessary for species conservation in human-dominated landscapes. The government, along with the non-governmental organizations working in this region, must take immediate steps to spread awareness and provide incentives to the people involved in the conservation of this species. Policies must be framed

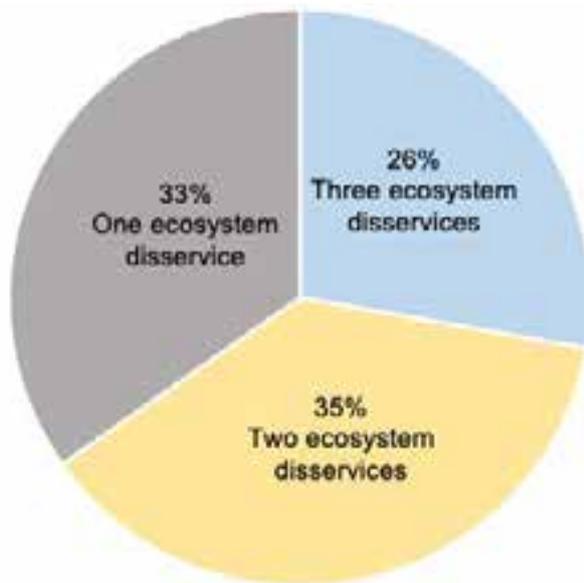


Figure 10. Number of ecosystem disservices provided by Painted Stork as perceived by respondents.

such that people are encouraged to protect and plant the preferred nesting trees of the Painted Stork, such as *Ficus religiosa*, *Syzygium cumini*, and *Terminalia arjuna* report hunting activities and manage wetlands sustainably. This study provides the first-ever insight into people's knowledge, attitudes, perceptions of ecosystem services and disservices provided by the Painted Stork from northern India. This study provides the baseline data for further field-based research aimed at understanding the interaction dynamics between birds and humans outside protected areas.

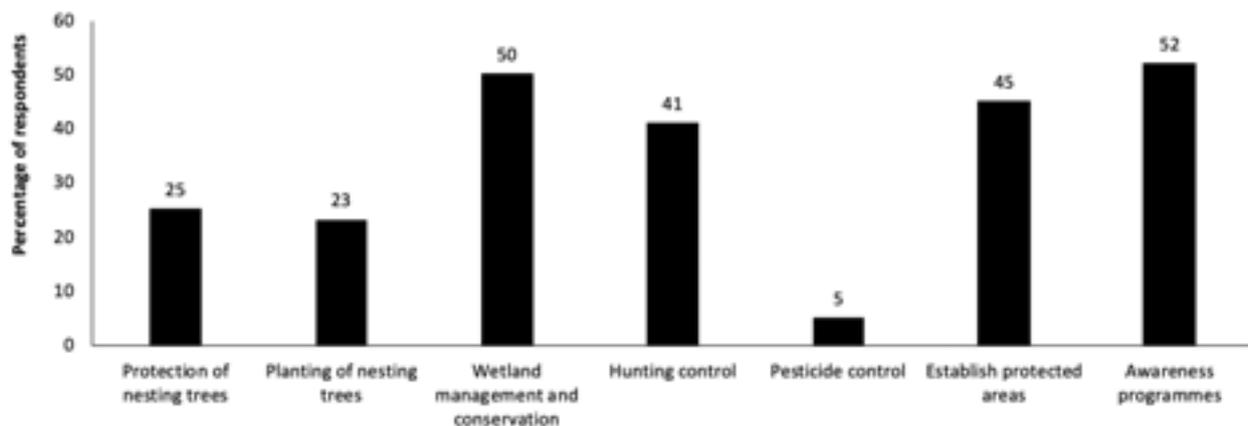


Figure 11. Conservation measures suggested by the respondents.

REFERENCES

- Acharya, B.K., B. Chettri & L. Vijayan (2009). Indigenous knowledge of Lepcha community for monitoring and conservation of birds. *Indian Journal of Traditional Knowledge* 8(1): 65–69.
- Aiyadurai, A. & S. Banerjee (2020). Bird conservation from obscurity to popularity: a case study of two bird species from Northeast India. *GeoJournal* 85: 901–912. <https://doi.org/10.1007/s10708-019-09999-9>
- Aiyadurai, A., S. Banerjee, Y. Patil & S. Joshi (2023). *Human-bird relations in India — An interdisciplinary Study*. Indian Institute of Technology, Gandhinagar and Environmental Humanities Research Group, 55 pp.
- Ali, S. & S.D. Ripley (1987). *Compact Handbook of the Birds of India and Pakistan*. Oxford University Press, Delhi, India, 737 pp.
- Arjunan, M., C. Holmes, J-P. Puyravaud & P. Davidar (2006). Do developmental initiatives influence local attitudes toward conservation? A case study from Kalakad-Mundanthurai Tiger Reserve, India. *Journal of Environmental Management* 79: 188–197. <https://doi.org/10.1016/j.jenvman.2005.06.007>
- Bajracharya, S., G.B. Gurung & K. Basnet (2007). Learning from community participation in conservation area management. *Journal of Forest and Livelihood* 6: 54–66. <https://www.nepjol.info/index.php/JFL/article/view/2325>
- Bhaskaran, V. & C.H. Nilon (2025). Exploring perceptions and attitudes towards wildlife in urban home gardens in Bangalore, India. *Urban Ecosystems* 28: 107. <https://doi.org/10.1007/s11252-025-01723-5>
- Bhattarai, B.P., H.B. Katuwal, S. Regmi, A. Nepali, R.N. Suwal, R. Acharya, K.C. Sabin, B. Aryal, K. Tamang, B. Rawal, A. Basnet, B.D. Baral, S. Devkota, S. Parajuli, N. Regmi, P. Kandel, B. Subedi, H.S. Giri, G.S. Gurung, J.L. Belant & H.P. Sharma (2025). Knowledge, attitudes, and conservation threats to globally vulnerable Sarus cranes in Lumbini province, Nepal. *Discover Conservation* 2: 15. <https://doi.org/10.1007/s44353-025-00034-2>
- BirdLife International (2025). Species factsheet: *Mycteria leucocephala*. <https://datazone.birdlife.org/species/factsheet/painted-stork-mycteria-leucocephala>. Accessed on 15.xi.2025.
- Bracebridge, C., T.R.B. Davenport, V.F. Mbofu & S.J. Marsden (2013). Is There a Role for Human-Dominated Landscapes in the Long-Term Conservation Management of the Critically Endangered Kipunji (*Rungwecebus kipunji*)? *International Journal of Primatology* 34: 1122–1136. <https://doi.org/10.1007/s10764-013-9719-3>
- Byju, H., H. Maitreyi, S. Ravichandran & N. Raveendran (2024). Avifaunal diversity and conservation significance of coastal ecosystems on Rameswaram Island, Tamil Nadu, India. *Journal of Threatened Taxa* 16(12): 26198–26212. <https://doi.org/10.11609/jott.9248.16.12.26198-26212>
- Canessa, S., S.J. Converse, M. West, N. Clemann, G. Gillespie, M.

- McFadden, A.J. Silla, K.M. Parris & M.A. McCarthy (2015). Planning for ex-situ conservation in the face of uncertainty. *Conservation Biology* 30(3): 599–609. <https://doi.org/10.1111/cobi.12613>
- Ceballos, G., P.R. Ehrlich, J. Pacheco, N. Valverde-Zuniga & G.C. Daily (2019). Conservation in human-dominated landscapes: Lessons from the distribution of the Central American squirrel monkey. *Biological Conservation* 237: 41–49. <https://doi.org/10.1016/j.biocon.2019.06.008>
- Chakanyuka, T. & B. Utete (2022). Adaptive co-management, co-existence or just wildlife conservation? Case study of the human and Nile crocodile *Crocodylus niloticus* conflicts in Ngezi Dam, Mashonaland West, Zimbabwe. *African Journal of Ecology* 60: 759–768. <https://doi.org/10.1111/aje.12974>
- Cornell Lab of Ornithology (2025). Cornell Lab of Ornithology, Birds of the World. <https://birdsoftheworld.org/bow/species/paist01/cur/introduction#distrib>. Accessed on 17.xi.2025.
- Cortes-Avizanda, A., B. Martin-Lopez, O. Ceballos & H.M. Pereira (2018). Stakeholders perceptions of the Endangered Egyptian vulture: insights for conservation. *Biological Conservation* 218: 173–180. <https://doi.org/10.1016/j.biocon.2017.09.028>
- Dabone, C., A. Oueda, L.J. Thompson, J.B. Adjakpa & P.D.M. Weesie (2022). Local perceptions and sociocultural value of Hooded Vultures *Necrosyrtes monachus* in Burkina Faso, West Africa. *Ostrich* 93(4): 233–247. <https://doi.org/10.2989/00306525.2022.2120558>
- Das, S., A. Srivastava & U. Hore (2025). Farmer's knowledge on bird conservation in the agricultural landscape of Gangetic plain. *Ornithology Research* 33: 26. <https://doi.org/10.1007/s43388-025-00231-6>
- Gaston, K.J., D.T.C. Cox, S.B. Canavelli, D. Garcia, B. Hughes, B. Maas, D. Martinez, D. Ogada & R. Inger (2018). Population abundance and ecosystem service provision: the case of birds. *Bioscience* 68: 264–272. <https://doi.org/10.1093/biosci/biy005>
- Gorbanov, M.A., A.V. Fadeeva, V.B. Shirshikov, P.A. Matveev, O.V. Popova, M.Y. Mitrofanova, J.Y. Bakaeva & N.A. Mashkin (2019). Nature protection potential of wildlife sanctuary: protection and preservation of its ecological biodiversity. *Ekoloji* 28(107): 5033–5037.
- GoUP (2025). Government of Uttar Pradesh. <https://etawah.nic.in/about-district/> Accessed on 10.xi.2025.
- Green, A.J. & J. Elmberg (2014). Ecosystem services provided by waterbirds. *Biological Reviews* 89: 105–122. <https://doi.org/10.1111/brv.12045>
- Gupta, T., E.J. Milner-Gulland, A. Dias & D. Karnad (2023). Drawing on local knowledge and attitudes for the conservation of critically endangered rhino rays in Goa, India. *People and Nature* 5: 645–659. <https://doi.org/10.1002/pan3.10429>
- Herzon, I. & M. Miikk (2007). Farmers' perceptions of biodiversity and their willingness to enhance it through agri-environment schemes: a comparative study from Estonia and Finland. *Journal for Nature Conservation* 15: 10–25. <https://doi.org/10.1016/j.jnc.2006.08.001>
- Iniguez-Gallardo, V., F. Reyes-Bueno, I. Gonzalez-Coronel, J. Freile & L. Ordóñez-Delgado (2024). Perceptions, knowledge, and emotions about owls in southern Ecuador. *Journal of Ethnobiology* 44(2): 98–111. <https://doi.org/10.1177/02780771241250129>
- IUCN (2025). The IUCN Red list of threatened species: search results for 'Birds'. International Union for Conservation of Nature. <https://www.iucnredlist.org/search?query=Birds&searchType=species>. Accessed on 25.x.2025.
- Jacobson, S.K., K.E. Sieving, G.A. Jones & A. Van Doorn (2003). Assessment of farmer attitudes and behavioral intentions toward bird conservation on organic and conventional Florida farms. *Conservation Biology* 17: 595–606. <https://doi.org/10.1046/j.1523-1739.2003.01472.x>
- Karanth, K.K., S. Jain & E. Weinthal (2019). Human-wildlife interactions and attitudes towards wildlife and wildlife reserves in Rajasthan, India. *Oryx* 53(3): 523–531. <https://doi.org/10.1017/S0030605317001028>
- Katuwal, H.B., H.P. Sharma, P. Rokka, N.K. Das & R.C. Quan (2024). Knowledge, attitudes and conservation challenges for the Lesser Adjutant in Nepal. *Global Ecology and Conservation* 49: e02795. <https://doi.org/10.1016/j.gecco.2023.e02795>
- Katuwal, H.B., M. Zhang, H.S. Baral, H.P. Sharma & R.-C. Quan (2021). Assessment of farmers' knowledge and perceptions towards farmland birds show the need of conservation interventions. *Global Ecology and Conservation* 27: e01563. <https://doi.org/10.1016/j.gecco.2021.e01563>
- Kross, S.M., K.P. Ingram, R.F. Long & M.T. Niles (2018). Farmer perceptions and behaviors related to wildlife and on-farm conservation actions. *Conservation Letters* 11(1): e12364. <https://doi.org/10.1111/conl.12364>
- KVK (2025). Krishi Vigyan Kendra Etawah. <https://etawah.kvk4.in/district-profile.php>. Accessed on 10.xi.2025.
- Lees, A.C., L. Haskell, T. Allinson, S.B. Bezeng, I.J. Burfield, L.M. Renjifo, K.V. Rosenberg, A. Viswanathan & S.H.M. Butchart (2022). State of the world's birds. *Annual Review of Environment and Resources* 47(1): 231–260. <https://doi.org/10.1146/annurev-environ-112420-014642>
- Leong, R.A.T., T.K. Fung, U. Sachidhanandam, Z. Drillet, P.J. Edwards & D.R. Richards (2020). Use of structural equation modelling to explore influences on perceptions of ecosystem services and disservices attributed to birds in Singapore. *Ecosystem Services* 46: 101211. <https://doi.org/10.1016/j.ecoser.2020.101211>
- Lewis, J.S., S. Spaulding, H. Swanson, W. Keeley, A.R. Gramza, S. VandeWoude & K.R. Crooks (2021). Human activity influences wildlife populations and activity patterns: implications for spatial and temporal refuges. *Ecosphere* 12(5): e03487. <https://doi.org/10.1002/ecs2.3487>
- Manigandan, S., H. Byju & P. Kannan (2024). Harmonizing ecology and society: an integrated analysis of vulture conservation in the Nilgiri Biosphere Reserve, India. *Journal of Threatened Taxa* 16(6): 25330–25344. <https://doi.org/10.11609/jott.8915.16.6.25330-25344>
- Mariyappan, M., M. Rajendran, S. Velu, A.D. Johnson, G.K. Dinesh, K. Solaimuthu, M. Kaliyappan & M. Sankar (2023). Ecological role and ecosystem services of birds: a review. *International Journal of Environment and Climate Change* 13(6): 76–87. <https://doi.org/10.9734/ijec/2023/v13i61800>
- Mehta, J.N. & J.T. Heinen (2001). Does community-based conservation shape favorable attitudes among locals? An empirical study from Nepal. *Environmental Management* 28: 165–177. <https://doi.org/10.1007/s002670010215>
- Messina, T., R. Figueira & J.M.L. Santos (2023). Integrating local and ecological knowledge to assess the benefits of trees for ecosystem services: a holistic process-based methodology. *Ecosystem Services* 63: 101556. <https://doi.org/10.1016/j.ecoser.2023.101556>
- Mir, Z.R., A. Noor, B. Habib & G.G. Veeraswami (2015). Attitudes of local people towards wildlife conservation: a case study from Kashmir valley. *Mountain Research and Development* 35(4): 392–400. <https://doi.org/10.1659/MRD-JOURNAL-D-15-00030.1>
- Mmassy, E.C. & E. Roskaft (2013). Knowledge of birds of conservation interest among the people living close to protected areas in Serengeti, Northern Tanzania. *International Journal of Biodiversity Science, Ecosystem Services and Management* 9(2): 114–122. <https://doi.org/10.1080/21513732.2013.788566>
- Morales-Reyes, Z., B. Martin-Lopez, M. Moleon, P. Mateo-Tomas, F. Botella, A. Margalida, J.A. Donazar, G. Blanco, I. Perez & J.A. Sanchez-Zapata (2018). Farmer perceptions of the ecosystem services provided by scavengers: what, who and to who. *Conservation Letters* 11(2): 1–11. <https://doi.org/10.1111/conl.12392>
- Nevard, T.D., I. Leiper, G. Archibald & S.T. Garnett (2019). Farming and cranes on the Atherton Tablelands, Australia. *Pacific Conservation Biology* 25: 184–192. <https://doi.org/10.1071/PC18055>
- Nima, P., T. Dorji, M.S. Rana & T. Dorji (2025). Knowledge, attitude, perceived threats and conservation challenges of the critically endangered White-bellied Heron, *Ardea insignis*, in Bhutan. *Global Ecology and Conservation* 58: e03484. <https://doi.org/10.1016/j.gecco.2025.e03484>
- Ntuli, H., S.C. Jagers, A. Linell, M. Sjøstedt & E. Muchapondwa (2019). Factors influencing local communities' perceptions towards conservation of transboundary wildlife resources: the case of the Great Limpopo Trans-frontier Conservation Area. *Biodiversity and Conservation* 28: 2977–3003. <https://doi.org/10.1007/s10531-019->

01809-5

- Ortega-Lasuen, U., O. Pedrera, E. Telletxea, O. Barrutia & J.R. Diez (2023). Secondary students' knowledge on birds and attitudes towards conservation: evaluation of an environmental education program. *International Journal of Environmental Research and Public Health* 20: 5769. <https://doi.org/10.3390/ijerph20105769>
- Parasharya, B.M. & R.M. Naik (1990). Ciconiiform birds breeding in Bhavnagar city, Gujarat, pp. 429–445. In: Daniel, J.C. & J.C. Serrao (eds.). *Conservation in Developing Countries: Problems and Prospects*. Bombay Natural History Society and Oxford University Press, Mumbai.
- Possingham, H.P., M. Bode & C.J. Klein (2015). Optimal Conservation Outcomes Require Both Restoration and Protection. *PLoS Biology* 13(1): e1002052. <https://doi.org/10.1371/journal.pbio.1002052>
- Romero-Bautista, Y.A., A.I. Moreno-Calles, F. Alvarado-Ramos, M. Reyes Castillo & A. Casas (2020). Environmental interactions between people and birds in semiarid lands of the Zapotitlan Valley, Central Mexico. *Journal of Ethnobiology and Ethnomedicine* 16: 32. <https://doi.org/10.1186/s13002-020-00385-1>
- Sridhar, S., A.K. Chakravarthy, K. Srihari & N.A. Prakash (2002). Priorities for conservation of Kokre Bellur heronry in Karnataka, south India, pp. 123–127. In: Rahmani, A.R. & G. Ugra (eds.). *Birds of Wetlands and Grasslands: Proceedings of the Salim Ali Centenary Seminar on Conservation of Avifauna of Wetlands and Grasslands*. Bombay Natural History Society, Mumbai.
- Stanton, R.L., C.A. Morrissey & R.G. Clark (2018). Analysis of trends and agricultural drivers of farmland bird declines in North America: a review. *Agriculture, Ecosystems & Environment* 254: 244–254. <https://doi.org/10.1016/j.agee.2017.11.028>
- Talukdar, S. & A. Gupta (2018). Attitudes towards forest and wildlife, and conservation-oriented traditions, around Chakrashila Wildlife Sanctuary, Assam, India. *Oryx* 52(3): 508–518. <https://doi.org/10.1017/S0030605316001307>
- Taylor-Brown, A., R. Booth, A. Gillett, E. Mealy, S.M. Ogbourne, A. Polkinghorne & G.C. Conroy (2019). The impact of human activities on Australian wildlife. *PLoS ONE* 14(1): e0206958. <https://doi.org/10.1371/journal.pone.0206958>
- Tiwari, G., P. Pandey, R. Kaul & R. Singh (2023). Farmer's perception of the ecosystem services provided by diurnal raptors in arid Rajasthan. *PeerJ* 11: e15996. <https://doi.org/10.7717/peerj.15996>
- Tiwary, N.K., B.B. Sharma & A.J. Urfi (2014). Two new nesting colonies of Painted Stork *Mycteria leucocephala* from northern India. *Indian Birds* 9(4): 85–88.
- Urfi, A.J. (1988). Painted Stork *Mycteria leucocephala* (Pennant) swallowing a snake. *Journal of the Bombay Natural History Society* 86: 96.
- Urfi, A.J. (2002). Waders and other wetland birds on Byet Dwarka Island, Gulf of Kutch, Western India. *Wader Study Group Bulletin* 99: 31–34.
- Urfi, A.J. (2011). Foraging ecology of the Painted Stork (*Mycteria leucocephala*): A review. *Waterbirds* 34(4): 448–456. <https://doi.org/10.1675/063.034.0407>
- Volenc, Z.M. & A.P. Dobson (2020). Conservation value of small reserves. *Conservation Biology* 34(1): 66–79. <https://doi.org/10.1111/cobi.13308>
- Volis, S. (2019). Conservation-oriented restoration – a two for one method to restore both threatened species and their habitats. *Plant Diversity* 41: 50–58. <https://doi.org/10.1016/j.pld.2019.01.002>
- Walpole, M.J. & H.J. Goodwin (2001). Local attitudes towards conservation and tourism around Komodo National Park, Indonesia. *Environmental Conservation* 28: 160–166. <https://doi.org/10.1017/S0376892901000169>
- Whelan, C.J., D.G. Wenny & R.J. Marquis (2008). Ecosystem services provided by birds. *Annals of New York Academy of Sciences* 1134: 25–60. <https://doi.org/10.1196/annals.1439.003>
- Winter, S.J., K.J. Esler & M. Kidd (2005). An index to measure the conservation attitudes of landowners towards Overberg Coastal Renosterveld, a critically endangered vegetation type in the Cape Floral Kingdom, South Africa. *Biological Conservation* 126: 383–394. <https://doi.org/10.1016/j.biocon.2005.06.015>
- WPA (1972). Wildlife (Protection) Act. <https://content.dgft.gov.in/Website/append10.pdf>. Accessed on 10.xi.2025.

- WPA (2022). Wildlife (Protection) Amendment Act. [https://prsindia.org/files/bills_acts/acts_parliament/2022/The%20Wild%20Life%20\(Protection\)%20Amendment%20Act,%202022.pdf](https://prsindia.org/files/bills_acts/acts_parliament/2022/The%20Wild%20Life%20(Protection)%20Amendment%20Act,%202022.pdf). Accessed on 10.xi.2025.
- Yashmita-Ulman & M. Singh (2021). Bird composition, diversity and foraging guilds in agricultural landscapes: A case study from eastern Uttar Pradesh, India. *Journal of Threatened Taxa* 13(8): 19011–19028. <https://doi.org/10.11609/jott.7089.13.8.19011-19028>
- Yashmita-Ulman & M. Singh (2022). Avifaunal diversity in unprotected wetlands of Ayodhya district, Uttar Pradesh, India. *Journal of Threatened Taxa* 14(8): 21561–21578. <https://doi.org/10.11609/jott.7067.14.8.21561-21578>
- Yashmita-Ulman & M. Singh (2025). A preliminary assessment of avifaunal diversity in Parwati Arga Bird Sanctuary, Uttar Pradesh, India. *Journal of Threatened Taxa* 17(11): 27976–27984. <https://doi.org/10.11609/jott.10160.17.11.27976-27984>
- Yashmita-Ulman (2022). Bird diversity in riverscapes of Ayodhya district, Uttar Pradesh. *Indian Journal of Ecology* 49(1): 280–287. <https://doi.org/10.55362/IJE/2022/3518>
- Yashmita-Ulman (2023). Bird diversity of Jagdishpur Jheel: An unprotected wetland in Ayodhya district, Uttar Pradesh. *Indian Journal of Ecology* 50(5) (S1): 1794–1800. <https://doi.org/10.55362/IJE/2023/4139>
- Yashmita-Ulman, A. Kumar & M. Sharma (2017). Traditional homegarden agroforestry systems: habitat for conservation of Baya Weaver *Ploceus philippinus* (Passeriformes: Ploceidae) in Assam, India. *Journal of Threatened Taxa* 9(4): 10076–10083. <https://doi.org/10.11609/jott.3090.9.4.10076-10083>
- Yashmita-Ulman, A. Kumar & M. Sharma (2018). Agroforestry systems as habitat for avian species: Assessing its role in conservation. *Proceedings of Zoological Society* 71: 127–145. <https://doi.org/10.1007/s12595-016-0198-3>
- Yashmita-Ulman, M. Singh, A. Kumar & M. Sharma (2020). Negative human-wildlife interactions in traditional agroforestry systems in Assam, India. *Journal of Threatened Taxa* 12(10): 16230–16238. <https://doi.org/10.11609/jott.5754.12.10.16230-16238>
- Yashmita-Ulman, M. Singh, A. Kumar & M. Sharma (2021a). Agroforestry systems: a boon or bane for mammal conservation in northeastern India? *Proceedings of Zoological Society* 74: 28–42. <https://doi.org/10.1007/s12595-020-00335-5>
- Yashmita-Ulman, M. Singh, A. Kumar & M. Sharma (2021b). Conservation of wildlife diversity in agroforestry systems in eastern Himalayan biodiversity hotspot. *Proceedings of Zoological Society* 74: 171–188. <https://doi.org/10.1007/s12595-021-00361-x>
- Zhong, L., T. Li, Y. Li, T. Zou, T. Yu & C. Dai (2023). Local farmers' perceptions of ecosystem services and disservices provided by the Black-necked Crane (*Grus nigricollis*) and their conservation implications. *Global Ecology and Conservation*, 46: e02614. <https://doi.org/10.1016/j.gecco.2023.e02614>

Hindi: किसी भी जागरूकता कार्यक्रम को शुरू करने से पहले उस प्रजाति के बारे में स्थानीय समुदायों के ज्ञान, सोच और हिचकण को समझना बहुत जरूरी होता है। इससे उस प्रजाति की सफलता और लंबे समय तक संरक्षण सुनिश्चित किया जा सकता है। उत्तर भारत में पेन्टेड स्टॉक (माइग्रेटरीया ल्यूकोसेफाला) के बारे में स्थानीय लोगों के ज्ञान, उनके विचार, पारिस्थितिकी सेवारों व हानियाँ, खतरों और संरक्षण के सुझावों पर अब तक कोई अध्ययन नहीं किया गया था। इस कमी को पूरा करने के लिए अगस्त-सितंबर 2024 में उत्तर प्रदेश के इटावा जिले के गाँवों में एक अध्ययन किया गया। यहाँ पेन्टेड स्टॉक मानव बस्तियों के पास घेतों में घोंसला बनाते हैं। इस अध्ययन में 200 लोगों से प्रश्नावली के माध्यम से जानकारी ली गई, जिसमें बंद और खुले दोनों प्रकार के प्रश्न शामिल थे। सभी उत्तरदाताओं ने इस पक्षी की पहचान की। अधिकांश लोग इसका स्थानीय नाम, प्रजनन व्यवहार, भोजन खोजने की आदतों और इसकी जनसंख्या की स्थिति के बारे में जानते थे। अधिकांश लोगों (52%) को यह पक्षी पसंद है। 51% लोग इसके संरक्षण के पक्ष में थे। 52% लोगों ने जागरूकता कार्यक्रमों की आवश्यकता महसूस की। 47% लोग घोंसला निगरानी प्रशिक्षण में भाग लेने के लिए तैयार थे और 58% लोग जागरूकता कार्यक्रमों में शामिल होने के इच्छुक थे। दूसरी ओर, कई लोग शिकार की सूचना देने में हिचकियाते थे (48%), घायल पक्षियों को पशु चिकित्सक के पास ले जाने में भी संकोच करते थे (46%), और 64% लोगों को इस पक्षी की संरक्षण स्थिति की सही जानकारी नहीं थी। लोगों ने पेन्टेड स्टॉकसे जुड़ी 12 पारिस्थितिकी सेवाओं और 5 पारिस्थितिकी हानियों को पहचाना। कीट नियंत्रण (50%) को सबसे अधिक लाभ के रूप में बताया गया, जबकि फसलों को नुकसान (72%) को सबसे बड़ी हानि माना गया। उत्तरदाताओं के अनुसार इस प्रजाति के लिए सबसे बड़ा खतरा आर्द्रमृत्तियों का नष्ट होना है (59%)। अधिकांश लोगों ने सुझाव दिया कि संरक्षण के प्रयासों में जागरूकता कार्यक्रम (52%) और आर्द्रमृत्ति प्रबंधन व संरक्षण (50%) पर ध्यान दिया जाना चाहिए। 48% लोगों का मानना था कि इन प्रयासों की शुरुआत स्वयं समुदाय को करनी चाहिए। यह अध्ययन दर्शाता है कि संरक्षित क्षेत्रों के बाहर भी इस प्रजाति के संरक्षण के लिए जागरूकता कार्यक्रमों को बढ़ाना, आर्द्रमृत्तियों का संरक्षण और प्रबंधन करना तथा घोंसले वाले पेड़ों की सुरक्षा करना बहुत आवश्यक है। यह अध्ययन संरक्षणकर्ताओं, शोधकर्ताओं और नीति निर्माताओं को स्थानीय समुदायों की भागीदारी के साथ प्रभावी संरक्षण रणनीति बनाने के लिए आधा प्रदान करता है।

Appendix 1. Questionnaire.

Name of Respondent:..... Age:..... Sex:.....
 District:..... Village name:..... Date:.....
 Occupation:..... Education: Caste:

A. Knowledge on Lesser Adjutant

1. Have you seen this species? (Showing Photo of Painted Stork)
2. Do you know the name of this species? Yes..... No..... If yes, name it.....
3. In which habitat you saw mostly?
4. In which trees does this species nest?
5. What is its breeding season?
6. Where does it feed/eat?.....
7. What does it eat?.....
8. Has the species population increased or decreased over the years?
9. Do you know about the species conservation status?

B. Attitudes towards the species

10. Is the species harmful?
 a) Yes b) No c) Don't know
11. Whether you like the species?
 a) Yes b) No c) Don't know
12. Do you support the conservation of Painted Stork?
 a) Yes b) No c) Don't know
13. Do you cut the nesting trees of Painted Stork if it makes nests?
 a) Yes b) No c) Don't know
14. If injured, will you take the bird to a veterinary doctor?
 a) Yes b) No c) Don't know
15. If hunting is found, will you inform Forest Department?
 a) Yes b) No c) Don't know
16. Will you be ready to get trained in Painted stork nest monitoring?
 a) Yes b) No c) Don't know
17. Is there any need for awareness programmes?
 a) Yes b) No c) Don't know
18. Will you participate in awareness programmes?
 a) Yes b) No c) Don't know

C. Conservation issues related to the species

19. In your opinion which different threats is the species facing?
 a) Wetland loss b) Hunting c) Felling of nesting trees d) Lack of nesting trees e) Pesticides
 f) Climate change g) Pollution h) Tower signals i) Electric wires
20. Have you seen people hunting Painted stork?
21. How do people hunt it (method)?
22. Have you seen people taking eggs and chicks from the nest?
23. Who among the following do you think must take initiative to conserve Painted Stork?
 a) Government b) NGO c) International organization d) Community
24. In your opinion which different measures will lead to conservation of Painted Stork?
 a) Organizing awareness programme b) Wetland management and conservation c) Establishment of protected areas
 d) Hunting control e) Protection of nesting trees f) Pesticide control

D. Farmers' perceptions of services and disservices

25. In your opinion, which of the following regulation and maintenance benefits do you think the Painted stork provides?
 a) pest control b) eats snakes c) nutrient cycling d) any other
26. In your opinion, which of the following provisioning benefits do you think the Painted stork provides?
 a) medicinal value b) meat value c) any other
27. In your opinion, which of the following cultural benefits do you think the Painted stork provides?
 a) sense of pride b) existence value c) aesthetic value d) conservation value e) conservation flagship
 f) educational value g) ecotourism h) any other
28. In your opinion, which of the following damage is caused due to Painted stork?
 a) eats fishes b) destroys crops c) makes noise d) makes area dirty e) spreads diseases
 f) any other

परिशिष्ट – 1 : प्रश्नावली

उत्तरदाता का नाम:

आयु: लिंग:

जिला: गाँव का नाम: दिनांक:

व्यवसाय: शिक्षा: जाति:

A. प्रजाति (पेंटेड स्टॉर्क) के बारे में ज्ञान

1. क्या आपने इस प्रजाति को देखा है? (पेंटेड स्टॉर्क का फोटो दिखाकर)
2. क्या आप इस प्रजाति का नाम जानते हैं?
 हाँ नहीं यदि हाँ, तो नाम लिखें:
3. आपने इसे अधिकतर किस प्रकार के आवास (हैबिटेट) में देखा है?
4. यह प्रजाति किन पेड़ों पर घोंसला बनाती है?
5. इसका प्रजनन काल (ब्रीडिंग सीज़न) कौनसा है?
6. यह कहाँ भोजन करती है?
7. यह क्या-क्या खाती है?
8. आपके अनुसार पिछले वर्षों में इस प्रजाति की संख्या बढ़ी है या घटी है?
9. क्या आप इस प्रजाति की संरक्षण स्थिति के बारे में जानते हैं?

B. प्रजाति के प्रति दृष्टिकोण (Attitude)

10. क्या यह प्रजाति हानिकारक है?
 हाँ नहीं नहीं जानते
11. क्या आपको यह प्रजाति पसंद है?
 हाँ नहीं नहीं जानते
12. क्या आप पेंटेड स्टॉर्क के संरक्षण का समर्थन करते हैं?
 हाँ नहीं नहीं जानते
13. यदि यह प्रजाति किसी पेड़ पर घोंसला बनाती है, तो क्या आप उस पेड़ को काटते हैं?
 हाँ नहीं नहीं जानते
14. यदि पक्षी घायल मिले, तो क्या आप उसे पशु-चिकित्सक के पास ले जाएँगे?
 हाँ नहीं नहीं जानते
15. यदि शिकार की घटना दिखे, तो क्या आप वन विभाग को सूचना देंगे?
 हाँ नहीं नहीं जानते
16. क्या आप पेंटेड स्टॉर्क के घोंसला-निगरानी (Nest Monitoring) का प्रशिक्षण लेने के लिए तैयार हैं?
 हाँ नहीं नहीं जानते
17. क्या आपको लगता है कि जागरूकता कार्यक्रमों की आवश्यकता है?
 हाँ नहीं नहीं जानते
18. क्या आप जागरूकता कार्यक्रमों में भाग लेंगे?
 हाँ नहीं नहीं जानते

C. प्रजातियों से संबंधित संरक्षण मुद्दे

19. आपके अनुसार यह प्रजाति किन-किन खतरों का सामना कर रही है?
- आर्द्रभूमि (वेटलैंड) का नुकसान
 - शिकार
 - घोंसला-पेड़ों की कटाई
 - घोंसला-पेड़ों की कमी
 - कीटनाशक
 - जलवायु परिवर्तन
 - प्रदूषण
 - मोबाइल/टावर सिग्नल
 - विद्युत तार
20. क्या आपने किसी को पेंटेड स्टॉक का शिकार करते देखा है?
21. लोग इसे किस तरीके से शिकार करते हैं?
22. क्या आपने लोगों को घोंसले से अंडे या चूजे लेते देखा है?
23. आपके अनुसार पेंटेड स्टॉक के संरक्षण की पहल किसे करनी चाहिए?
- सरकार गैर-सरकारी संगठन (NGO)
 - अंतरराष्ट्रीय संगठन स्थानीय समुदाय
24. आपके अनुसार कौन-कौन से उपाय पेंटेड स्टॉक के संरक्षण में सहायक होंगे?
- जागरूकता कार्यक्रमों का आयोजन
 - आर्द्रभूमि प्रबंधन एवं संरक्षण
 - संरक्षित क्षेत्रों की स्थापना
 - शिकार पर नियंत्रण
 - घोंसला-पेड़ों का संरक्षण
 - कीटनाशकों पर नियंत्रण

D. किसानों की सेवाओं एवं असुविधाओं के प्रति धारणा

25. आपके अनुसार पेंटेड स्टॉक कौन-कौन सी **नियामक एवं रखरखाव सेवाएँ** प्रदान करता है?
- कीट नियंत्रण
 - साँप खाता है
 - पोषक तत्व चक्र (न्यूट्रिएंट साइकिलिंग)
 - अन्य (कृपया लिखें):
26. आपके अनुसार पेंटेड स्टॉक कौन-कौन से **उपयोगी लाभ (Provisioning Benefits)** प्रदान करता है?
- औषधीय मूल्य
 - मांस मूल्य
 - अन्य (कृपया लिखें):
27. आपके अनुसार पेंटेड स्टॉक के **सांस्कृतिक लाभ** क्या हैं?
- गर्व की भावना
 - अस्तित्व मूल्य
 - सौंदर्यात्मक मूल्य
 - संरक्षण मूल्य
 - संरक्षण का प्रतीक (फ्लैगशिप)
 - शैक्षणिक मूल्य
 - ईको-पर्यटन
 - अन्य (कृपया लिखें):
28. आपके अनुसार पेंटेड स्टॉक से कौन-कौन सी **हानियाँ/असुविधाएँ** होती हैं?
- मछली खाता है
 - फसल को नुकसान
 - शोर करता है
 - क्षेत्र को गंदा करता है
 - रोग फैलाता है
 - अन्य (कृपया लिखें):



Analysis revealed minuscule DNA sequence data availability for Indian marine macroalgal diversity

Digvijay Singh Yadav¹ , Aswin Alichen²  & Vaibhav A. Mantri³ 

^{1,2,3}Applied Phycology and Biotechnology Division, CSIR- Central Salt and Marine Chemicals Research Institute, Gijubhai Badheka Marg, Bhavnagar, Gujarat 364002, India.

³Academy of Scientific and Innovative Research (AcSIR), Ghaziabad, Uttar Pradesh 201002, India.

¹digvijaysingh.yadav@gmail.com, ²aswinalichan12@gmail.com, ³vaibhav.csmcri@csir.res.in (corresponding author)

Abstract: Seaweeds hold immense economic potential due to multifarious applications in pharmaceuticals and everyday products. India's 11,099 km coastline harbours a rich diversity of seaweeds in the Indian Ocean. Identifying seaweeds based on morphology is challenging due to high phenotypic and reproductive plasticity, so DNA barcoding is often used. This initiative marks the first national effort to compile relevant scientific information on DNA barcoding of Indian marine macroalgae, the current-status of knowledge and the scope for study. Despite decades of molecular research on Indian macroalgae, the resulting sequence data remain scattered across online repositories without systematic integration or quality assessment. The study is a comprehensive analysis of current barcode coverage of Indian seaweeds available on GenBank. With 207 unique sequences, only 11% of total Indian macroalgal diversity has been studied yet. The priority gaps that demonstrate direct benefits such as accurate taxonomic identification, cultivation strain authentication, and assessment of invasive species and surveillance of algal blooms, and indirect benefits like policy support, conservation planning, reference libraries for eDNA, training, and capacity building were identified. We consider that DNA barcoding at the national level would not only help in the sustainable commercial utilisation of economically important species but also in the conservation of endemic taxa. This is identified as a major research gap. It needs to be addressed through concentrated efforts by national research organisations and universities, ascertaining the availability of adequate infrastructure, and focused efforts on capacity building. A comprehensive and collaborative research program is urgently needed at the Pan-India level.

Keywords: AlgaeBase, aquaculture, bioprospecting, conservation, DNA barcoding, GenBank, genetic resources, molecular systematics, species identification, taxonomy.

Editor: Ram Chandra Poudel, Nepal Academy of Science and Technology (NAST), Lalitpur, Nepal.

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

Citation: Yadav, D.S., A. Alichen & V.A. Mantri (2026). Analysis revealed minuscule DNA sequence data availability for Indian marine macroalgal diversity. *Journal of Threatened Taxa* 18(2): 28343–28349. <https://doi.org/10.11609/jott.9679.18.2.28343-28349>

Copyright: © Yadav et al. 2026. 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: Funding from Council of Scientific and Industrial Research, New Delhi is gratefully acknowledged.

Competing interests: The authors declare no competing interests.

Author details: DIGVIJAY SINGH YADAV has PhD in Biosciences with expertise in molecular taxonomy and pharmaceutical application of seaweeds. Currently working as a postdoctoral researcher at the CSIR-Central Salt and Marine Chemicals Research Institute (CSMCRI) in India, his work focuses on seaweed-propagule transport, biostimulant application, and large-scale seaweed cultivation along the Indian coast. ASWIN ALICHEN has completed his post graduation and is a young and motivated researcher with strong interest in seaweed biology and seaweed-based climate changes studies. The research work in the current publication was carried out during his dissertation work at CSMCRI, India. VAIBHAV A. MANTRI is the chief principal scientist at CSMCRI, Dr. Mantri advances year-round Indian seaweed farming through improved cultivation techniques. His research focuses on strain enhancement, artificial seedling protocols to minimize epiphytic infestation, and developing viable farming methods by analyzing environmental determinants.

Author contributions: DS—investigation, formal analysis, methodology, validation, visualization, data curation, manuscript preparation. AA—investigation, formal analysis, methodology, validation, visualization, data curation. VAM—conceptualization, methodology, project administration, supervision, writing – review & editing, funding acquisition. All authors provided critical feedback and helped shape the research analysis and manuscript.

Acknowledgements: We thank the director, CSIR Central Salt and Marine Chemicals Research Institute, Bhavnagar, for the support and facilities. This manuscript has PRIS registration number 96/2024.



CSIR
The Innovation Engine of India

INTRODUCTION

Marine macroalgae are gaining importance globally due to their multifarious applications in commodity products being used in day-to-day life. They are the only source of polysaccharides such as, ulvan, agar, alginates, mannitol, and carrageen having niche applications in biomedical, and pharmaceutical domains (Pereira & Cotas 2024). Studying the marine macro-algal biodiversity is pivotal for understanding the health of marine ecosystems, searching for potent bioactive compounds, and finding latent alternatives for food, feed, and fuels (Rajauria et al. 2015). Conventional morphology-based identification often yields inaccuracies due to phenotypic plasticity coupled with lack of specialized taxonomic expertise. Therefore, DNA barcoding offers a universal and standardized approach including for seaweeds (Hebert et al. 2003; Kowalska et al. 2019). This technique is less susceptible to errors caused by phenotypic variation, life stage, reproductive age, and does not require specialized traditional taxonomy knowledge. Further, it is also important to learn evolutionary lineages, discover novel species, and identify commercially valuable species (Saunders 2005; Chac & Thinh 2023). DNA barcoding provides legally defensible scientific evidence-based lab-to-market species identification, ensuring traceability and linking product authenticity to performance outcomes. For example, use of DNA barcoding for identifying novel seaweed species (Lagourgue et al. 2022), uncover genetic groups and morphospecies of *Saccharina* sp. (Saunders and McDevit 2014), or correctly identify *Bulung sangu* (*Gracilaria* sp.) to decide specific and correct cultivation methods to meet falling supply to high demands (Wirawan et al. 2021). For seaweeds such as *Gracilaria dura* known for high gel strength ($> 1,900 \text{ g cm}^{-2}$ at 1%) if misidentified with other *Gracilaria* spp. may lead to performance failure and economic loss (Mantri et al. 2022a). Further DNA barcode information may be used to track and stop illegal trade of endangered species (Mishra et al. 2017).

India is globally recognized as a megadiverse country, with 7–8% of the world's recognized flora and fauna and ranks fourth among the 34 biodiversity hotspots across the 17 megadiverse countries of the world (Mantri et al. 2020). Indian coastline stretches over 11,099 km and the highest number of marine macro-algal taxa have been reported from India compared to countries neighbouring the Indian Ocean (Sahoo 2001). Despite decades of research involving molecular identification of species, the online sequence data for Indian seaweeds is scarce, for example DBIndalgae, first centralized

database effort in India to systematically compile information on native marine algae (Bhushan et al. 2016). However, repositories like DIDI (Diatoms image database of India), and Algal Database exist to address the challenges and discrepancies in identifying diatoms and freshwater microalgae respectively (Sharma et al. 2013; Pandey et al. 2016). The studies encompassing systematic integration or quality assessment are highly desired to ensure accuracy and reliability. To our knowledge, this is the first attempt to comprehensively analyse the online available sequence data for Indian seaweeds based on the sequences available in GenBank. The current study aims to provide a comprehensive, scientific inventory of publicly available DNA sequence database of Indian seaweeds. Such analyses would establish an integrated, quality-assured national baseline by consolidating decades of fragmented DNA sequence records. Standardized markers and metadata would enhance comparability across national laboratories, strengthening research and policy synthesis practices. Molecular identification would enhance value-chain growth and product traceability, along with accurate detection of potential invasive, harmful bloom-forming taxa thereby reinforcing biosecurity. Further this effort would be also crucial in identification of rare and threatened taxa, those need immediate conservation attention. Thus, we emphasize the urgent need for continued research, including marker-based sequencing efforts and standardized methodologies to enhance our knowledge base and unlock the full potential of Indian macroalgal biodiversity.

METHODS

DNA-barcode sequences for Indian macroalgal species reported in the checklist of Indian marine algae by Rao & Gupta (2015) were obtained from the GenBank database (GenBank 2025). The search terms used were: "India" + "Chlorophyta", "India" + "Rhodophyta", "India" + "Phaeophyta", and "India" + "Ochrophyta" for all the data available throughout the database, irrespective of submission date range. All records for Phaeophyta were combinedly presented under Ochrophyta throughout the manuscript. For each record, accession, organism name, marker/gene, publication, and collection location were extracted. The results were then verified against Web of Science, Scopus, and PubMed databases to confirm species name, marker usage, and sampling locations. Entries without peer-reviewed published record, geographical locations, and the duplicate entries

were removed and not considered for the analysis. The accepted taxonomic nomenclature was confirmed from AlgaeBase (Guiry & Guiry 2024). The cleaned data of collected sequences were then categorized based on phylum, class, and primer used to generate the DNA barcodes. The dataset thus obtained was used for the analysis against the latest checklist by Rao & Gupta (2015). The checklist represents 865 macro-algal species from India, including 212 green algae from 46 genera, 211 brown algae from 50 genera, and 442 red algae in 138 genera.

RESULTS AND DISCUSSION

A total of 207 unique sequences were obtained for Indian macro-algal species (Table 1) across chloroplast (*rbcl*, *tufA*, UPA, *atpB*, *psbA*), mitochondria (COI-5P, *cox*), nucleus (ITS), and ribosome (LSU rDNA, 23S rRNA, 18S rRNA) (Figure 1) loci from GenBank establishing a unified baseline for national-scale assessment and reuse. The study found that only 11% of the India marine macro algae were documented from India. The data revealed that in Chlorophyta, only nine genera containing 33 species from six unique orders have been amplified based on chloroplast (39), mitochondrial (5), nuclear (22), and ribosomal (16) gene markers. *Ulva sapor*a and *U. paschima* are now recognized as synonyms of *Ulva tepida* and *Caulerpa peltata* is synonymised with *Caulerpa chemnitzia* (Guiry & Guiry 2024). For Ochrophyta, 13

species of six genera were identified from three unique orders, with 55% of the generated sequences from chloroplast, 25% from mitochondria, and 10% each from nuclear and ribosomal genes. Moreover, 49 species of 22 genera from 10 unique orders and four varieties have been studied for Rhodophyta. *Gracilaria verrucosa* has now been renamed *Gracilariopsis longissima* (Guiry & Guiry 2024). Results revealed an uneven focus on molecular studies, with only 19% of green, 12% of brown, and 16% of red algae species globally. This depends largely on availability and due to more focused attention towards economically important seaweeds that are given priority. The observed seaweeds species of genus *Kappaphycus*, *Gracilaria*, *Porphyra*, *Sargassum*, *Turbinaria*, *Padina* are cultivated at scale for high value compound extraction (carrageenan, agar, alginates, pigments) and to be used as food (*Ulva* and *Caulerpa* species). Further, *Laurencia*, *Acanthophora*, *Caulerpa*, *Bryopsis* were studied for their bioactive properties due to presence of halogenated and terpenoid metabolites. At the genus level, it is only nine of the 46 reported green algal genera (20%), six out of 50 brown algal genera (12%), and 22 of the 138 reported red algal genera (16%) were reported from India. Further, among the 11 molecular markers that were investigated *rbcl* is the most studied marker (81 sequences), while *atpB* is the least (only one sequence) investigated marker for Indian marine macro algae (Figure 1). An effective DNA barcode couples sufficient interspecific sequence variation and ease of amplification across diverse taxa

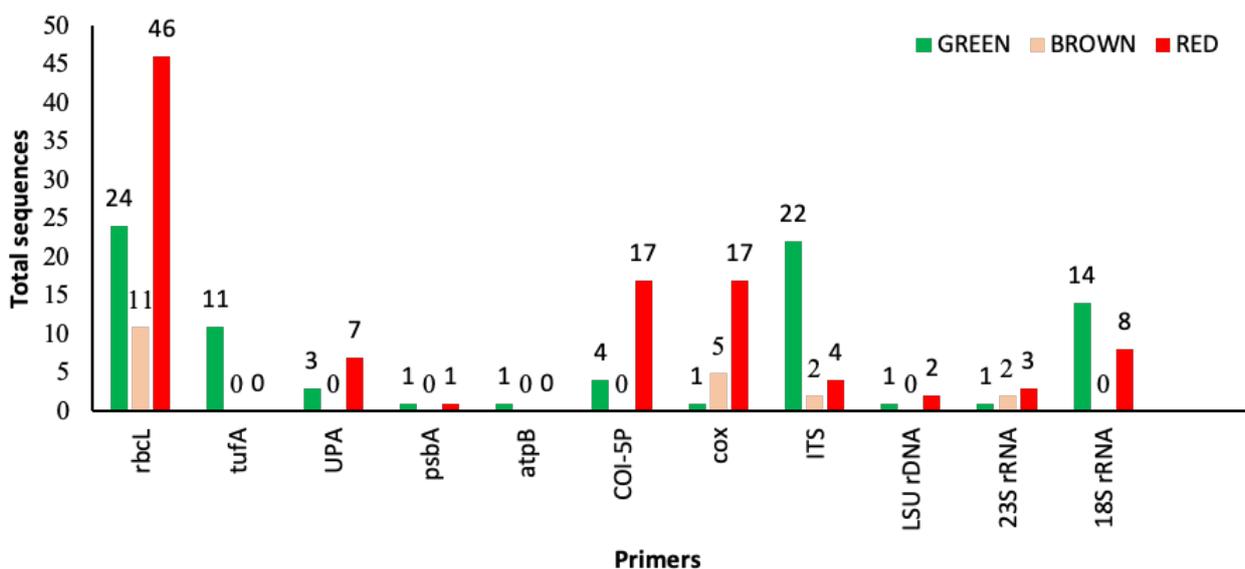


Figure 1. Marker-wise distribution of publicly available DNA barcode sequences for Indian marine macroalgae, showing counts per locus for Green (Chlorophyta), Brown (Ochrophyta), and Red (Rhodophyta) seaweeds.

Table 1. Marker-wise distribution of publicly available DNA barcode sequences from GenBank for Indian marine macroalgae by phylum, class, order and taxonomically accepted scientific names of seaweeds from India.

Phylum	Class	Order	Scientific Name	Primers
Chlorophyta	Ulvophyceae	Bryopsidales	<i>Bryopsis</i> sp.	rbcl
			<i>Caulerpa racemosa</i> var. <i>lamourouxii</i>	ITS
			<i>Caulerpa agardhii</i>	rbcl, 18S rRNA
			<i>Caulerpa fergusonii</i>	ITS
			<i>Caulerpa mexicana</i> var. <i>pluriseriata</i>	tufA
			<i>Caulerpa mexicana</i> .	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa microphysa</i>	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa peltata</i> (<i>C. chemnitzia</i>)	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa racemosa</i>	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa scalpelliformis</i>	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa serrulata</i>	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa sertularioides</i>	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa taxifolia</i>	rbcl, 18S rRNA, tufA, ITS
			<i>Caulerpa veravalensis</i>	rbcl, 18S rRNA, tufA, LSU rDNA
			<i>Caulerpa verticillata</i>	rbcl, 18S rRNA, tufA, ITS
		Cladophorales	<i>Chaetomorpha antennina</i>	rbcl
			<i>Cladophora goensis</i>	ITS
		Dasycladales	<i>Acetabularia jalakanyakae</i>	18S rRNA
		Ulvales	<i>Ulva chaugulei</i>	rbcl, ITS
			<i>Ulva compressa</i>	rbcl, COI-5P, UPA
			<i>Caulerpa chemnitzia</i>	rbcl
			<i>Ulva flexuosa</i>	rbcl, COI-5P, UPA
			<i>Ulva intestinalis</i>	rbcl, ITS, cox
			<i>Ulva lactuca</i>	rbcl, 18S rRNA, ITS
			<i>Ulva ohnoi</i>	rbcl, ITS
			<i>Ulva paschima</i> (<i>U. tepida</i>)	rbcl, COI-5P, UPA
			<i>Ulva reticulata</i>	rbcl, ITS
			<i>Ulva sapora</i> (<i>U. tepida</i>)	ITS, atpB, 23S rRNA
			<i>Ulva uniseriata</i>	ITS
			<i>Ulvella leptochaete</i>	rbcl, ITS, COI-5P
<i>Ulvella</i> sp.	rbcl, ITS			
	Ulvophyceae	Ulotrichales	<i>Gayralia brasiliensis</i>	ITS
	Chlorodendrophyceae	Chlorodendrales	<i>Tetraselmis indica</i>	18S rRNA
Ochrophyta	Phaeophyceae	Ectocarpales	<i>Chnoospora implexa</i>	rbcl, cox
			<i>Chnoospora</i> sp.	rbcl, cox
		Dictyotales	<i>Dictyota bartayresiana</i>	rbcl
			<i>Dictyota dichotoma</i>	rbcl
			<i>Padina tetrastromatica</i>	rbcl
		Fucales	<i>Sargassum aquifolium</i>	23S rRNA
			<i>Sargassum linearifolium</i>	rbcl
			<i>Sargassum plagiophyllum</i>	23S rRNA
			<i>Sargassum polycystum</i>	rbcl
			<i>Sargassum swartzii</i>	rbcl
			<i>Sargassum tenerrimum</i>	rbcl
			<i>Sargassum zhangii</i>	ITS, cox
			<i>Turbinaria ornata</i>	ITS, cox
			<i>Anthophycus longifolius</i>	rbcl
<i>Anthophycus</i> sp.	rbcl, cox			

Phylum	Class	Order	Scientific Name	Primers
Rhodophyta	Bangiophyceae	Bangiales	<i>Phycocalidia acanthophora</i> var. <i>robusta</i>	rbcl, COI-5P
			<i>Phycocalidia sukshma</i>	rbcl, COI-5P
			<i>Phycocalidia vietnamensis</i>	rbcl, COI-5P
			<i>Porphyra kanyakumariensis</i>	rbcl, COI-5P
			<i>Porphyra tenera</i>	rbcl
			<i>Porphyra yamadae</i>	rbcl, cox
			<i>Porphyra yezoensis</i>	rbcl
			<i>Pyropia acanthophora</i> var. <i>robusta</i>	rbcl, cox
			<i>Pyropia vietnamensis</i>	cox
	Florideophyceae	Batrachospermales	<i>Lemanea manipurensis</i>	rbcl
			<i>Sirodotia assamica</i>	rbcl, COI-5P
			<i>Sheathia assamica</i>	rbcl
		Ceramiales	<i>Caloglossa fluviatilis</i>	rbcl
			<i>Palisada perforata</i>	rbcl
			<i>Caloglossa beccarii</i>	rbcl, LSU rDNA
			<i>Acanthophora spicifera</i>	rbcl
			<i>Laurencia thyrsoifera</i>	rbcl, ITS, COI-5P
<i>Herposiphonia akidoglossa</i>			rbcl, COI-5P, psbA	
Rhodophyta	Florideophyceae	Ceramiales	<i>Spyridia hypnoides</i>	rbcl, UPA, cox, LSU rDNA
			<i>Jania rubens</i>	rbcl
		Corallinales	<i>Gelidiella acerosa</i>	rbcl, COI-5P
			<i>Gelidiella indica</i>	rbcl, COI-5P, cox
		Gigartinales	<i>Hypnea bullata</i>	rbcl, COI-5P, UPA
			<i>Hypnea indica</i>	rbcl, COI-5P, UPA
			<i>Hypnea musciformis</i>	rbcl
			<i>Hypnea nidifica</i>	rbcl, COI-5P, UPA, cox
			<i>Hypnea nigrescens</i>	rbcl, COI-5P, UPA
			<i>Hypnea spinella</i>	rbcl, COI-5P, UPA
			<i>Hypnea valentiae</i>	rbcl, ITS
			<i>Kappaphycus alvarezii</i>	rbcl, ITS, COI-5P, UPA, cox
			<i>Sarconema filiforme</i>	rbcl, COI-5P, cox
			Gracilariales	<i>Gracilaria corticata</i>
		<i>Gracilaria corticata</i> var. <i>corticata</i>		rbcl, 18s RNA, cox
		<i>Gracilaria dura</i>		rbcl, 18s RNA, cox
		<i>Gracilaria corticata</i> var. <i>cylindrica</i>		rbcl, 18s RNA, cox
		<i>Gracilaria debilis</i>		rbcl, 18s RNA, cox
		<i>Gracilaria edulis</i>		23S rRNA
		<i>Gracilaria fergusonii</i>		23S rRNA
		<i>Gracilaria foliifera</i>		rbcl, 18s RNA, cox
		<i>Gracilaria gracilis</i>		rbcl, 18s RNA, cox
		<i>Gracilaria salicornia</i>		rbcl
		<i>Gracilaria textorii</i>		rbcl, 18s RNA, cox
		<i>Gracilaria verrucosa</i> (<i>Gracilariopsis longissima</i>)		rbcl, 23S rRNA
		<i>Gracilariopsis lemaneiformis</i>		rbcl, 18s RNA, cox
		<i>Hydropuntia edulis</i>	rbcl	
Halymeniales	<i>Grateloupia catenata</i>	rbcl		
	<i>Grateloupia orientalis</i>	rbcl		
	<i>Grateloupia</i> sp.	rbcl		
Nemaliales	<i>Liagora albicans</i>	rbcl		

(Hollingsworth et al. 2009). Based on assessments of recoverability, sequence quality, and levels of species discrimination, a 2-loci combination of *rbcL*+*matK* as the plant barcode is recommended to provide a universal framework for the routine use of DNA sequence data to identify specimens and contribute toward the discovery of overlooked species of land plants (Leliaert et al. 2012). Because land plants evolved from green algal ancestors, the use of *rbcL* succeeded for seaweed DNA barcoding, as its conserved priming sites and informative variation support dependable amplification and species discrimination. The species delineation in marine macroalgal taxa poses a considerable challenge due to high morphological, anatomical, and reproductive plasticity. Nevertheless, taxonomic concepts in this group are fast evolving globally with the advent of DNA barcoding techniques. This is the first national effort to compile relevant scientific information on DNA barcoding pertaining to Indian marine macro-algae, which was scattered and difficult to access. The analysis revealed minuscule DNA sequence data availability.

Seaweeds offer socio-economic benefits to coastal communities through aquaculture and represent a valuable, yet underexplored resource (Mantri et al. 2020). The seaweed aquaculture industry is valued at USD 14 billion globally, producing 34.7 million tonnes of wet weight annually (FAO 2022) encompassing 51.3% of the global aquaculture industry with 6.2% annual growth (Duarte et al. 2022), but India contributes only 0.01% of the cultivated seaweeds, indicating a colossal gap (Mantri et al. 2022b). The lack of DNA sequence data significantly hinders our ability to understand the full spectrum of seaweed biodiversity range (endemic, exotic, and migratory species), abundance (dominant, rare, vulnerable, and endangered species), ecological roles, and correct taxonomic placement of Indian macroalgal species. We consider, DNA barcoding data at the national level would not only help us in the sustainable commercial utilisation of economically important species (Rao & Mantri 2006) but also in the conservation of endemic taxa (Rathod et al. 2023). This is identified as a major research gap. It needs to be addressed through concentrated efforts by national research organizations and universities, ascertaining the availability of adequate infrastructure, and focused efforts on capacity building (Mantri et al. 2020). However, the reliance on public-domain with heterogenous quality, incomplete metadata, and marker bias may limit resolution for certain clades and addressing these gaps would require coordinated national sampling, sequencing efforts, and capacity building.

The results provide first national current coverage of barcodes for Indian seaweed species, marker bias, and the availability of minuscule molecular data compared to the huge biodiversity. This calls for a comprehensive and collaborative research program urgently needed at the Pan-India level. India is investing large amounts of money in seaweed farming and value-chain development, and dependable species authentication underpins quality, traceability of high value products (Mantri et al. 2022a). Early detection of invasive species, surveillance of harmful algae, and identifying species at risk would aid in strengthening coastal biosecurity, select germplasm banking, risk management, and conservation and policy formation (Armstrong & Ball 2005; Hofmann et al. 2025). Multi-gene and method-integrated barcoding frameworks further improve resolution for difficult groups, enhancing surveillance sensitivity and reliability. This efficiency compounds benefits across ecology, systematics, and bioprospecting, where barcoding underpins access to novel bioactives and authentic species-level insights.

Data availability

The datasets generated during and/or analysed during the current study are available from the corresponding author upon reasonable request.

REFERENCES

- Armstrong, K.F. & S.L. Ball (2005). DNA barcodes for biosecurity: invasive species identification. *Philosophical Transactions of the Royal Society B* 360: 1813–1823. <https://doi.org/10.1098/rstb.2005.1713>
- Bhushan, S., R. Mehra, P. Rani & F. Bast (2016). DB IndAlgae: an online resource of marine algae from India identified on the basis of molecular and morphological features. *Current Science* 111(4): 723–726.
- Chac, L.D. & B.B. Thinh (2023). Species identification through DNA barcoding: and its applications: a review. *Biology Bulletin* 50(6): 1143–1156. <https://doi.org/10.1134/S106235902360229X>
- Duarte, C.M., A. Bruhn & D. Krause-Jensen (2022). A seaweed aquaculture imperative to meet global sustainability targets. *Nature Sustainability* 5(3): 185–193. <https://doi.org/10.1038/s41893-021-00773-9>
- FAO (2022). *The State of World Fisheries and Aquaculture 2022: Towards Blue Transformation*. FAO, Rome, Italy, 266 pp.
- GenBank (2024). National Institute of Health, National Centre for Biotechnology Information. <https://www.ncbi.nlm.nih.gov/nucleotide>. Accessed on 7.vi.2024.
- Guiry, M.D. & G.M. Guiry (2024). AlgaeBase: Listing the world's algae. AlgaeBase. <https://www.algaebase.org/>. Accessed on 7.vi.2024.
- Hebert, P.D., A. Cywinska, S.L. Ball & J.R. deWaard (2003). Biological identifications through DNA barcodes. *Proceedings Biological Sciences* 270(1512): 313–321. <https://doi.org/10.1098/rspb.2002.2218>
- Hofmann, L.C., J. Brakel, I. Bartsch, G.M. Arismendi, R. Bermejo, M.I. Parente & T. Wichard (2025). A European biobanking strategy for safeguarding macroalgal genetic material to ensure food security,

- biosecurity and conservation of biodiversity. *European Journal of Phycology* 60(2): 197–220. <https://doi.org/10.1080/09670262.2025.2480569>
- Hollingsworth, P.M., L.L. Forrest, J.L. Spouge, M. Hajibabaei, S. Ratnasingham, M. VanDerBank & M.W. Chase (2009). A DNA barcode for land plants. *Proceedings of the National Academy of Sciences* 106(31): 12794–12797. <https://doi.org/10.1073/pnas.0905845106>
- Kowalska, Z., F. Pniewski & A. Latała (2019). DNA barcoding – A new device in phycologist’s toolbox. *Ecohydrology & Hydrobiology* 19(3): 417–427. <https://doi.org/10.1016/j.ecohyd.2019.01.002>
- Lagourgue, L., S. Gobin, M. Brisset, S. Vandenberghe, C. Bonneville, T. Jauffrais, S.V. Wynsberge & C.E. Payri (2022). Ten new species of *Ulva* (Ulvophyceae, Chlorophyta) discovered in New Caledonia: genetic and morphological diversity, and bloom potential. *European Journal of Phycology* 57(4): 458–478. <https://doi.org/10.1080/09670262.2022.2027023>
- Leliaert, F., D.R. Smith, H. Moreau, M.D. Herron, H. Verbruggen, C.F. Delwiche & O. DeClerck (2012). Phylogeny and Molecular Evolution of the Green Algae. *Critical Reviews in Plant Sciences* 31(1): 1–46. <https://doi.org/10.1080/07352689.2011.615705>
- Mantri, V.A., V. Veeragurunthan, K. Sambhwani & A.M. Kazi (2022a). Concise review of industrially important red seaweed *Gracilaria dura* (C. Agardh) J. Agardh. *Journal of Applied Phycology* 34(4): 1825–1841. <https://doi.org/10.1007/s10811-022-02755-6>
- Mantri, V.A., A. Ghosh, K. Eswaran & M. Ganesan (2022b). Notes on recommendations for enabling policy interventions in the seaweed cultivation and processing domain in India. *Sustainability* 14(16): 10416. <https://doi.org/10.3390/su141610416>
- Mantri, V.A., M.G. Kavale & M.A. Kazi (2020). Seaweed biodiversity of India: Reviewing current knowledge to identify gaps, challenges, and opportunities. *Diversity* 12(1): 13. <https://doi.org/10.3390/d12010013>
- Mishra, P., A. Kumar, G. Sivaraman, A.K. Shukla, R. Kaliamoorthy, A. Slater & S. Velusamy (2017). Character-based DNA barcoding for authentication and conservation of IUCN Red listed threatened species of genus *Decalepis* (Apocynaceae). *Scientific Reports* 7: 14910. <https://doi.org/10.1038/s41598-017-14887-8>
- Pandey, L.K., K.K. Ojha, P.K. Singh, C.S. Singh, S. Dwivedi & E.A. Bergery (2016). Diatoms image database of India (DIDI): a research tool. *Environmental Technology & Innovation* 5: 148–160.
- Rajauria, G., L. Cornish, F. Ometto, F.E. Msuya & R. Villa (2015). Identification and selection of algae for food, feed, and fuel applications (pp. 315–345). In: Brijesh K.T. & D.J. Troy (eds.). *Seaweed Sustainability*. Academic Press, 470 pp. <https://doi.org/10.1016/B978-0-12-418697-2.00012-X>
- Rao, P. & R. Gupta (2015). A Checklist of Indian Marine Algae (excluding Diatoms & Dinoflagellate). Botanical Survey of India, Ministry of Environment, Forests & Climate Change, Kolkata, India, 93 pp.
- Rao, P.S. & V.A. Mantri (2006). Indian seaweed resources and sustainable utilization: Scenario at the dawn of new century. *Current Science* 91(2): 164–174. <https://www.jstor.org/stable/24094208>
- Rathod, S.G., M.A. Kazi & V.A. Mantri (2023). Molecular evidence to support the transfer of *Enteromorpha ovata* to genus *Ulva* and evaluate its divergence using multi-locus time-calibrated phylogeny. *Nordic Journal of Botany* 2023(12): e04103. <https://doi.org/10.1111/njb.04103>
- Sahoo, D. (2001). *Seaweeds of Indian Coast*. APH Publication Corporation, New Delhi, 276 pp.
- Saunders G.W. (2005). Applying DNA barcoding to red macroalgae: a preliminary appraisal holds promise for future applications. *Philosophical transactions of the Royal Society of London Series B Biological sciences* 360(1462): 1879–1888. <https://doi.org/10.1098/rstb.2005.1719>
- Saunders G.W. & D.C. McDevitt (2014). A DNA barcode survey of Haida Gwaii kelp (Laminariales, Phaeophyceae) reveals novel ecological and distributional observations and *Saccharina druehlii* sp. nov. *Botany* 92(11): 821–826. <https://doi.org/10.1139/cjb-2014-0119>
- Sharma, P., P. Patil, N. Rao, K.V. Swamy, M.B. Khetmalas & G.D. Tandon (2013). Algal Database—Bioprospecting indigenous algae for industrial application. *Indian Journal of Biotechnology* 12: 548–549.
- Wirawan, I.G.P., M.M.V. Sasadara, I.N. Wijaya & A.A.K. Krinandika (2021). DNA barcoding in molecular identification and phylogenetic relationship of beneficial wild Balinese red algae, *Bulung sangu* (*Gracilaria* sp.). *Bali Medical Journal* 10(1): 82–88. <https://doi.org/10.15562/bmj.v10i1.2093>



Checklist of rust fungi of the Nuratau Nature Reserve, Uzbekistan

I.M. Mustafaev¹ , M.M. Iminova² , I.Z. Ortiqov³ , S.A. Teshaboyeva⁴  & N.Q. Iskanov⁵ 

^{1,2,4} Institute of Botany of Academy of Sciences of the Republic of Uzbekistan, Tashkent 100053, Uzbekistan.

³ Andijan Institute of Agriculture and Agrotechnologies, Andijan 170600, Uzbekistan.

⁵ Jizzakh State Pedagogical University, Jizzakh 130100, Uzbekistan.

¹ elyor-mustafaev@inbox.ru (corresponding author), ² malika.mashrabovna1@gmail.com, ³ ortiqovi@inbox.ru,

⁴ shteshaboeva@gmail.com, ⁵ nurbekiskanov0409@gmail.com

Abstract: A checklist of rust fungi of the Nuratau Nature Reserve (Nuratau Mountains, Uzbekistan) was compiled for the first time as a result of field research conducted in 2009–2022. In total, 70 species of rust fungi belonging to six genera and four families have been identified. Three of these species (*Puccinia behenis*, *P. onopordi*, *Uromyces helichrysi*) were found for the first time for the mycobiota of Uzbekistan. Thirteen species of rust fungi were recorded on 15 new host plant species. Most species of rust fungi belong to the genera *Puccinia* and *Uromyces*. The annotated checklist includes data on host plant, location, date and collection number of every species.

Keywords: Basidiomycetes, host plants, mycobiota, new records, Nuratau Mountains, protected mountain ecosystems, Pucciniales.

Annotatsiya: Nurota davlat qo'riqxonasi (Nurota tog'lari, O'zbekiston) hududida tarqalgan zang zamburug'larining cheklisi 2009–2022-yillarda olib borilgan dala tadqiqotlari natijalari asosida ilk bor tuzildi. Tadqiqot davomida oltita turkum va to'rtta oilaga mansub jami 70 tur zang zamburug'i aniqlandi. Shulardan uch tur — *Puccinia behenis*, *P. onopordi* hamda *Uromyces helichrysi* — O'zbekiston mikrobiotasi uchun birinchi marta qayd etildi. Bundan tashqari, 13 tur zang zamburug'i 15 ta yangi xo'jayin o'simlik turlarida aniqlangan. Aniqlangan turlar orasida *Puccinia* va *Uromyces* turkumlariga mansub vakillar ustunlik qiladi. Ushbu ro'yxat har bir tur bo'yicha xo'jayin o'simlik nomi, topilgan joyi, yig'ilgan sanasi hamda kolleksiya raqamiga oid ma'lumotlarni o'z ichiga oladi.

Editor: Sanli Kabaktepe, Malatya Turgut Ozal University, Malatya, Türkiye.

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

Citation: Mustafaev, I.M., M.M. Iminova, I.Z. Ortiqov, S.A. Teshaboyeva & N.Q. Iskanov (2026). Checklist of rust fungi of the Nuratau Nature Reserve, Uzbekistan. *Journal of Threatened Taxa* 18(2): 28350–28357. <https://doi.org/10.11609/jott.9116.18.2.28350-28357>

Copyright: © Mustafaev et al. 2026. 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: This work was carried out within the framework of the State Program "Preservation of Tashkent Botanical Garden Collections, Introduction of Prospective Species, and Their Recommendation for Various Sectors of the Republic of Uzbekistan".

Competing interests: The authors declare no competing interests.

Author details: ILYOR MURADDULLAYEVICH MUSTAFAEV, Institute of Botany of Academy of Sciences of the Republic of Uzbekistan. Specialization – fungal diversity, fungal taxonomy, fungal ecology, plant disease management. MALIKA MASHRAPOVNA IMINOVA, Institute of Botany of Academy of Sciences of the Republic of Uzbekistan. Specialization – fungal diversity, fungal taxonomy, fungal ecology. ISLOM ZIYODULLA UGLI ORTIQOV, Andijan Institute of Agriculture and Agrotechnologies. Specialization – fungal diversity, fungal taxonomy, fungal ecology, plant disease management. SHAXNOZA ARABBOYEVNA TESHABOYEVA, Institute of Botany of Academy of Sciences of the Republic of Uzbekistan. Specialization – fungal diversity, fungal taxonomy, fungal ecology, NURBEK ISKANOV, Jizzakh State Pedagogical University. Specialization – mycology.

Author contributions: I.M.M.—data collection, writing and reviewing; M.M.I.—reviewing; I.Z.O.—writing, data collection; Sh.S.T.—data collection; N.Q.I.—data collection. All authors have read and agreed to the published version of the manuscript.

Acknowledgements: This work was partly supported by the state program "Pathogenic fungi of economically important plants exporting fruits, vegetables and melons: diversity, monitoring, and creation of an electronic database". The author expresses his great thanks to Dr. N.Yu. Beshko for identification of host plants of rust fungi. Valuable suggestions of anonymous reviewers for improving the manuscript are appreciated.



INTRODUCTION

Rust fungi are the larger and the most important obligate biotrophic plant group of Mycota. These fungi comprise more than 7,000 species belonging to a single order (Pucciniales), with an estimated 14 families and 168 genera (Kirk et al. 2008). Rust fungi parasitize a wide range of host plants including ferns, conifers, and angiosperms.

Research related to the rust fungi in Uzbekistan mainly began with Zaprometov in 1912–1926s and by Golovin in 1947–1950. Studies on rust fungi in Uzbekistan were intensified between 1950 and 1986 by N.I. Gaponenko, T.S. Panfilova, T.K. Rotkevich, S.S. Ramzanova, F.G. Akhmedova, and G.T. Baymuratova. The synopsis of the rust fungi was published in “Fungal flora of Uzbekistan” in 1986 (Ramzanova et al. 1986). During the last two decades, a large number of new species of rust fungi and host records have been added (Nuraliev 1999; Solieva & Gafforov 2001, 2002; Gafforov et al. 2016; Mustafaev 2020).

Study area

All specimens of the rust fungi were collected in 2009–2021 in the territory of Nuratau Nature Reserve (NNR) located between 40.468–40.562° N and 66.659–66.927° E in the central part of the Nuratau Ridge, a major ridge of the Nuratau Mountains in Uzbekistan. (Figure 1).

The NNR is a strictly protected area of IUCN Category I established in 1975. The area is 177.52 km², and altitudes range 530–2,169 m. The Nuratau Mountains with the adjacent small insular ridges are the peripheral northwestern branches of the Pamir-Alay Mountain System, wedged deeply into the Kyzylkum Desert. The climate regime is temperate continental semi-arid with a mean annual temperature of 14°C and a mean annual precipitation of 300–400 mm. The flora of the Nuratau Mountains includes 1,289 species of vascular plants, 34 of them are local endemics; the checklist of the flora of Nuratau Nature Reserve includes 820 species belonging to 385 genera and 81 families (Tojibaev et al. 2017). The mycobiota of the Nuratau Mountains and the NNR was poorly studied until the author began in 2009 and then intensified (Mustafaev & Nuraliev 2012a,b; Mustafaev 2014a,b, 2015, 2016, 2017, 2022; Mustafaev et al. 2019, 2021; Mustafaev & Khujanov 2020; Mustafaev & Islomiddinov 2022; Islomiddinov et al. 2022). The current study aims to compile a checklist of the rust fungi of the NNR.

METHODS

Around 1,000 samples of the rust fungi were collected in 2009–2021 in different habitats of NNR which are designated in the checklist by following abbreviations: AbV—Andibarout valley (40.521° N, 66.741° E) | AnV—Andigen Valley (40.547° N, 66.689° E) | BMt—Beshbarmoq Mt. (40.479° N, 66.811° E) | GV—Gurdara Valley (40.502° N, 66.918° E) | HMt—Hayatbashi Mt. (40.498° N, 66.729° E) | HV—Hayat Valley (40.517° N, 66.748° E) | MV—Majrum Valley (40.565° N, 66.702° E) | PMt—Parandaz Mt. (40.484° N, 66.791° E) | QV—Qarisoy Valley (40.498° N, 66.807° E) | TV—Tikcha Valley (40.488° N, 66.763° E).

Specimens were examined with a light microscope and identified using the relevant literature (Kuprevich & Tranzchel 1957; Karbonskaya 1969; Azbukina 1974; Kuprevich & Ulyanishchev 1975; Uljanishev 1978; Ramzanova et al. 1986). Host plant species were identified using “Conspectus Florae Asiae Mediae” (1968–1993) and “Flora of Uzbekistan” (1941–1962). All collected specimens are stored in Fungarium of the Institute of Botany in Tashkent. Voucher specimens for each species of rust fungi are cited in the checklist below. Name of collector is designated by abbreviation: IM—Ilyor Mustafaev. The taxonomy and nomenclature of rust fungi in the checklist follows international databases “Index Fungorum” (2022). The nomenclature of host plants is given according to powo.science.kew.org/results (2022).

RESULTS

Checklist of rust fungi of the Nuratau Nature Reserve is compiled for the first time as a result of field research conducted by authors in 2009–2021. In total, 70 species of rust fungi belonging to six genera and four families were found. The largest genera are *Puccinia* (44), *Uromyces* (15), *Phragmidium* (6), and other genera (*Tranzschelia*, *Aecidium*, *Melampsora*) are represented with 1–3 species. Among them, four species – *Puccinia behenis* G.H.Otth – on *Silene obtusedentata* B.Fedtsch. et Popov, *P. onopordi* P.Syd. et Syd. – on *Onopordum olgae* Regel et Schmalh., *Uromyces helichrysi* Lagerh. – on *Helichrysum nuratavicum* Krasch. were recorded for the first time for the mycobiota of Uzbekistan. Rust fungi parasitize 92 host species belonging to 24 families and 68 genera on territory of the NNR. The most representative host families are: Asteraceae (14 rust species), Rosaceae (8), Fabaceae (7), Apiaceae (6), Lamiaceae (6), Poaceae

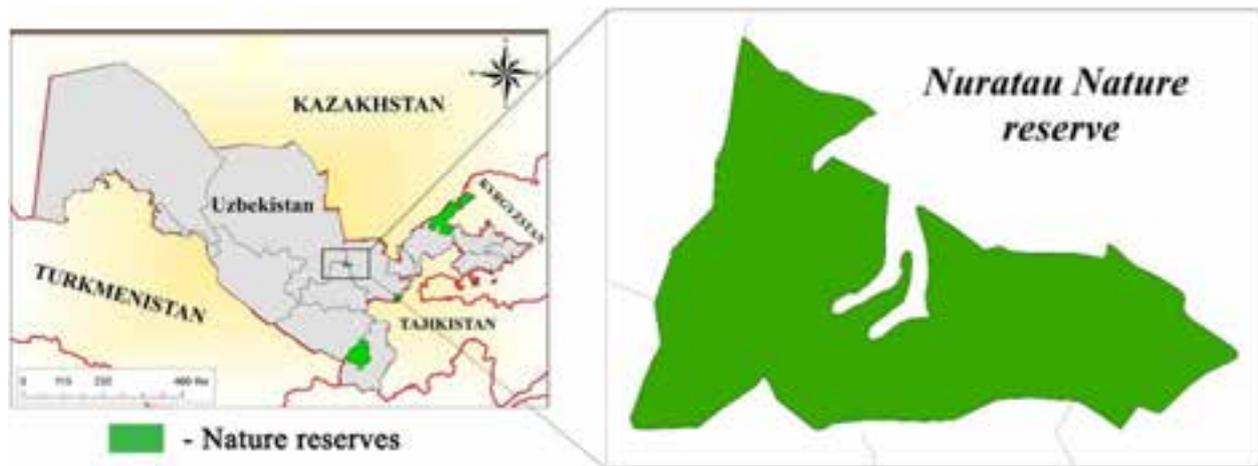


Figure 1. Location of the study area: Nuratau Nature Reserve.

Table 1. Comparison of the rust diversity of Nuratau Nature Reserve with other regions of Uzbekistan.

Study areas	Plant flora species	Rust species	Rust host plant species (Percentage towards to overall flora)
Uzbekistan (Ramazanova et al. 1986)	4500	261	511 (13.35%)
Angren River basin (Panfilova & Gaponenko 1963)	1500	124	212 (14.13%)
Fergana Valley (Gafforov et al. 2016)	2625	95	140 (5.33%)
Nuratau Nature Reserve (This research)	820	70	92 (11.13%)

(4), Euphorbiaceae (3), Ranunculaceae (3). Thirteen species of rust fungi were recorded for the first time on 15 new host plant species in the host plant index of Uzbekistan: *Uromyces dactylidis* G.H.Oth. – *Ranunculus mindshelkensis* B.Fedtsch., *Puccinia cousiniae* P.Syd. et Syd. – *Cousinia pseudodshisakensis* Tschern. et Vved., *P. phlomidis* Thüm. – *Leonurus turkestanicus* V.I.Krecz. et Kuprian. and *Phlomis nubilans* Zakirov, *P. monticola* Kom. – on *Geranium linearilobum* DC., *Puccinia tanacetii* DC. – *Tanacetopsis karataviensis* (Kovalevsk.) Kovalevsk., *P. sogdiana* Kom. – *Ferula angreni* Korovin, *P. echinopsis* DC. – *Echinops nuratavicus* A.D.Li, *P. galii-cruciatae* Duby – *Galium karakulense* Pobed., *P. recondita* Roberge ex Desm. – on *Thalictrum isopyroides* C.A.Mey, *P. behenis* – on *Silene obtusedentata*, *P. onopordi* – on *Onopordum olgae*, *P. thymi* (Fuckel) P.Karst. – on *Thymus seravschanicus*, *Uromyces helichrysi* – on *Helichrysum nuratavicum*, *U. acantholimonis* Syd. et P.Syd. – on *Acantholimon nuratavicum* Zakirov.

Among them, *Acantholimon nuratavicum*, *Helichrysum nuratavicum*, *Phlomis nubilans* are endemic species to the Nuratau Ridge and *Phlomis nubilans* and *Helichrysum nuratavicum* are listed in the Red Data Book of Uzbekistan since 2009 (Red 2019).

The recorded rust species were found on 24 medicinal species such as *Ziziphora clinopodioides*, *Taraxacum officinale*, *Origanum vulgare* subsp. *gracile*, *Ferula moschata*, *Tanacetopsis karataviensis*, *Atraphaxis virgata*, *Mentha longifolia* var. *asiatica*, *Malva neglecta*, *Cichorium intybus*, *Urtica dioica*, *Helichrysum nuratavicum*, and *Rosa canina*.

List of 70 species of rust fungi from study area:

Melampsoraceae

Melampsora Castagne

M. euphorbiae (Ficinus & C.Schub.) Castagne — on *Euphorbia helioscopia* L., HV, 29 V 2009, IM062.

M. hissarica Faizieva — on *Salix alba* L., HV, 6 VI 2012, IM153.

M. populnea (Pers.) P.Karst. — on *Populus alba* L., HV, 15 VII 2017, IM355. (Image 1).

Phragmidiaceae

Phragmidium Link

Ph. bulbosum F.Strauss — on *Rubus caesius* L., HV, 24.ix.2010, IM259.

Ph. circumvallatum Magnus — on *Geum kokanicum* Regel & Schmalh. (= *Orthurus kokanicus* Juz.), HMT,



Image 1. *Melampsora populnea* (Pers.) P. Karst.—on *Populus alba* L.

25.vi.2015, IM139, 15.vii.2017, IM350, PMt, 10.v.2010, IM183, 3.v.2011, IM074, BMt, 16.v.2017, IM344.

Ph. devastatrix Sorokĭn — on *Rosa canina* L., HV, 28.v.2009, IM063.

Ph. rosae-lacerantis Dietel — on *Rosa webbiana* Wall. ex Royle (= *Rosa maracandica* Bunge), HV, 14.vii.2010, IM096, HV, 15.vii.2017, IM356.

Ph. sanguisorbae (DC.) J.Schröt. — on *Sanguisorba minor* subsp. *lasiocarpa* (Boiss. Et Hausskn.) Nordborg (= *Poterium lasiocarpum* Boiss. et Hausskn), HV, 13.vii.2010, IM142.

Ph. tuberculatum Jul.Müll. — on *Rosa canina* L., MV, 03.viii.2009, IM064; on *Rosa persica* Michaut ex Juss. (= *Hulthemia persica* (Michaut ex Juss.) Bornm.), HV, 11.v.2010, IM297. (Image 2).

Pucciniaceae

Aecidium Pers.

Aecidium thalictri Grev. — on *Thalictrum sultanabadense* Stapf, PMt, 10.v.2010, IM178, MV, 5.v.2012, IM071.

Puccinia Pers.

P. chrysanthemi Roze — *Artemisia juncea* Kar. et Kir.: HV, 14.iv.2010, IM008. *Artemisia oliveriana* J.Gay ex Besser (= *Artemisia sogdiana* Bunge), MV, 2.v.2011, IM065, HV, 15.vii.2017, IM357, *Artemisia tenuisecta* Nevski, HV, 13.vii.2010, IM036.

P. cnici-oleracei Pers. — on *Dieteria canescens* (Pursh) Nutt. (= *Aster canescens* Pursh), BMt, 15.v.2010, IM301.



Image 2. *Phragmidium tuberculatum* Jul. Müll.—on *Rosa canina* L.

P. behenis G.H.Oth — on *Silene obtusidentata* B.Fedtsch. et Popov, QV, 12.v.2010, IM505.

P. bromina Erikss. — on *Bromus sterilis* L., TV, 29.v.2009, IM049, HV, 1.v.2011, IM225; on *Bromus inermis* Leyss., HV, 09.v.2010, IM199.

P. bulbocastani (Cumino) Fuckel — on *Elwendia chaerophylloides* (Regel et Schmalh.) Pimenov et Kljuykov (= *Bunium chaerophylloides* (Regel et Schmalh.) Drude), QV, 07.vi.2012, IM258.

P. caricina DC. — on *Urtica dioica* L., QV, 12.v.2010, IM015, MV, 19.vi.2011, IM378,

P. galii-cruciatae Duby — *Galium pamirolaicum* Pobed., PMt, 10.v.2010, IM027, BMt, 15.vii.2010, IM010, BMt, 16.vii.2017, IM351; *Galium karakulense* Pobed., MV, 16.vii.2011, IM 224. First record on *Galium karakulense* in Uzbekistan.

P. carthami Corda — on *Leuzea repens* (L.) D.J.N. Hind (= *Acroptilon repens* (L.) DC.), HV, 25.ix.2010, IM020, MV, 3.vii.2009, IM058.

P. cesatii J.Schröt. — *Bothriochloa ischaemum* (L.) Keng, HV, 5.vii.2011, IM229.

P. hieracii (Röhl.) H.Mart. — *Cichorium intybus* L., HV, 5.vii.2009, IM326, 13.v.2010, IM013.

P. cnici H.Mart. — on *Picnomon acarna* (L.) Cass., HV, 9.v.2010, IM022, HV, 30.v.2016, IM324, 6.vi.2011, IM039.

P. conferta Dietel et Holw. — on *Artemisia juncea* Kar. et Kir., MV, 19.vii.2011, IM326.

P. cousiniae P.Syd. et Syd. — on *Arctium umbrosum* (Bunge) Kuntze (= *Cousinia umbrosa* Bunge), HV, 24.ix.2010, IM035, *A. korolkowii* Kuntze (≡ *Cousinia korolkowi* Regel et Schmalh.), HV, 14.v.2010, IM018, HV, 18.vii.2011, IM277; *Cousinia radians* Bunge, HV, 29.v.2010, IM033; *C. resinosa* Juz., HV, 13.vii.2010,

IM019; *C. eriotricha* Juz., HMT, 27.vii.2015, IM137; *C. pseudodshizakensis* Tschern. et Vved., HMT, 27.vii.2015, IM037, MV, 3.viii.2009, IM243. HMT, 15.vii.2015, IM358, 27.v.2009, IM450. First record on *C. pseudodshizakensis* Uzbekistan.

P. cynodontis Lacroix ex Desm. — on *Cynodon dactylon* (L.) Pers., HV, 13.vii.2010, IM012. HV, 14.v.2010, IM295.

P. droborii Solkina — on *Mediasia macrophylla* Pimenov, GV, 28.v.2014, IM125, PMt, 27.vii.2016, IM237, BMT, 16.vii.2017, IM342. (Image 3).

P. echinopsis DC. — on *Echinops nuratavicus* A.D. Li, TV, 27.vii.2016, IM162. First record on *Echinops nuratavicus* in Uzbekistan.

P. eremuri Kom. — on *Eremurus olgae* Regel, HV, 10.v.2010, IM009; on *Eremurus sogdianus* (Regel) Benth. et Hook. f., TV, 29.v.2009, IM044. (Image 4).

P. falcariae Fuckel — on *Falcaria vulgaris* Bernh., HV, 11.v.2010, IM005, 1.v.2011, IM263, 18.v.2011, IM042.

P. fuckelii P.Syd. et Syd. — on *Jurinea olgae* Regel et Schmalh., MV, 2.v.2011, IM061.

P. hieracii (Röhl.) H.Mart. — on *Centaurea besseriana* DC. (= *Centaurea squarrosa* Willd.), QV, 15.v.2010, IM003.

P. komarovii Tranzschel — on *Impatiens parviflora* DC., 28.v.2014, IM128.

P. kupreviczii Golovin — on *Scutellaria ramosissima* Popov, HV, 30.v.2015, IM194.

P. libani Magnus — on *Prangos pabularia* Lindl., GV, 10.iv.2013, IM034; *Ferula ovina* (Boiss.) Boiss., PMt, 10.v.2010, IM011.

P. littoralis Rostr. — on *Juncus inflexus* L., MV, 30.x.2009, IM198.

P. litvinovii Tranzschel et Erem. — on *Alcea litvinovii*

(Iljin) Iljin, HV, 13.v.2010, IM050.

P. malvacearum Bertero ex Mont. — on *Malva neglecta* Wallr., HV, 16.v.2010, IM021; on *Alcea litvinovii* (Iljin) Iljin, HV, 13.v.2010, IM302.

P. medioasiatica Uljan. — on *Hypericum scabrum* L., PMt, 3.v.2011, IM031, BMT, 15.vii.2010, IM030, MV, 26.iii.2015, IM188.

P. menthae Pers. — on *Mentha longifolia* var. *asiatica* (Boriss.) Rech.f. (= *Mentha asiatica* Boriss.), QV, 5.vii.2010, IM029, MV, 30.x.2009, IM046.

P. monticola Kom. — on *Geranium linearilobum* DC., MV, 26.iii.2015, IM145. First record on *Geranium linearilobum* in Uzbekistan.

P. onopordi P.Syd. et Syd. — on *Onopordum leptolepis* DC. (= *Onopordum olgae* Regel et Schmalh.), TV, 11.v.2010, IM434.

P. recondita Roberge ex Desm. — on *Thalictrum isopyroides* C.A.Mey., GV, 6.vi.2012, IM043. First record on *Thalictrum isopyroides* in Uzbekistan.

P. phlomidis Thüm. — on *Phlomis thapsoides* Bunge, HV, 13.vii.2010, IM023, IM024, IM383; on *Phlomis nubilans* Zakirov, HV, 3.vii.2019, IMe001; on *Phlomoides kaufmanniana* (Regel) Adylov, Kamelin et Makhm. (= *Eremostachys kaufmanniana* Regel), TV, 29.v.2009, IM047, BMT, 12.v.2010, IM025, MV, 2.v.2011, IM222, QV, 7.vi.2012, IM129; on *Leonurus turkestanicus* V.I.Krecz. et Kuprian., BMT, 12.v.2010, IM026. First record on *Leonurus turkestanicus* and *Phlomis nubilans* in Uzbekistan.

P. platypoda Syd. et P.Syd. — on *Atraphaxis virgata* (Regel) Krasn., MV, 24.vii.2015, IM146.

P. plicata Kom. — on *Prangos pabularia* Lindl., HV, 13.vii.2010, IM006.

P. poarum E.Nielsen — on *Poa pratensis* L., HV, 9.v.2010, IM052.



Image 3. *Puccinia droborii* Solkina—on *Mediasia macrophylla* Pimenov.



Image 4. *Puccinia eremuri* Kom.—on *Eremurus olgae* Regel.



Image 5. *Puccinia violae* DC.—on *Viola suavis* M. Bieb.



Image 6. *Uromyces acantholimonis* Syd. et P. Syd.—on *Acantholimon erythraeum* Bunge.

P. maculosa Schwein. — on *Chondrilla* sp., HV, 3.viii.2009, IM048.

P. punctata Link — on *Asperugo procumbens* L., HV, 9.v.2010, IM233; on *Galium tricornutum* Dandy (= *Galium spurium* L.), HV, 11.v.2010, IM028, QV, 15.vii.2010, IM353; on *Galium humifusum* M. Bieb., QV, 15.vii.2010, IM007; on *Galium pamirolaicum* Pobed., PMt, 3.v.2011, IM040, HMT, 30.v.2015, IM261; on *G. aparine* L., HV, 14.v.2010, IM038.

P. tanacetii DC. — on *Lepidolopsis turkestanica* (Regel et Schmalh.) Poljakov, HV, 27.vii.2017, IM369; on *Tanacetopsis karataviensis* (Kovalevsk.) Kovalevsk., TV, 27.vii.2016, IM165. First record on *Tanacetopsis karataviensis* in Uzbekistan.

P. thymi (Fuckel) P.Karst. — on *Thymus seravschanicus* Klovov, BMt, 15.vi.2010, IM002.

P. sogdiana Kom. — on *Ferula moschata* (H.Reinsch) Koso-Pol., PMt, 10.v.2010, IM246; *F. kokanica* Regel et Schmalh., PMt, 3.v.2011, IM262; on *F. angreni* Korovin, HV, 15.vii.2017, IM367. First record on *Ferula angreni* in Uzbekistan.

P. stipina Tranzschel — on *Origanum vulgare* subsp. *gracile* (K.Koch) Letsw., MV, 13.v.2010, IM051.

P. hieracii (Röhl.) H.Mart. — on *Taraxacum* sect. *Taraxacum* F.H.Wigg. (= *Taraxacum officinale* Webb), HV, 25.ix.2010, IM016.

P. violae DC. — on *Viola suavis* M. Bieb., HV, 9.v.2010, IM017, 4.viii.2009, IM013, 15.vii.2017, IM361. (Image 5).

P. ziziphorae P.Syd. et Syd. — on *Ziziphora clinopodioides* Lam., HV, 14.v.2010, IM004, BMt, 16.vii.2017, IM352.

Uromyces (Link) Unger

U. acantholimonis Syd. et P.Syd. — on *Acantholimon nuratavicum* Zakirov, AbV, 7.vi.2014, IM057; on *Acantholimon erythraeum* Bunge, BMt, 12.v.2010, IM184 (Image 6); on *A. tataricum* Boiss., PMt, 3.v.2011, IM250, AbV, 16.vii.2014, IM266. First record on *A. nuratavicum* in Uzbekistan.

U. arenariae Tranzschel — on *Eremogone griffithii* (Boiss.) Ikonn. (= *Arenaria griffithii* Boiss.), HMT, 25.vii.2015, IM138, 15.vii.2017, IM360.

U. astragali-lasiosemi Vienn.-Bourg. — on *Astragalus lasiosemius* Boiss., QV, 16.vii.2017, IM341.

U. tuberculatus (Fuckel) Fuckel — on *Euphorbia* sp., TV, 27.vii.2016, IM189.

U. flectens Lagerh. — on *Trifolium repens* L., HV, 3.viii.2009, IM060, 14.vii.2012, IM144.

U. glycyrrhizae (Rabenh.) Magnus — on *Glycyrrhiza glabra* L., AbV, 9.vii.2011, IM186, AnV, 16.vii.2014, IM267, 6.vi.2012, IM155. (Image 7).

U. hedsari-obscuri (DC.) Carestia et Picc. — on *Hedysarum mogianicum* (B.Fedtsch.) B.Fedtsch., BMt, 15.vii.2010, IM307.

U. helichrysi Lagerh. — on *Helichrysum nuratavicum* Krasch. BMt, 12.v.2010, IMh001

U. pisi-sativi (Pers.) Liro — on *Astragalus sewertzowii* Bunge, BMt, 12.v.2010, IM316, 15.vii.2010, IM054; on *A. eximius* Bunge, MV, 3.viii.2009, IM379.

U. scrophulariae (DC.) Berk. et Broome ex J.Schröt. — on *Scrophularia oblongifolia* Loisel. (= *Scrophularia umbrosa* Dumort.), HMT, 30.v.2016, IM173

U. scutellatus (Schrank) Lév. — on *Euphorbia falcata*



Image 7. *Uromyces glycyrrhizae* (Rabenh.) Magnus—on *Glycyrrhiza glabra* L.

L., QV, 15.vii.2010, IM059.

U. striatus J.Schröt. — on *Medicago sativa* L., HV, 3.viii.2009, IM053, 9.v.2010, IM305.

U. trifolii (R.Hedw. ex DC.) Fuckel — on *Trifolium repens* L., HV, 20.vii.2011, IM055.

U. vesicatorius (Bubák) Nattrass — on *Leontice ewersmanni* Bunge, GV, 3.v.2012, IM056.

U. dactylidis G.H.Otth. — on *Ranunculus mindshelkensis* B. Fedtsch., PMt, 3.v.2011, IM177; on *R. paucidentatus* Schrenk, BMt, 12.v.2010, IM405.

Tranzscheliaceae

Tranzschelia Arthur

T. pruni-spinosae (Pers.) Dietel — on *Prunus bucharica* (Korsh.) Hand.-Mazz. (= *Amygdalus bucharica* Korsh.), HV, 14.vii.2010, IM032, TV, 27.vii.2016, IM172; on *Prunus spinosissima* (Bunge) Franch. (= *Amygdalus spinosissima* Bunge), HMt, 14.vii.2010, IM248.

DISCUSSION

It is known that the diversity of the rust fungi is closely related to the diversity of the plant flora. The Uzbekistan plant flora consists of more than 4,500 species and 261 rust species were registered on 511 host plant species from 43 families (Ramazanova et al. 1986). The flora of NNR includes 820 species belonging to 385 genera and 81 families and were found 70 rust species on 92 host plant species from 24 families. It is noted that studies on rust fungi of many regions of Uzbekistan including Angren River basin (5220 km²), Fergana Valley carried out by some mycologists (Panfilova & Gaponenko 1963; Ramazanova et al. 1986; Gafforov et al. 2016). The

diversity of rust fungi of NNR have been compared with their research results (Table 1).

This diversity of rust fungi of NNR is represented by six genera and 70 species and has approximately 27% of the currently known rust biota of Uzbekistan. However, territory of NNR (177.52 km²) is smaller than that of other studied areas: Angren River basin (5,220 km²), Fergana Valley (Uzbekistan part 18,540 km²). This represents the significance of the NNR not only from a botanical point of view, but also from a mycological one. Among the recorded rust genera, the most species rich and widespread genus is *Puccinia*, frequently found on 59 host plant species (64% of the total number of host plant species) from Asteraceae, Apiaceae, Lamiaceae, Poaceae, Urticaceae, Violaceae, Geraniaceae, Asphodelaceae; *Uromyces* species are found on Fabaceae, Polygonaceae, Scrophulariaceae, Euphorbiaceae, Plumbaginaceae; species of the genus *Phragmidium* are mainly found on Rosaceae. On the territory of NNR, the rust diseases occur frequently and severely damage plants belonging to *Acantholimon*, *Artemisia*, *Rosa*, *Ferula*, *Cousinia*, *Trifolium*, *Euphorbia*, *Viola*, *Galium*, *Leontice*, *Mentha*, *Salix*, *Populus*. It should be noted that species of the genus *Gymnosporangium* have not been found in the NNR. However, species of *Gymnosporangium* are widespread in many mountainous areas of Uzbekistan.

It has been found that the distribution of species of *Gymnosporangium* within mountainous areas of Uzbekistan depends largely on the distribution of juniper woodlands. While the aecial hosts, species of *Crataegus* and *Cotoneaster*, are common in all studied areas, the telial hosts, *Juniperus* species, are dominant in mountain forests in Ugam-Chatkal and Zaamin National Parks as well as in the Boysun Mountains, but extremely rare in the Nuratau Range. Respectively, *Gymnosporangium* species are widespread in all studied areas of Uzbekistan with the exception of the Nuratau Range, where representatives of this genus have not been found despite the long-term surveys. This fact indicates that species of *Juniperus* play the main role in the life cycle of species of *Gymnosporangium* (Mustafaev et al. 2021). Aeciospores of *Gymnosporangium* species spread over long distances by the wind. At the same time, it has been found that these aeciospores infect only junipers (Cummins & Hiratsuka 2003; Deacon 2006; Kellerhals 2012).

The checklist of the rust fungi presents the first complete list of all rust fungi in the NNR since 1975 when the NNR was established. This publication serves towards to the complete checklist of rust fungi of Uzbekistan.



REFERENCES

- Academy of Sciences of the Republic of Uzbekistan (2019).** *Red Data Book of the Republic of Uzbekistan. Volume 1.* Tashkent: Chinor ENK Publishing House, 360 pp. (In Uzbek).
- Azbukina, Z.M. (1974).** *Rust Fungi of Far East.* Rzhavchinnye griby Dal' nego Vostoka, Moscow, 527 pp. (In Russ.).
- Cummins, G.B. & Y. Hiratsuka (2003).** *Illustrated Genera of Rust Fungi.* St. Paul, 240 pp.
- Deacon, J.W. (2006).** *Fungal Biology.* 4th edition. Blackwell Publishing, Malden, 371 pp.
- Gafforov, Y., A. Abdurazzokov, M. Yarasheva & Y. Ono (2016).** Rust Fungi from the Fergana Valley, Chatkal and Kurama Mountain Ranges in Uzbekistan. *Staphia* 105: 161–175.
- Golovin, P.N. (1950).** *New species for Central Asia: Trudy Sredneaziatskogo gos. un-ta, Biologicheski Nauki.* Proceedings of the Central Asian State University, Biological Sciences 14(5): 5–47. (In Russ.). 14(5): 5–47. (In Russ.).
- Islomiddinov, Z.S., S.A. Teshaboyeva & I.M. Mustafaev (2022).** Checklist of genus *Septoria* (Mycosphaerellaceae) in Uzbekistan. *Asian Journal of Mycology* 5(1): 91–106.
- Karbonskaya, Y.I. (1969).** *Key to rust fungi of Central Asia and south Kazakhstan.* Dushanbe. Donish Publishing House, 219 pp. (In Russ.).
- Kellerhals, M. (2012).** European pome fruit genetic resources evaluated for disease resistance. *Trees* 26: 1799–189. <https://doi.org/10.1007/s00468-011-0660-9>
- Kirk, P.M., P.F. Cannon, D.W. Minter & J.A. Stalpers (2008).** *Dictionary of the Fungi, 10th Edition.* Wallingford, UK: CABI Publishing. 771 pp.
- Kuprevich, V.F. & V.G. Tranzhel (1957).** *Cryptogamic plants of the USSR: Rust fungi: Melampsoraceae.* 4(1): — Moscow, Leningrad, 518 pp. (In Russ.).
- Kuprevich, V.F. & V.I. Ulyanishchev (1975).** *Key to rust fungi of the USSR.* Vol. 2. Minsk, 528 pp. (In Russ.).
- Mustafaev, I.M. & K.K. Nuraliev (2012a).** Rust fungi of the Nuratau nature reserve. *O'zbekiston Biologiya Jurnal Tashkent*: 20–23. (In Uzbek).
- Mustafaev, I.M. & K.K. Nuraliev (2012b).** Powdery mildew fungi of the Nuratau Nature Reserve. *O'zbekiston Biologiya Jurnal Special issue*: 43–46. (In Uzbek).
- Mustafaev, I.M. (2014a.)** Phytopathogenic fungi on trees and shrubs in the Nuratau Nature Reserve. *O'zbekiston Biologiya Jurnal* 1: 14–17.
- Mustafaev, I.M. (2014b).** Some data about Pycnidial fungi of the Nuratau Nature Reserve. Biodiversity, conservation and rational use of the gene pool of plants and animals. Scientific Conference of Republic of Uzbekistan. Tashkent: 42–44. (In Russ.).
- Mustafaev, I.M. (2015).** New data on macromycetes of Nuratau Nature Reserve. *Modern mycology in Russia.* Vol. 4. Materials of the III International Mycological Forum. Moscow: 159–160 (in Russ.).
- Mustafaev, I.M. (2016).** New species of rust fungi (Pucciniales) for mycobiota of Uzbekistan. *Bulletin of the Agrarian Science of Uzbekistan Tashkent* 6: 84–86. (In Russ.).
- Mustafaev, I.M. (2017).** New records of Ascomycetes (Pezizales) for the mycobiota of Uzbekistan. *Iranian Journal of Botany* 23(1): 72–75.
- Mustafaev, I.M., N.Y. Beshko & M.M. Iminova (2019).** Checklist of ascomycetous microfungi of the Nuratau Nature Reserve (Uzbekistan) *Novosti sistematiki nizshikh rastenii* 53(2): 315–332. <https://doi.org/10.31111/nsnr/2019.53.2.315>
- Mustafaev, I.M. & A.N. Khujanov (2020).** First record and new host of *Uromyces helichrysi* (Pucciniales) from Uzbekistan. *Novosti Sistematiki Nizshikh Rastenii* 54(2): 381–385. <https://doi.org/10.31111/nsnr/2020.54.2.381>
- Mustafaev, I.M., Z.S. Islomiddinov, M.M. Iminova & I.Z. Ortiqov (2021).** Distribution of species of the genus *Gymnosporangium* (Pucciniales) in Uzbekistan. *Ukrainian Botanical Journal* 78(1): 39–46. <https://doi.org/10.15407/ukrbotj78.01.039>
- Mustafaev, I.M. & Z.S. Islomiddinov (2022).** The first record of the genus *Geopora* (Pezizales) for Uzbekistan. *Ukrainian Botanical Journal* 79(1): 51–55. <https://doi.org/10.15407/ukrbotj79.01.051>
- Mustafaev, I.M. (2022).** Diversity of species of the genus *Puccinia* in the Nurata State Reserve, Uzbekistan. *Modern mycology in Russia.* Volume 9. Materials of the 5th Congress of Mycologists of Russia. Moscow: 93–94 pp. (In Russ.).
- Nuraliev, K.K. (1999).** Micromycetes on vascular plants of Kashkadarya province. PhD thesis, Institute of Botany, Academy of Sciences of the Republic of Uzbekistan, Tashkent. (In Russ.).
- Panfilova, T.S. & N.I. Gaponenko (1963).** *Mycoflora of Basin River of Angren.* AN Uzbek SSR Publ., Tashkent, 206 pp. (In Russ.).
- Ramazanova, S.S., F.K. Faizieva, M.S. Sagdullaeva, K.M. Kirgizbaeva & N.I. Gaponenko (1986).** *Fungal flora of Uzbekistan.* Vol. 3. Tashkent, 229 pp.
- Ramazanova, S.S., F.Kh. Faizieva, M.Sh. Sagdullaeva, Kh.M. Kirgizbaeva & N.I. Gaponenko, (1986).** *Flora of the Fungi of Uzbekistan,* vol. 3. Rzhavchinnye griby. Tashkent, Fan, 232 pp. (In Russ.).
- Solieva, Y.S. & Y.S. Gafforov (2001).** New species for mycoflora of Uzbekistan. *Bulletin of the agrarian science of Uzbekistan* 3(5): 36–39.
- Solieva, Y.S. & Y.S. Gafforov (2002).** New species and genera of micromycetes for flora of Uzbekistan. *Bulletin of Academy of Sciences of Republic of Uzbekistan* 4: 42–45
- Tojibaev, K.S., N.Y. Beshko, V.A. Popov, C.G. Jang & K.S. Chang (2017).** *Botanical Geography of Uzbekistan.* Pocheon, 250 pp.
- Uljanishev, V.I. (1978).** *Key to Rust fungi of the USSR.* Leningrad: Nauka Publishing House. 384 pp. (In Russ.).
- Zaprometov, N.G. (1926).** *Materials on the Mycoflora of Central Asia, Volume 1.* Tashkent: Plant Protection Experimental Station Publishing House. 36 pp. (In Russ.).
- Zaprometov, N.G. (1928).** *Materials on the Mycoflora of Central Asia, Volume 2.* Tashkent: Plant Protection Experimental Station Publishing House. 71 pp. (In Russ.).





Checklist of moths (Lepidoptera: Heterocera) from the campus of University of North Bengal, Siliguri, India

Abhirup Saha¹ , Ratnadeep Sarkar² , Rujas Yonle³ , Subhajit Das⁴ , Prapti Das⁵  & Dhiraj Saha⁶ 

^{1,2,4,5,6} Insect Biochemistry and Molecular Biology Laboratory, Department of Zoology, University of North Bengal, Raja Rammohanpur, Darjeeling, West Bengal 734013, India.

³ Environmental Biology Laboratory, Department of Zoology, Darjeeling Government College, 15, Leborg Cart Road, Darjeeling, West Bengal 734101, India.

¹rs_abhirup@nbu.ac.in, ²ratnadeepsarkar37@gmail.com, ³rujasyonle@gmail.com, ⁴dsubhajit644@gmail.com, ⁵rs_prapti@nbu.ac.in, ⁶dhirajsaha@nbu.ac.in (corresponding author)

^{1,2} Both authors contributed equally and share the first authorship.

Abstract: A year-long light-trap study recorded the moth faunal diversity from the University of North Bengal campus, which is situated in the Himalayan foothills or Terai region of West Bengal, from September 2023 to August 2024. A total of 125 species of moths representing 104 genera belonging to 14 families were recorded during this study. Among them, the families Erebidae (36 spp.), Crambidae (32 spp.), and Geometridae (28 spp.) contributed the maximum species records. Their presence in this area highlights the need for regular monitoring throughout the district.

Keywords: Crambidae, Darjeeling, diversity, Erebidae, Geometridae, NBU, sub-Himalaya.

পশ্চিমবঙ্গের হিমালয়-পাদদেশ বা 'তরাই' অঞ্চলে অবস্থিত উত্তরবঙ্গ বিশ্ববিদ্যালয় চত্বর জুড়ে ২০২৩ সালের সেপ্টেম্বর থেকে ২০২৪-এর আগস্ট মাস পর্যন্ত আলোর-ফাঁদের সাহায্যে মথ সন্নিবেশ চালানো হয়। একবর্ষব্যাপী এই সন্নিবেশের মাধ্যমে মোট ১০৪টি পরিবারের অন্তর্গত ১২৫টি প্রজাতির মথকে নথিভুক্ত করা হয়েছে। এদের মধ্যে এরিবিডিই (৩৬টি প্রজাতি), কামবিডিই (৩২টি প্রজাতি) এবং জিওমেট্রিডিই (২৮টি প্রজাতি) —এই তিনটি মথ পরিবারের প্রজাতি সংখ্যাই সর্বাধিক। এ অঞ্চলে মথদের এমন উপস্থিতিই, সমগ্র জেলাজুড়ে নিয়মিত মথ পর্যবেক্ষণের প্রয়োজনকে তুলে ধরে।

Editor: Sanjay Sondhi, Titli Trust, Dehradun, India.

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

Citation: Saha, A., R. Sarkar, R. Yonle, S. Das, P. Das & D. Saha (2026). Checklist of moths (Lepidoptera: Heterocera) from the campus of University of North Bengal, Siliguri, India. *Journal of Threatened Taxa* 18(2): 28358–28369. <https://doi.org/10.11609/jott.9872.18.2.28358-28369>

Copyright: © Saha et al. 2026. 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: Authors received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Competing interests: The authors declare no competing interests.

Author details: SAHA, A., DAS, S. AND DAS, P. are researchers under supervision of SAHA, D., professor in Zoology, University of North Bengal. Their work primarily focuses on studying mosquito-vectors, while also exploring the insect diversity of the area. SARKAR, R. worked as a researcher at NBU, ATREE and WWF, cherishes his close interest in insects. YONLE, R. is an associate professor in Zoology, Darjeeling Government College and experienced in moth diversity and taxonomy.

Author contributions: Conceptualization: DS and AS; Data curation: AS and RS; Formal analysis: RS and AS; Investigation: DS, RY; Methodology: AS and RS; Resources: RS and AS; Software: SD and PD; Supervision: DS; Validation: RY and DS; Visualization: SD and PD; Writing original draft: RS and AS; Writing review and editing: AS and RS. All authors read and approved the final manuscript.

Acknowledgements: Authors are grateful to the officer-in-charge, Watch and Ward Department, University of North Bengal for required permissions to conduct fieldworks inside of the university campus. The head, Department of Zoology, University of North Bengal is duly acknowledged for the required permission and extending laboratory facilities all along. Dr. Rujas Yonle, associate professor at Department of Zoology, Darjeeling Government College are also thanked for supplying the equipment for the light trap studies during the field and identification of moth species.



INTRODUCTION

Moths, an integral subgroup (Heterocera) of the order Lepidoptera, with over 1,60,000 species worldwide, display remarkable morphological diversity in forms (Nayak & Ghosh 2020). Their crucial roles as pollinators, nutrient recyclers and environmental indicators make them an essential focus for studying their diversity (Shubhalaxmi 2018). The study of diversity not only identifies the pattern of biodiversity but also sheds some light on the impact of potential environmental changes. Being mostly nocturnal, moths are less studied compared to other insects, such as butterflies (Shubhalaxmi 2018).

Over the last 100 years, around 13,500 moth species have been documented in India and among them, more than 1,000 species belonging to 36 families have been reported from West Bengal (Shah et al. 2018; Dar & Jamal 2021; Joshi et al. 2021, 2025). In a recent study, Chandra et al. (2019) reported 1,274 moth species belonging to 704 genera under 25 families from the central Himalayan region of India. Similar studies have been carried out from different universities, such as Banaras Hindu University (BHU, Varanasi, Uttar Pradesh) and M.K. Bhavnagar University (Bhavnagar, Gujarat) (Nayak & Ghosh 2020).

It is, therefore, essential to conduct local surveys and identify the moth species to build up a preliminary checklist. The 'Terai' region of West Bengal has profound ecological significance, supporting the need to conduct such studies. This area covers a vast range of habitats, including open grass fields, dense natural forests, and wetlands that support a wide variety of both fauna and flora. Situated at the Mechi-Balason interfluves, the University of North Bengal (NBU) (26.709° N, 88.404° E, elevation: approx. 130 m) represents the unique undulating Terai landscape. It covers approx. 335 acres of land in the lap of the extremely biodiverse eastern Himalaya (Image 1; NBU, official website). Small semi-perennial (rain-fed) rivers, 'Magurmari' divides the campus into two halves and 'Lachka' on the west, are the main drainage of the campus, which remain almost dry in summer and winter. Additionally, 10 small seasonal ponds are present in the Magurmari River basin. The campus has over 700 plant species (flowering and non-flowering plants, ferns, mosses, and fungal species), 100 species of birds, 69 species of odonates, and more than 50 species of butterflies (Green Audit Report of University of North Bengal 2021–2022; Saha et al. 2023). The diverse deciduous and evergreen trees make some natural forest patches inside the campus. Besides its natural topography, the campus includes

(mixed-deciduous) social forests dominated by Litsea, Jarul, Sisso, Teak, Palash, Sirish, rubber plantations, tea gardens, medicinal plant parks, native fruit plants, and Sal plantations. A number of native trees, shrubs, climbers, and grass fields create a favourable environment for insects, such as moths.

This study aims to fill the knowledge gap on the diversity of moths by preparing a preliminary checklist from NBU as a significant eco-geographic zone. Supported by photographs, this manuscript may be useful for the identification of local moth species from the area. The study results will additionally highlight the diversity status of moths from this district and will help to protect different moth species effectively in the face of rapid urbanization in Siliguri development area.

MATERIALS AND METHODS

An exploratory moth survey was conducted throughout a year, from September 2023 to August 2024 in the NBU campus (Image 1). It was primarily involved 'light-trap study' using mercury vapor bulb (160 Watt) which was carried out twice a month during two consecutive nights (one new moon night and the next night; in total: 24 trap nights) in the evening from 2000 h to 0200 h. The light traps were conducted alongside of the forest patches inside the campus. Along with light-trap study, moths were randomly photographed from the street lamps, lights from the different departments at night and by visual records during diurnal field visits. The documentation of the species was solely based on the photographic records which was carried out using a DSLR and a cell-phone camera (Google Pixel 6a). The photographed moth species were identified using previously published literature (Bell 1937), standard identification keys (Hampson 1893, 1894, 1895, 1896), relevant websites (iNaturalist 2025; Sondhi et al. 2025) and proper consultation with lepidopteran specialists for a conclusive identification. The number of species as well genera were counted for the abundance study. Genus and species-level identification were done according to Shubhalaxmi (2018). Images 2–5 were prepared in Microsoft Office-PowerPoint-2019.

RESULTS

A total of 125 species of moths belonging to 104 genera of 14 families were recorded from the NBU campus from September 2023 to August 2024 (Table 1;

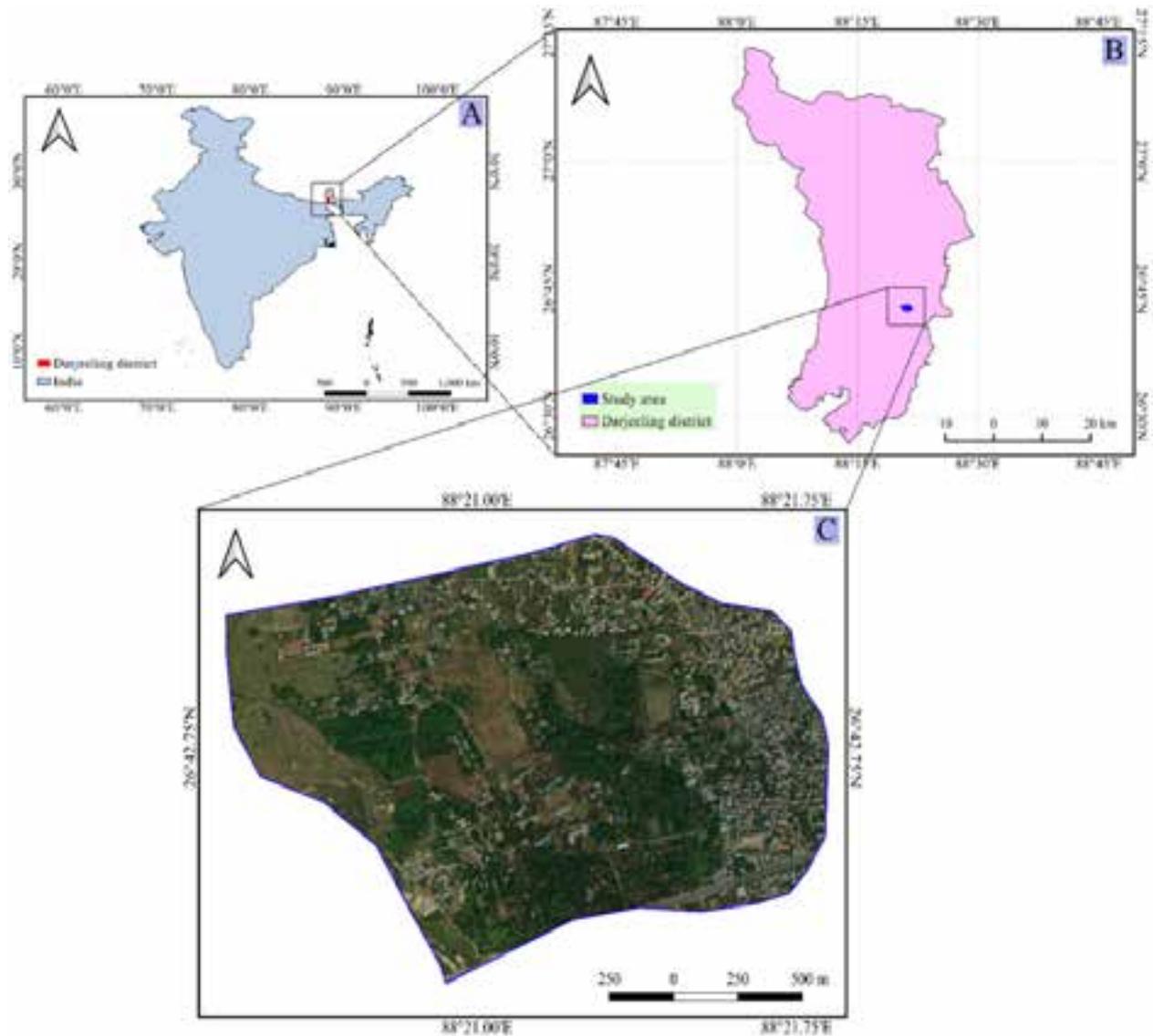


Image 1. Map depicting the location of the study area: A—Darjeeling District in respect to India | B—Location of study area within the Darjeeling District | C—University of North Bengal campus. (QGIS software (version 3.22) was used to create this map)

Images 2–5). During this study, the maximum number of species was recorded from the family Erebidae (30 genera, 36 species), followed by Crambidae (28 genera, 32 species), Geometridae (21 genera, 28 species), Noctuidae (six genera, seven species), Pyralidae (five genera, six species), and Nolidae (four genera, five species) (Table 1; Figure 1). Three families—Sphingidae, Uraniidae, & Zygaenidae—recorded two species in each family, and a single species was recorded from five families—Ethmiidae, Euterotidae, Lasiocampidae, Notodontidae, & Tortricidae (Table 1). In this study, 26 moth species, including *Arthroschista hilaralis* (Walker, 1859), *Cnaphalocrocis medinalis* (Guenée, 1854), *Conogethes punctiferalis* (Guenée, 1854), *Haritalodes*

derogata (Fabricius, 1775), *Parapoynx stagnalis* (Zeller, 1852), *Scirpophaga incertulas* (Walker, 1863), *Spoladea recurvalis* (Fabricius, 1775), *Anomis flava* (Fabricius, 1775), *Artaxa guttata* (Walker, 1855), *Chiasmia eleonora* (Cramer, 1780), *Hipoepa biasalis* (Walker, 1859), *Mocis frugalis* (Fabricius, 1775), *Mocis undata* (Guenée, 1852), *Orygia postica* (Walker, 1855), *Orvasca subnotata* (Walker, 1865), *Rivula bioculalis* (Moore, 1877), *Somena scintillans* (Walker, 1856), *Spilarctia obliqua* (Walker, 1855), *Ectropis crepuscularia* (Denis & Schiffermüller, 1775), *Hyposidra talaca* (Walker, 1860), *Trabala vishnou* (Lefebvre, 1827), *Amyna axis* (Guenée, 1852), *Chrysodeixis eriosoma* (Walker, 1858), *Spodoptera ciliun* (Guenée, 1852), *S. litura* (Fabricius, 1775), and *Eterusia*

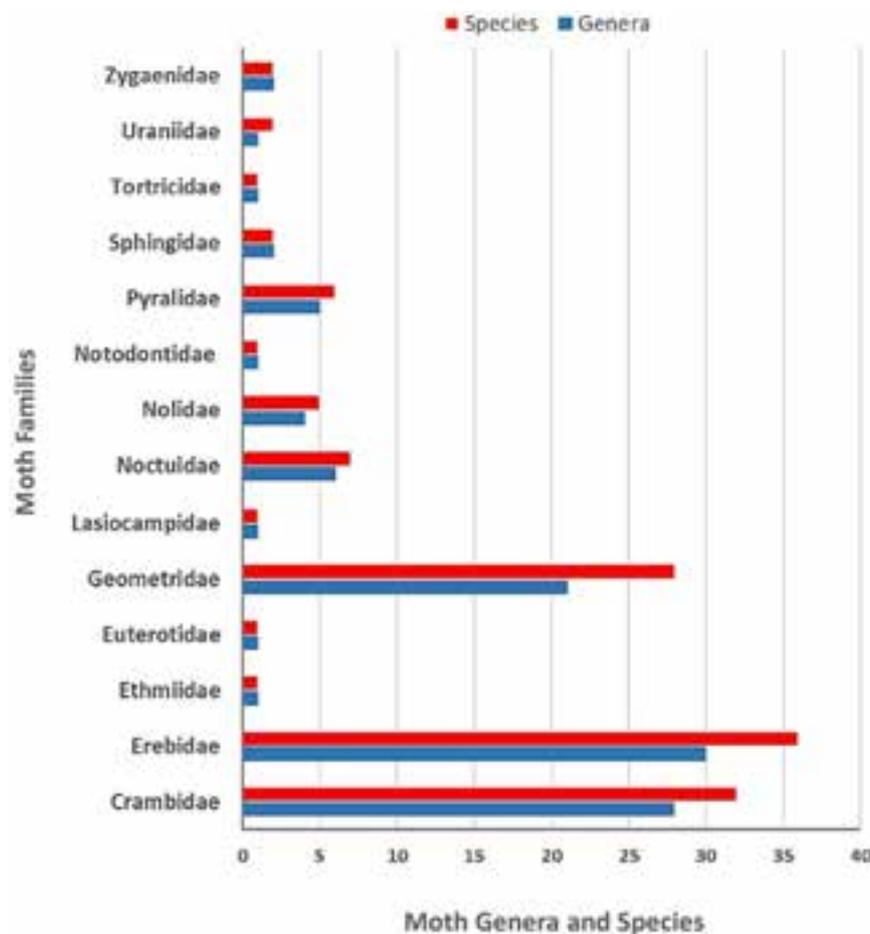


Figure 1. Family-wise record of lepidopteran moth genera and species from the University of North Bengal campus.

aedeae (Linnaeus, 1763) have been recorded as potential predators of agricultural crops (Sondhi et al. 2025) in the study area (Table 1).

DISCUSSION

In the present study, Erebidae was the most dominant moth family, followed by Crambidae and Geometridae. Dominance of the Erebidae (e.g., tiger moths, tussock moths) and Crambidae (e.g., grass moths) families in the study area might be because of the abundant larval host plants grown in grass fields of the campus which includes *Senegalia catechu* L.f., *Albizia lebbeck* Benth, *Bombax ceiba* Burm.f., *Camellia sinensis* Kuntze, *Chrysopogon aciculatus* Trin., *Cinchona* sp., *Cinnamomum verum* J.Presl, *Erythrina variegata* Merr., *Eleusine indica* Gaertn., *Ficus benghalensis* L., *Lagerstroemia speciosa* Pers., *Lantana camara* L., *Mangifera indica* L., *Santalum album* L., *Sesamum indicum* L., *Shorea robusta* Gaertn., *Tectona grandis* L.f., *Ricinus communis* L., *Ziziphus jujuba*

Miller, *Ziziphus oenopolia* Mill, etc., essential for growth, survival and flourishing of moths (Nayak & Ghosh 2020; Green Audit Report of University of North Bengal 2021–2022). These natural and mixed forests, fruit plants, shrubs, climbers, and grasses serve as larval hosts to the Erebidae moths. Local agricultural fields adjacent to the NBU campus additionally contribute several grass moths (crop pests) fauna and tea plantations are one of the potential hosts of some Geometrids, such as *Hyposidra talaca* (Green Audit Report of University of North Bengal 2021–2022; Sondhi et al. 2025). Similar dominance was also found from the BHU and M.K. Bhavnagar University campuses (Nayak & Ghosh 2020). From these studies, it can be concluded that the presence of grass fields and rich diversity of larval host plants play crucial roles in shaping moth communities among different University campuses throughout the country.

Presence of pest (moth) species in this area (Table 1) also highlights the need for regular monitoring which will ultimately assist in evaluating their population dynamics and potential outbreaks in future. Anthropogenic

Table 1. Checklist of moths recorded during the survey in University of North Bengal campus (September 2023–August 2024).

	Scientific name	Common name	Predatory status
I. Family Crambidae (28 genera, 32 species)			
01.	<i>Arthroschista hilaralis</i> (Walker, 1859)	Kadam defoliator	Defoliator
02.	<i>Cnaphalocrocis trebiusalis</i> (Walker, 1859)	-	-
03.	<i>Cnaphalocrocis medinalis</i> (Guenée, 1854)	Rice leafroller	Predator of crops
04.	<i>Conogethes punctiferalis</i> (Guenée, 1854)	Durian fruit borer	Predator on fruit trees
05.	<i>Crambidae</i> sp.	-	-
06.	<i>Culladia</i> sp. (Moore, 1886)	Grass-veneer	-
07.	<i>Diasemia</i> sp.	-	-
08.	<i>Elophila</i> sp. (Hübner, 1822)	-	-
09.	<i>Eoophyla</i> sp. (Swinhoe, 1900)	-	-
10.	<i>Eurrhparodes tricoloralis</i> (Zeller, 1852)	-	-
11.	<i>Glyphodes actorionalis</i> (Walker, 1859)	-	-
12.	<i>Glyphodes bivitalis</i> (Guenée, 1854)	-	-
13.	<i>Haritalodes derogata</i> (Fabricius, 1775)	Cotton leaf roller	Predator
14.	<i>Herpetogramma rudis</i> (Warren, 1892)	-	-
15.	<i>Lamprosema tampiusalis</i> (Walker, 1859)	-	-
16.	<i>Mabra eryxalis</i> (Walker, 1859)	-	-
17.	<i>Marasmia poeyalis</i> (Boisduval, 1833)	-	-
18.	<i>Metoea foedalis</i> (Guenée, 1854)	-	-
19.	<i>Nosophora semitritalis</i> (Lederer, 1863)	-	-
20.	<i>Omiodes diemenalis</i> (Guenée, 1854)	Bean Leaf Roller	-
21.	<i>Omiodes milvinalis</i> (Swinhoe, 1886)	-	-
22.	<i>Paliga</i> sp. (Moore, 1886)	Teak Leaf Skeletonizer	-
23.	<i>Parapoinx bilinealis</i> (Snellen, 1876)	-	-
24.	<i>Parapoinx stagnalis</i> (Zeller, 1852)	Rice Case Bearer	Major predator of rice
25.	<i>Parotis</i> sp. (Hampson, 1893)	-	-
26.	<i>Pycnarmon virgatalis</i> (Moore, 1867)	-	-
27.	<i>Pygospila tyres</i> (Cramer, 1780)	-	-
28.	<i>Sameodes cancellalis</i> (Zeller, 1852)	-	-
29.	<i>Scirpophaga incertulas</i> (Walker, 1863)	Yellow Stem Borer	Predator of rice
30.	<i>Spinosuncus contractalis</i> (Warren, 1896)	-	-
31.	<i>Spoladea recurvalis</i> (Fabricius, 1775)	Beet Webworm Moth	Major predator in the tropics
32.	<i>Synclera traducalis</i> (Zeller, 1852)	Variegated Pearl	-
II. Family Erebidae (30 genera, 36 species)			
33.	<i>Anomis flava</i> (Fabricius, 1775)	Cotton Looper	Defoliator
34.	<i>Arctornis</i> sp. (Germar, 1810)	-	-
35.	<i>Artaxa guttata</i> (Walker, 1855)	-	Minor predator
36.	<i>Asota caricae</i> (Fabricius, 1775)	Tropical Tiger Moth	-
37.	<i>Ataboruza divisa</i> (Walker, 1862)	-	-
38.	<i>Attonda</i> sp.	-	-
39.	<i>Collita griseola</i> (Hubner, 1803)	Dingy Footman	-
40.	<i>Cretonotos transiens</i> (Walker, 1855)	-	-
41.	<i>Dichromia cognata</i> (Guenée, 1854)	-	-
42.	<i>Donda</i> sp. (Moore, 1882)	-	-
43.	<i>Eublemma</i> sp.	-	-
44.	<i>Eublemma versicolor</i> (Walker, 1864)	-	-

	Scientific name	Common name	Predatory status
45.	<i>Euproctis</i> sp.	-	-
46.	<i>Gesonía</i> sp. 1	-	-
47.	<i>Gesonía</i> sp. 2	-	-
48.	<i>Hamodes propitia</i> (Guerin-Meneville, 1831)	-	-
49.	<i>Herminiinae</i> sp. (Leach, 1815)	-	-
50.	<i>Hipoepa biasalis</i> (Walker, 1859)	-	Defoliator
51.	<i>Hipoepa fractalis</i> (Guenée, 1854)	-	-
52.	<i>Hydrillodes</i> sp.	-	-
53.	<i>Lithosiini</i> sp. (Billberg, 1820)	Lichen Moths	-
54.	<i>Lymantria marginata</i> (Moore, 1883)	Dark Mango Tussock Moth	-
55.	<i>Miltochrista undulosa</i> (Swinhoe, 1903)	-	-
56.	<i>Mocis frugalis</i> (Fabricius, 1775)	Sugarcane Looper	Major predator of crops
57.	<i>Mocis undata</i> (Fabricius, 1775)	Brown-striped Semi-looper	Predator
58.	<i>Nodaria</i> sp. (Moore, 1885)	-	-
59.	<i>Olene inclusa</i> (Walker, 1856)	-	-
60.	<i>Orygia postica</i> (Walker, 1855)	Cocoa Tussock Moth	Defoliator
61.	<i>Orvasca subnotata</i> (Walker, 1865)	Nygmíine Tussock Moth	Predator of millets
62.	<i>Rivula</i> sp. (Guenée, 1845)	-	Predator on crops
63.	<i>Somena scintillans</i> (Walker, 1856)	Yellow-tail Tussock Moth	Minor predator
64.	<i>Somena</i> sp.	-	-
65.	<i>Spilarctia obliqua</i> (Walker, 1855)	Jute Hairy Caterpillar	Polyphagous predator
66.	<i>Spilarctia</i> sp.	-	-
67.	<i>Syntomoides imaan</i> (Cramer, 1779)	Handmaiden Moth	-
68.	<i>Trigonodes hyppasia</i> (Cramer, 1779)	-	-
III. Family Ethmiidae (1 genus, 1 species)			
69.	<i>Ethmia</i> sp.	-	-
IV. Family Euterotidae (1 genus, 1 species)			
70.	<i>Eupterote gardneri</i> (Bryk, 1950)	-	-
V. Family Geometridae (21 genera, 28 species)			
71.	<i>Agathia lycaenaria</i> (Kollar, 1848)	-	-
72.	<i>Celenna festivaría</i> (Fabricius, 1794)	-	-
73.	<i>Chiasmia eleonora</i> (Cramer, 1780)	-	Predator
74.	<i>Chiasmia emersaria</i> (Walker, 1861)	-	-
75.	<i>Chiasmia</i> sp. 1	-	-
76.	<i>Chiasmia</i> sp. 2	-	-
77.	<i>Cleora</i> sp. (Curtis, 1825)	-	-
78.	<i>Comibaena fuscidorsata</i> (Prout, 1912)	-	-
79.	<i>Comostola laesaria</i> (Walker, 1861)	-	-
80.	<i>Dindica</i> sp.	-	-
81.	<i>Ectropis crepuscularia</i> (Denis & Schiffermüller, 1775)	Small Engrailed	Polyphagous predator on woody plants
82.	<i>Ectropis</i> sp. (Swinhoe, 1889)	-	-
83.	<i>Eois grataria</i> (Walker, 1861)	-	-
84.	<i>Eois</i> sp.	-	-
85.	<i>Fascellina chromataria</i> (Walker, 1860)	-	-
86.	<i>Herochroma cristata</i> (Warren, 1905)	-	-
87.	<i>Hyperythra lutea</i> (Stoll, 1781)	-	-
88.	<i>Hypomecis transcissa</i> (Walker, 1860)	-	-

	Scientific name	Common name	Predatory status
89.	<i>Hyposidra infixaria</i> (Walker, 1860)	-	-
90.	<i>Hyposidra talaca</i> (Walker, 1860)	Black Looper	Major tea predator
91.	<i>Iridopsis</i> sp.	-	-
92.	<i>Pelagodes</i> sp. (Galsworthy, 1997)	-	-
93.	<i>Petelia</i> sp.	-	-
94.	<i>Pingasa ruginaria</i> (Guenée, 1858)	Bordered Duster	-
95.	<i>Psilalcis</i> sp. (Warren, 1893)	-	-
96.	<i>Scopula emissaria</i> (Walker, 1861)	-	-
97.	<i>Traminda aventiaria</i> (Guenée, 1858)	Cross-line Wave Moth	-
98.	<i>Traminda mundissima</i> (Walker, 1861)	-	-
VI. Family Lasiocampidae (1 genus, 1 species)			
99.	<i>Trabala vishnou</i> (Lefebvre, 1827)	Rose-myrtle Lappet Moth	Predator
VII. Family Noctuidae (6 genera, 7 species)			
100.	<i>Amyna axis</i> (Guenée, 1852)	The Eight-spot	Minor predator
101.	<i>Chrysodeixis eriosoma</i> (Walker, 1858)	Soybean Looper	Severe predator of bean crops
102.	<i>Fodina pallula</i> (Guenée, 1852)	-	-
103.	<i>Maliattha separata</i> (Walker, 1863)	-	-
104.	<i>Spodoptera</i> sp. (Guenée, 1852)	Dark Mottled Willow	Occasional predator
105.	<i>Spodoptera litura</i> (Fabricius, 1775)	Cotton Leafworm, Tobacco Cutworm	Serious polyphagous predator
106.	<i>Zonoplusia ochreata</i> (Walker, 1865)	-	-
VIII. Family Nolidae (4 genera, 5 species)			
107.	<i>Alcanola tympanistis</i> (Hampson, 1900)	-	-
108.	<i>Alcanola</i> sp.	-	-
109.	<i>Meganola major</i> cf. (Hampson, 1891)	-	-
110.	<i>Nola</i> sp.	-	-
111.	<i>Risoba</i> sp.	-	-
IX. Family Notodontidae (1 genus, 1 species)			
112.	<i>Spatialia</i> sp.	-	-
X. Family Pyralidae (5 genera, 6 species)			
113.	<i>Arippara indicator</i> (Walker, 1864)	-	-
114.	<i>Endotricha mesenterialis</i> (Walker, 1859)	-	-
115.	<i>Endotricha</i> sp.	-	-
116.	<i>Epicrocis oegnusalis</i> (Walker, 1859)	-	-
117.	<i>Sacada</i> sp.	-	-
118.	<i>Termioptycha</i> sp. (Meyrick, 1889)	-	-
XI. Family Sphingidae (2 genera, 2 species)			
119.	<i>Hippotion</i> sp.	Swinhoe's Striated Hawkmoth	-
120.	<i>Theretra silhetensis</i> (Walker, 1856)	Brown-banded Hunter Hawkmoth	-
XII. Family Tortricidae (1 genus, 1 species)			
121.	<i>Archips</i> sp.	-	-
XIII. Family Uraniidae (1 genus, 2 species)			
122.	<i>Phazaca theclata</i> (Guenée, 1857)	Cotton Leaf Roller	-
123.	<i>Phazaca</i> sp.	-	-
XIV. Family Zygaenidae (2 genera, 2 species)			
124.	<i>Eterusia aedea</i> (Linnaeus, 1763)	Red slug caterpillar	Predator on tea
125.	<i>Gynautocera papilionaria</i> (Guérin-Ménéville, 1831)	-	-



Image 2. Moths of University of North Bengal: 1—*Arthroschista hilaralis* | 2—*Cnaphalocrocis trebiusalis* | 3—*Cnaphalocrocis medinalis* | 4—*Conogethes punctiferalis* | 5—*Crambidae* sp. | 6—*Culladia* sp. | 7—*Diasemia* sp. | 8—*Elophila* sp. | 9—*Eoophyla* sp. | 10—*Eurrhyarodes tricoloralis* | 11—*Glyphodes actorionalis* | 12—*Glyphodes bivitalis* | 13—*Haritalodes derogata* | 14—*Herpetogramma rudis* | 15—*Lamprosema tampiusalis* | 16—*Mabra eryxalis* | 17—*Marasmia poeyalis* | 18—*Metoea foedalis* | 19—*Nosophora semitritalis* | 20—*Omiodes diemenalis* | 21—*Omiodes milvinalis* | 22—*Paliga* sp. | 23—*Parapoynx bilinealis* | 24—*Parapoynx stagnalis* | 25—*Parotis* sp. | 26—*Pycnarmon virgatalis* | 27—*Pygospila tyres* | 28—*Sameodes cancellalis* | 29—*Scirpophaga incertulas* | 30—*Spinosuncus contractalis* | 31—*Spoladea recurvalis* | 32—*Synclera traducalis*. © Abhirup Saha & Ratnadeep Sarkar.



Image 3. Moths of University of North Bengal: 33—*Anomis flava* | 34—*Arctornis* sp. | 35—*Artaxa guttata* | 36—*Asota caricae* | 37—*Ataboruza divisa* | 38—*Attonda adpersa* | 39—*Collita griseola* | 40—*Creatonotos transiens* | 41—*Dichromia cognata* | 42—*Donda* sp. | 43—*Eublemma* sp. | 44—*Eublemma versicolor* | 45—*Euproctis* sp. | 46—*Gesonía* sp. 1 | 47—*Gesonía* sp. 2 | 48—*Hamodes propitia* | 49—*Herminiinae* sp. | 50—*Hipoepa biasalis* | 51—*Hipoepa fractalis* | 52—*Hydrillodes* sp. | 53—*Lithosiini* sp. | 54—*Lymantria marginata* | 55—*Mitochrista undulosa* | 56—*Mocis frugalis* | 57—*Mocis undata* | 58—*Nodaria* sp. | 59—*Olene inclusa* | 60—*Orygia postica* | 61—*Orvasca subnotata* | 62—*Rivula* sp. | 63—*Somena scintillans* | 64—*Somena* sp. © Abhirup Saha & Ratnadeep Sarkar.



Image 4. Moths of University of North Bengal: 65—*Spilarctia obliqua* | 66—*Spilarctia* sp. | 67—*Syntomoides imaon* | 68—*Trigonodes hyppasia* | 69—*Ethmia* sp. | 70—*Eupterote gardneri* | 71—*Agathia lycanaria* | 72—*Celenna festivarica* | 73—*Chiasmia eleonora* | 74—*Chiasmia emersaria* | 75—*Chiasmia* sp. 1 | 76—*Chiasmia* sp. 2 | 77—*Cleora* sp. | 78—*Comibaena fuscidorsata* | 79—*Comostola laesaria* | 80—*Dindica* sp. | 81—*Ectropis crepuscularia* | 82—*Ectropis* sp. | 83—*Eois grataria* | 84—*Eois* sp. | 85—*Fascellina chromataria* | 86—*Herochroma cristata* | 87—*Hyperythra lutea* | 88—*Hypomecis transcissa* | 89—*Hyposidra infixaria* | 90—*Hyposidra talaca* | 91—*Iridopsis* sp. | 92—*Pelagodes* sp. | 93—*Petelia* sp. | 94—*Pingasa ruginaria* | 95—*Psilalcis* sp. | 96—*Scopula emissaria*. © Abhirup Saha & Ratnadeep Sarkar.



Image 5. Moths of University of North Bengal: 97—*Traminda aventiaria* | 98—*Traminda mundissima* | 99—*Trabala vishnou* | 100—*Amyna axis* | 101—*Chrysodeixis eriosoma* | 102—*Fodina pallula* | 103—*Maliattha separata* | 104—*Spodoptera* sp. | 105—*Spodoptera litura* | 106—*Zonoplusia ochreata* | 107—*Alcanola tympanistis* | 108—*Alcanola* sp. | 109—*Meganola major* | 110—*Nola* sp. | 111—*Risoba* sp. | 112—*Spatalia* sp. | 113—*Arippara indicator* | 114—*Endotricha mesenterialis* | 115—*Endotricha* sp. | 116—*Epicrocis oegnusalis* | 117—*Sacada* sp. | 118—*Termioptycha* sp. | 119—*Hippotion* sp. | 120—*Theretra silhetensis* | 121—*Archips* sp. | 122—*Phazaca theclata* | 123—*Phazaca* sp. | 124—*Eterusia aedea* | 125—*Gynautocera papilionaria*. © Abhirup Saha & Ratnadeep Sarkar.

activities, such as pollution, habitat disturbances, artificial lighting, collection of green leafy vegetables, and cattle grazing, are quite high inside the campus area and may disrupt moth diversity as well as their abundance. Sustainable campus management through addressing these threats can protect biodiversity in urban or semi-urban university campuses, such as NBU.

Finally, the study also includes a few limitations that nocturnal insects, such as moths got trapped in the artificial lights from street lamps as well as lights from different departments of the campus. As a result, the number of moths in each light trap was limited. Further studies with a more systematic way in forested edges or areas near dark places from the adjacent areas may report more species. Moths were identified based on their morphological characters rather than genetic analysis, such as DNA sequencing or genitalia dissections. Despite these limitations, this study gives a comprehensive checklist of moths as a base-line data from the university campus and adjacent areas.

CONCLUSION

For the first-time, the study provides a preliminary checklist of 125 moth species with the photo-plates from NBU campus. Among the recorded species, families Erebidae and Crambidae are dominant. These results straightly depicting the importance of conservation management throughout the campus, particularly its vegetation. To improve the conservation strategies in this region, future research should further investigate the seasonal variations and ecological interactions of these species.

REFERENCES

- Bell, T.R.D. & F.B. Scott (1937). *The Fauna of British India, Including Ceylon and Burma. Moths. Vol-V.* Taylor & Francis, London, 588 pp.
- Chandra, K., V. Kumar, N. Singh, A. Raha & A.K. Sanyal (2019). *Assemblages of Lepidoptera in Indian Himalaya Through Long Term Monitoring Plots.* Zoological Survey of India, Kolkata, 457 pp.
- Dar, A.A. & K. Jamal (2021). Moth (Insecta: Lepidoptera) fauna of Sariska Tiger Reserve, Rajasthan, India. *Notulae Scientia Biologicae* 13(2): 10906.
- Green Audit Report of University of North Bengal (2021–2022). Published by the Registrar, NBU, 54 pp. https://www.nbu.ac.in/doc/IQAC/QualityAudits/GreenAudit/GreenAuditReport_22_23.pdf. Accessed on 2.viii.2025.
- Hampson, G.F. (1893). *The Fauna of British India Including Ceylon and Burma-Moths, Vol-I.* Taylor & Francis, London, 527 pp.
- Hampson, G.F. (1894). *The Fauna of British India, Including Ceylon and Burma, Moths, Vol-II. Arctiidae, Agrostidae, Noctuidae,* Taylor & Francis, London, 609 pp.
- Hampson, G.F. (1895). *The Fauna of British India, including Ceylon and Burma, Moths, Vol-III. Noctuidae (cont.) to Geometridae,* Taylor & Francis, London, 546 pp.
- Hampson, G.F. (1896). *The Fauna of British India, including Ceylon and Burma, Moths, Vol-IV. Pyralidae,* Taylor & Francis, London, 594 pp.
- iNaturalist (2025). <https://www.inaturalist.org>. Accessed on 10.ii.2025.
- Joshi, R., N. Singh & N. Kuni (2021). A catalogue of Nolidae Bruand, 1846 from India (Lepidoptera, Noctuoidea). *Zootaxa* 5034(1): 1–112. <https://doi.org/10.11646/zootaxa.5034.1.1>
- Joshi, R., R. Zahiri, D. Banerjee & N. Singh (2025). A catalogue of the Erebidae of India (Lepidoptera, Noctuoidea). *Zootaxa* 5635(1): 1–247. <https://doi.org/10.11646/zootaxa.5635.1.1>
- NBU (2025). www.nbu.ac.in. Accessed on 12.ii.2025.
- 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>
- Saha, A., S. Das, P. Das, D. Raha & D. Saha (2023). Butterfly Diversity in the Campus Area of University of North Bengal, West Bengal, India. *Journal of Tropical Biology and Conservation* 20: 245–255. <https://doi.org/10.51200/jtbc.v20i.4520>
- Shah, S.K., A. Das, R. Dutta & B. Mitra (2018). A current list of the moths (Lepidoptera) of West Bengal. *Bionotes* 20(1): 24–91.
- Shubhalaxmi, V. (2018). *Field Guide to Indian Moths, Edition 1.* Birdwing Publishers, India, 461 pp.
- Sondhi, S., R.P. Singh, G. Iyer, J. D'silva & K. Kunte (Chief Eds.) (2025). *Moths of India, v. 4.11.* Indian Foundation for Butterflies Trust. <https://www.mothsofindia.org>. Accessed on 17.viii.2025.



Vulture diversity and long-term trends in the Ranikhet region, Kumaon Himalaya, Uttarakhand, India

Mirza Altaf Baig¹ , Nazneen Zehra²  & Jamal Ahmad Khan³ 

¹⁻³Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh 202002, India.

¹gi3958@myamu.ac.in (corresponding author), ²nzehra@myamu.ac.in, ³jamal.wl@amu.ac.in

Abstract: Vultures are keystone species in maintaining ecosystem health, but their populations have experienced catastrophic declines across the Indian subcontinent in last three decades. The study was conducted in the Ranikhet region of Kumaon Himalaya, Uttarakhand, India in 2021–2024 covering different seasons. Through opportunistic sightings we documented 90 distinct records comprising 326 individuals representing six species: Himalayan Griffon *Gyps himalayensis*, Egyptian Vulture *Neophron percnopterus*, Red-headed Vulture *Sarcogyps calvus*, White-rumped Vulture *Gyps bengalensis*, Cinereous Vulture *Aegypius monachus*, and Eurasian Griffon *Gyps fulvus*. Himalayan Griffon and Egyptian Vulture dominated the observations (92.7% of total individuals). Critically Endangered species showed alarmingly low numbers, and no breeding or nesting activity was observed for any species. Historical comparison spanning nine decades (1931–2024) revealed local extirpations of Bearded Vulture *Gypaetus barbatus* and Slender-billed Vulture *Gyps tenuirostris*. Our findings highlight urgent conservation needs and emphasize the necessity of monitoring primary regional threats including NSAIDs and poison baits, while waste disposal sites offer opportunities for targeted surveillance and intervention.

Keywords: Diclofenac, *Gyps himalayensis*, Kumaon, local extirpation, *Neophron percnopterus*, NSAIDs, *Sarcogyps calvus*, scavengers, seasonal occurrence, waste disposal sites.

Editor: Chris Bowden, The Royal Society for the Protection of Birds, UK.

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

Citation: Baig, M.A., N. Zehra & J.A. Khan (2026). Vulture diversity and long-term trends in the Ranikhet region, Kumaon Himalaya, Uttarakhand, India. *Journal of Threatened Taxa* 18(2): 28370–28377. <https://doi.org/10.11609/jott.9843.18.2.28370-28377>

Copyright: © Baig et al. 2026. 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: Department of Wildlife Sciences, Aligarh Muslim University.

Competing interests: The authors declare no competing interests.

Author details: Mr. Mirza Altaf Baig holds a post-graduate degree in Biodiversity Studies and Management from the Department of Wildlife Sciences, Aligarh Muslim University (2019). Enrolled for Ph.D. in 2021, he conducted extensive fieldwork in Ranikhet, Kumaon Himalaya (2021–24). His research focuses on biodiversity assessment, herpetofauna, birds and mammals, with active participation in bird count programs across India.

Dr. Nazneen Zehra completed her post-graduate degree in Wildlife Science from Aligarh Muslim University and earned her Ph.D. after working in Gir National Park (2007–2014), accumulating over 5000 hours observing collared leopards. Currently she is serving as Assistant Professor at the Department of Wildlife Sciences, AMU, she has authored/co-authored four books and conducts research on leopard ecology and biodiversity assessment.

Prof. Jamal Ahmad Khan attended the Smithsonian Wildlife Training Program (1992) and earned Ph.D. from Aligarh Muslim University (1993). He has served four terms as Chairman, Department of Wildlife Sciences, AMU, and was selected by India's Ministry of Education for the Leadership for Academicians Program at the University of Michigan, USA (2018). His research spans large carnivore ecology and biodiversity across India and beyond.

Author contributions: MR. MIRZA ALTAF BAIG: Conceptualization, field data collection, data analysis, writing the manuscript, and corresponding author responsibilities including manuscript submission and communication with the journal. DR. NAZNEEN ZEHRA: Supervision of the research, critical review and editing of the manuscript. PROF. JAMAL AHMAD KHAN: Co-supervision, overall research direction, funding acquisition, institutional support, and final review and approval of the manuscript.

Acknowledgements: We are immensely grateful to Lieutenant General Zameer Uddin Shah (Retd.), Former Deputy Chief of Army Staff and Ex Vice Chancellor, AMU, for securing necessary permissions and approving funds for the renovation of Ardee Estate Bungalow, which served as our base station throughout fieldwork. We sincerely thank Mr. Hammad Ur Rahman, caretaker of the base camp, whose dedication made field explorations in Ranikhet's rugged terrain possible. We are also thankful to Mr. Shariq Safi, Fieldman, Department of Wildlife Sciences, AMU, for his valuable assistance during field visits. We extend our gratitude to the officers and personnel of Ranikhet Cantonment for their cooperation which greatly facilitated our fieldwork.



INTRODUCTION

The decline in vulture populations across the Indian subcontinent depicts one of the most severe biodiversity crises of recent times. These declines, particularly during the last three decades, have resulted in population reductions of more than 99.9% for some species (Prakash et al. 2007). As vultures are primary scavengers providing vital ecosystem services such as disease management and nutrient cycling, this catastrophic loss possesses serious consequences to the ecosystem health and function (Ogada et al. 2012). The primary factors of vulture decline have been identified as the widespread use of veterinary non-steroidal anti-inflammatory drugs (NSAIDs), particularly diclofenac, that causes renal failure in vultures consuming treated livestock carcasses (Oaks et al. 2004). Additional factors documented across the Indian subcontinent include unintentional poisoning through poison baits, mortality from power grid infrastructure through electrocution & collisions and habitat degradation at nesting sites (Botha et al. 2017). This has led International Union for Conservation of Nature to classify four species as 'Critically Endangered' (CR): White-rumped Vulture *Gyps bengalensis*, Indian Vulture *Gyps indicus*, Slender-billed Vulture *Gyps tenuirostris*, and Red-headed Vulture *Sarcogyps calvus*. One species, the Egyptian Vulture *Neophron percnopterus*, is listed as 'Endangered' (EN), while three species—Himalayan Griffon *Gyps himalayensis*, Cinereous Vulture *Aegypius monachus*, and Bearded Vulture *Gypaetus barbatus*—are categorized as 'Near Threatened' (NT). The Eurasian Griffon *Gyps fulvus* remains in the 'Least Concern' (LC) category (IUCN 2025). Moreover, the Indian government announced a ban on the veterinary use of the non-steroidal anti-inflammatory drug (NSAID) diclofenac in 2006 and more recent bans of three other vulture-toxic drugs in 2023 and 2024 (SAVE 2025) to halt the precipitous declines, and these bans have been partially but not completely successful so far (Prakash et al. 2012, 2019).

The Himalayan region, serving as a crucial habitat for multiple vulture species, requires particular attention in conservation efforts due to its unique ecological characteristics and relatively lower human population density (Paudel et al. 2016). Long-term monitoring of vulture populations is essential to understand population dynamics and developing effective conservation strategies (Prakash et al. 2019). However, comprehensive studies comparing current population status with historical records are rare. This study bridges

this gap by focusing on the Ranikhet region of Kumaon Himalaya, an area historically known for its diverse vulture populations.

MATERIAL AND METHODS

Study Area

Ranikhet (29.630–29.660 °N and 79.410–79.440 °E) region of Almora District, Uttarakhand, India (Figure 1) is situated on one of the ridges of the Kumaon Himalaya, which stretches half way across the district west to east and forms the northern boundary of Kosi basin. With an average altitude of 1,800 m, its southern summit at Chaubatia attained a height of 2,100 m. The area comprises of round and flat ridges with gentle to moderate slopes featuring numerous springs and streams at breast level. The Gagas and Kosi river valleys occupy the lower portions. It covers 389.9 km² (12.3% of Almora District). The region experiences moderate heat, increasing in valleys, with mean annual temperature of 21.5°C (range: 14.44–25.23 °C). Ranikhet receives ~1,300 mm annual rainfall, with 75% during monsoon (July–September). Over 90% of forested area is dominated with *Pinus roxburghii*, along with patches of *Quercus leucotricophora*, *Cedrus deodara*, and *Cupressus torulosa*. The fauna includes four amphibians, 11 reptiles, and 15 mammal species (Baig et al. 2025a). The area serves as habitat for approximately 209 bird species and functions as a stopover point for migratory birds during summer and winter seasons (Bhatt & Joshi 2011; Sathyakumar et al. 2011; Baig et al. 2025a,b).

Survey Methods

The data on the status of vultures was recorded opportunistically between August 2021 and June 2024. As part of a broader biodiversity assessment program, all the incidental encounters of vultures during vegetation sampling, bird counts, herpetofauna records, and mammal searches were recorded by the first author. Observations were not based on predetermined transects or fixed survey schedules, and coverage across the region was uneven, with greater efforts in areas accessible for broader biodiversity monitoring. Most sightings were concentrated around waste disposal sites, particularly the SWM Plant at Ghingarikhal, though observations were recorded across the entire study area when encountered. However, observations spanned all the 12 months of the year, providing complete seasonal coverage across summer, monsoon, and winter periods. For each vulture observation, either in flight or on the

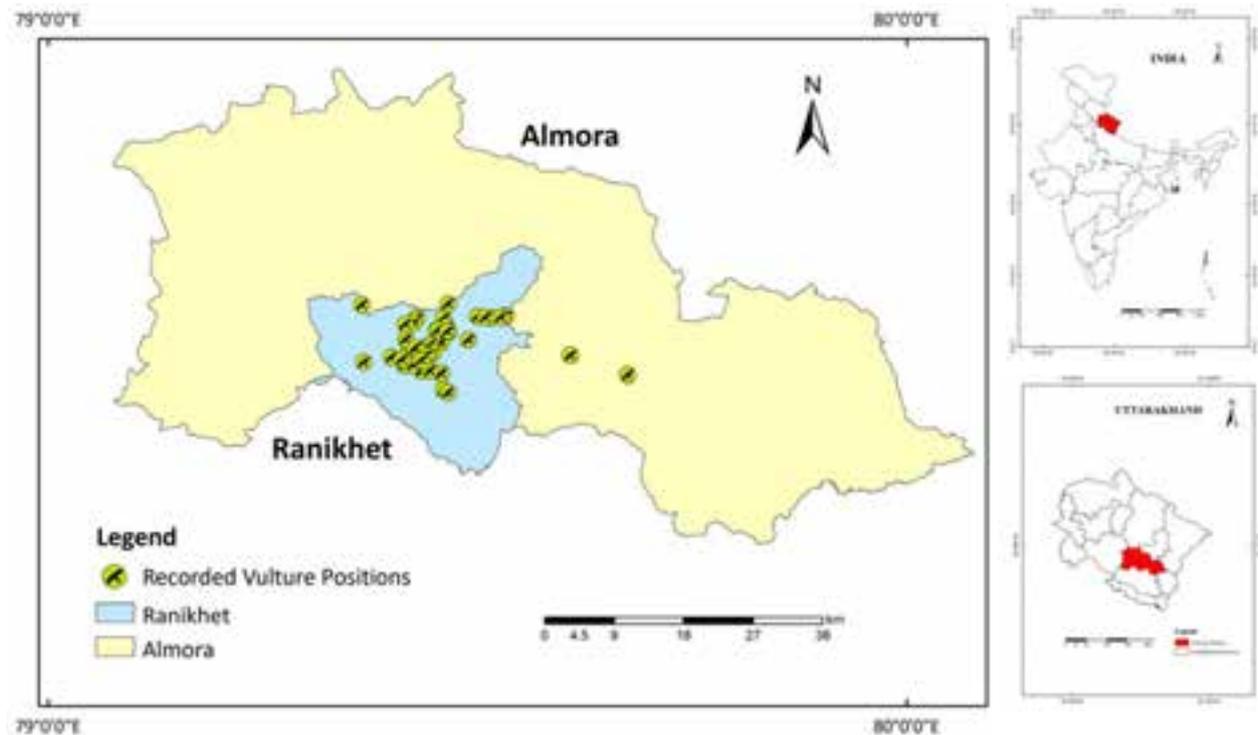


Figure 1. Map showing recorded vulture locations in Ranikhet region of Almora District, Uttarakhand, India.

ground or trees, we recorded geographical location, species composition, individual counts, flock size & composition, activity patterns (such as roosting, feeding, and flying), habitat characteristics, and any interspecific associations observed. The maximum number of individuals of vultures sighted from various sites was added to give some indication of vulture abundance in the area (Shafi et al. 2020).

To establish historical context and evaluating long-term changes in species composition and population trends, we made comparisons with previous studies from the region, despite a lack of directly comparable methodology. These span almost a century, and included Briggs's 1931 pioneering survey of Ranikhet birds, Ganguli's mid-century assessment from 1966, Sharma's late-century bird documentation in 1995, and Baig's recent bird assessment conducted in 2019. This historical comparison provided valuable insights into the temporal dynamics of vulture populations in the region spanning more than nine decades (similar to approaches by Prakash et al. 2012).

RESULTS

Our surveys documented 326 individual vultures through 90 distinct sightings, representing six species (Table 1). The Himalayan Griffon and Egyptian Vulture dominated observations, collectively accounting for 92.7% of all individuals. The Himalayan Griffon showed the highest abundance (156 individuals, 48 sightings), followed by Egyptian Vulture (146 individuals, 27 sightings). Critically Endangered species showed markedly lower numbers: Red-headed Vulture (11 individuals, 8 sightings) and White-rumped Vulture (1 individual, 1 sighting) (Table 1). Two species, Cinereous Vulture (5 individuals, 3 sightings) and Eurasian Griffon (7 individuals, 3 sightings), were documented during our surveys, although these species, despite being within their known distributional range, had not been recorded in any previous studies of the region (Table 3).

Vulture species showed distinct seasonal patterns in occurrence. Himalayan Griffon was present year-round but with higher observations during winter periods. In contrast, Egyptian Vulture being summer visitor at Ranikhet, predominantly recorded during summer and monsoon periods with complete absence during winter months. Red-headed Vulture was observed in all seasons but in low numbers. The three less frequently recorded

Table 1. Current status of vulture diversity in Ranikhet region (August 2021–June 2024).

	Species	No. of sightings	No. of individuals	Flock size	IUCN Red List status	Population Trend	Location of sighting
1	Egyptian Vulture	27	146	1 to 20	EN	Decreasing	SWM Plant Ghingarikhal, Tipola
2	Red-headed Vulture	8	11	1 to 3	CR	Decreasing	SWM Plant Ghingarikhal, Mall Road, Ardee Estate
3	White-rumped Vulture	1	1	1 to 1	CR	Decreasing	Chaubatia
4	Himalayan Griffon	48	156	1 to 21	NT	Decreasing	SWM Plant Ghingarikhal, Majkhali, Sadar Bazar, Thapla, Mall Road, Jhula Devi Temple
5	Cinereous Vulture	3	5	1 to 2	NT	Decreasing	Majkhali, Chaubatia
6	Eurasian Griffon	3	7	1 to 4	LC	Increasing	SWM Plant Ghingarikhal (29.66431°N; 79.46511°E)
	Total	90	326				

CR—Critically Endangered | EN—Endangered | NT—Near Threatened | LC—Least Concern

Table 2. Vulture species associations observed in Ranikhet region.

	Association	Flock size	Occasions	Activity
1	Egyptian Vulture – Red-headed Vulture	10, 5	2	Roosting
2	Egyptian Vulture – Himalayan Griffon	6, 3	2	Roosting
3	White Rumped Vulture – Red-headed Vulture – Himalayan Griffon	3	1	Flying
4	Cinereous Vulture – Himalayan Griffon – Eurasian Griffon	15, 4	2	Resting, Flying
5	Red-headed Vulture – Himalayan Griffon – Egyptian Vulture	5	1	Flying
6	Eurasian Griffon – Egyptian Vulture	21	1	Roosting

species showed limited temporal occurrence: Cinereous Vulture (winter only), Eurasian Griffon (winter and summer), and White-rumped Vulture (single summer record in June 2022).

Our observations revealed that vultures were concentrated around waste disposal sites, particularly the SWM Plant, Ghingarikhal (29.66431°N; 79.46511°E). Mixed-species associations were observed (Table 2), particularly centered around feeding and roosting sites. The most common associations involved Egyptian Vulture with other species, suggesting this species’ role in social facilitation (consistent with findings by Cortés-Avizanda et al. 2014). Group sizes varied considerably between species, with Egyptian Vulture showing the largest average group size (5.4 individuals) and White-rumped Vulture the smallest (1.0 individuals).

Comparison with historical records revealed significant changes in vulture community composition (Table 3). Two species previously recorded (Slender-billed Vulture and Bearded Vulture) were not observed during our study, representing local extirpations. Bearded Vulture, described as ‘very numerous’ with documented nesting by Briggs (1931), was completely absent during three years of continuous year-round observations, indicating the species has been extirpated

from the immediate Ranikhet region. Similarly, Slender-billed Vulture, recorded by Briggs (1931), was not recorded during this study. Two species absent in the 2019 survey (Red-headed Vulture and White-rumped Vulture) were recorded again, though in critically low numbers. Notably, while Cinereous Vulture and Eurasian Griffon were documented in our current surveys, these species had remained unrecorded in all previous studies of the region despite being within their known distributional range (Grimmett et al. 2011).

DISCUSSION

Population Status and Conservation Implications

Our findings reveal a highly skewed vulture community dominated by two species (similar to patterns observed by Ganguli 1966), with critically endangered species persisting at alarmingly low numbers. Throughout the study period, we found no active nests or breeding activity, contrasting with the historical nesting site record of Bearded Vulture by Briggs (1931). The complete absence of breeding activity, contrasting with historical records of successful nesting, suggests serious reproductive limitations that threaten long-term

Table 3. Comparison of vulture species records in Ranikhet region across different time periods.

	Species	Briggs (1931)	Ganguli (1966)	Sharma (1995)	Baig (2019)	This study
		April–June 1931	Oct–Nov 1965	April–May 1995	April–June 2019	Aug 2021–June 2024
1	Red-headed Vulture	P	P	P	-	P
2	Himalayan Griffon	P	P	P	P	P
3	Slender-billed Vulture*	P	-	-	-	-
4	White-rumped Vulture	P	P	P	-	P
5	Egyptian Vulture	P	P	P	P	P
6	Bearded Vulture	P	P	P	-	-
7	Cinereous Vulture	-	-	-	-	P
8	Eurasian Griffon	-	-	-	-	P

P—species presence | — indicates species absence or no record | *—Recorded as Long-billed Vulture *Gyps indicus* in Briggs (1931). Taxonomic split in 2001 suggests this was Slender-billed Vulture *Gyps tenuirostris* based on geographical range.

population viability (similar to patterns observed by Thakur et al. 2018).

The concentration of vultures around waste disposal sites presents both opportunities and challenges for conservation. While these sites provide reliable food sources, they potentially expose vultures to harmful substances, including pharmaceutical drugs (Plaza & Lambertucci 2020). This suggests the need for careful management of waste disposal practices and consideration of supplementary feeding programs using uncontaminated carcasses (similar to approaches by Morales-Reyes et al. 2017).

Species-specific Concerns

The near-absence of White-rumped Vulture (single individual sighted on 07 June 2022) indicates potential local extirpation risk, requiring immediate conservation intervention. Similarly, the low numbers of Red-headed Vulture suggest a precarious population status. Historical comparison revealed local extirpations of Bearded Vulture *Gypaetus barbatus* and what was historically recorded as Long-billed Vulture *Gyps indicus*. It should be noted that during Briggs's 1931 survey, what is now recognized as two distinct species – Indian Vulture *G. indicus* and Slender-billed Vulture *G. tenuirostris* was considered a single species with two subspecies (*G. indicus indicus* and *G. indicus tenuirostris*). Briggs did not differentiate between these subspecies in his records, referring only to Long-billed Vulture *Gyps indicus*. Given the geographical location of Ranikhet in the Himalayan region, the locally extinct population most likely corresponds to what is now classified as Slender-billed Vulture *Gyps tenuirostris* (Rasmussen & Parry 2001). The local extirpation of Slender-billed Vulture and Bearded

Vulture, historically present in the region, underscores the severity of vulture decline in the Himalayas (Paudel et al. 2016).

The documentation of Cinereous Vulture and Eurasian Griffon suggests possible range shifts, potentially driven by climate change or changes in food availability (Paudel et al. 2016). These new arrivals may indicate the region's continued importance as vulture habitat, despite overall population declines.

CONCLUSION

This study provides the first assessment of vulture populations in Ranikhet over an extended period, revealing significant changes in community composition and highlighting urgent conservation needs. The findings demonstrate a dynamic vulture community with recent local extirpations, recolonizations, and critically low populations of globally threatened species.

The spatial concentration of vultures around waste disposal sites, where cattle carcasses are often dumped, suggests both opportunities and challenges for conservation. While these sites provide reliable food sources, they potentially expose vultures to contaminants (Blanco et al. 2017). The multi-species action plan for African-Eurasian vultures identifies NSAIDs, poison baits, and power infrastructure as the primary threats to vulture populations across the Indian subcontinent, ranking ahead of nest habitat limitations, food scarcity, or human disturbance (Botha et al. 2017). The documented interspecific associations highlight the community structure of vultures in the region and suggest potential for multi-species conservation



© Mirza Altaf Baig

Image 1. Red-headed Vulture perched on Pine Tree.



© Mirza Altaf Baig

Image 2. Egyptian Vultures at SWM Plant, Ghingarikhal.



© Mirza Altaf Baig

Image 3. Himalayan Griffons inspecting the carcass.



© Mirza Altaf Baig

Image 4. Himalayan Griffon feeding on the carcass.



© Mirza Altaf Baig

Image 5. Eurasian Griffon perched on Pine tree.



© Mirza Altaf Baig

Image 6. Cinereous Vulture soaring near carcass dumping site.

approaches (Kane et al. 2014).

The complete absence of breeding activity during our three-year survey, contrasting with historical breeding records of Bearded Vulture (Briggs 1931), signals a critical reproductive limitation threatening long-term population viability (Prakash et al. 2012). Although this study focused on vulture diversity and population status rather than threat evaluation, several conservation priorities emerge from our findings. First, systematic monitoring is required to assess NSAID prevalence in the Ranikhet region, as these chemicals remain a major threat across many parts of India despite Government imposing ban on them (Prakash et al. 2019). Second, documentation of any poison bait incidents over the past decade would help evaluate this threat locally. Third, while food availability appears adequate given vulture concentrations at waste disposal sites, systematic assessment of carrion availability and quality—particularly regarding NSAIDs contamination—would inform targeted conservation interventions. Finally, although habitat loss is not generally considered a primary threat to vultures in regional assessments (Botha et al. 2017), the complete absence of breeding activity during this study warrants investigation into specific local limiting factors, which may include but are not limited to nest site availability.

The documented interspecific associations highlight the community structure of vultures in the region and suggest potential for multi-species conservation approaches (Kane et al. 2014). However, effective conservation requires addressing the documented primary threats through:

1. Monitoring and enforcement of NSAID regulations at local veterinary practices and livestock disposal sites,
2. Investigation of any poison incidents through systematic mortality surveillance, and
3. Assessment of power infrastructure risks in vulture foraging areas.

These actions, combined with protection of waste disposal sites that currently support the vulture population, could help stabilize populations while addressing the causes of vulture population decline identified in regional threat assessments.

While this study focused on diversity and population status of vultures in Ranikhet region, systematic assessments of specific threats particularly NSAID prevalence in livestock carcasses, poison bait incidents, and power infrastructure impacts was beyond the scope of this survey but represents a critical need for future research in this region.

REFERENCES

- Baig, M.A. (2019).** *The assessment of bird community structure using line transect method at the Cantonment Forest, Ranikhet, Uttarakhand* [Master's dissertation]. Department of Wildlife Sciences, Aligarh Muslim University.
- Baig, M.A., N. Zehra & J.A. Khan (2025a).** Population Structure and Regeneration Status of Tree Species: An Assessment in the Ranikhet Forest of Almora District, Kumaon Himalaya, Uttarakhand, India. *International Journal of Ecology and Environmental Sciences* 51(3): 311–320. <https://doi.org/10.55863/ijees.2025.0636>
- Baig, M.A., N. Zehra & J.A. Khan (2025b).** *Country's First Trilingual Pictorial Field Guide: Birds of Ranikhet*. Authors Press, New Delhi, 232 pp.
- Bhatt, D. & K.K. Joshi (2011).** Bird assemblages in natural and urbanized habitats along elevational gradient in Nainital district (western Himalaya) of Uttarakhand state, India. *Current Zoology* 57(3): 318–329. <https://doi.org/10.1093/czoolo/57.3.318>
- Botha, A.J., J. Andevski, C.G.R. Bowden, M. Gudka, R.J. Safford, J. Tavares & N.P. Williams (2017).** *Multi-species Action Plan to conserve African-Eurasian Vultures*. CMS Raptors MOU Technical Publication No. 4. CMS Technical Series No. 35. Coordinating Unit of Raptors MOU, Abu Dhabi.
- Blanco, G., A. Junza, D. Segarra, J. Barbosa & D. Barrón (2017).** Wildlife contamination with fluoroquinolones from livestock: widespread occurrence of enrofloxacin and marbofloxacin in vultures. *Chemosphere* 167: 309–315. <https://doi.org/10.1016/j.chemosphere.2016.10.023>
- Briggs, F.S. (1931).** Birds observed in the neighbourhood of Ranikhet. *Journal of the Bombay Natural History Society* 34: 1072–1079.
- Cortés-Avizanda, A., R. Jovani, J.A. Donázar & V. Grimm (2014).** Bird sky networks: How do avian scavengers use social information to find carrion? *Ecology* 95(7): 1799–1808. <https://doi.org/10.1890/13-0574.1>
- Ganguli, U. (1966).** Three weeks of birdwatching in Ranikhet in Autumn. *Newsletter for Birdwatchers* 6(2): 3–6.
- Grimmett, R., C. Inskipp & T. Inskipp (2011).** *Birds of the Indian Subcontinent* (2nd ed.). Oxford University Press.
- IUCN (2025).** The IUCN Red List of Threatened Species. Version 2020-2. <https://www.iucnredlist.org>. Accessed on 05.iv.2025.
- Kane, A., A.L. Jackson, D.L. Ogada, A. Monadjem & L. McNally (2014).** Vultures acquire information on carcass location from scavenging eagles. *Proceedings of the Royal Society B: Biological Sciences* 281(1793): 20141072. <https://doi.org/10.1098/rspb.2014.1072>
- Morales-Reyes, Z., B. Martín-López, M. Moleón, P. Mateo-Tomás, F. Botella, A. Margalida, J.A. Donázar, G. Blanco, I. Pérez & J.A. Sánchez-Zapata (2017).** Farmer perceptions of the ecosystem services provided by scavengers: what, who, and to whom. *Conservation Letters* 11(2): e12392. <https://doi.org/10.1111/conl.12392>
- Oaks, J.L., M. Gilbert, M.Z. Virani, R.T. Watson, C.U. Meteyer, B.A. Rideout, H.L. Shivaprasad, S. Ahmed, M.J.I. Chaudhry, M. Arshad, S. Mahmood, A. Ali & A.A. Khan (2004).** Diclofenac residues as the cause of vulture population decline in Pakistan. *Nature* 427(6975): 630–633. <https://doi.org/10.1038/nature02317>
- Ogada, D.L., F. Keesing & M.Z. Virani (2012).** Dropping dead: causes and consequences of vulture population declines worldwide. *Annals of the New York Academy of Sciences* 1249(1): 57–71. <https://doi.org/10.1111/j.1749-6632.2011.06293.x>
- Paudel, K., T. Amano, R. Acharya, A. Chaudhary, H.S. Baral, K.P. Bhusal, I.P. Chaudhary, R.E. Green, R.J. Cuthbert & T.H. Galligan (2016).** Population trends in Himalayan Griffon in Upper Mustang, Nepal, before and after the ban on diclofenac. *Bird Conservation International* 26(3): 286–292. <https://doi.org/10.1017/S0959270915000192>
- Plaza, P.I. & S.A. Lambertucci (2020).** Ecology and conservation of a rare species: What do we know and what may we do to preserve Andean condors? *Biological Conservation* 251: 108782. <https://doi.org/10.1016/j.biocon.2020.108782>

[org/10.1016/j.biocon.2020.108782](https://doi.org/10.1016/j.biocon.2020.108782)

- Prakash, V., M.C. Bishwakarma, A. Chaudhary, R. Cuthbert, R. Dave, M. Kulkarni, S. Kumar, K. Paudel, S. Ranade, R. Shringarpure & R.E. Green (2012).** The population decline of Gyps vultures in India and Nepal has slowed since veterinary use of diclofenac was banned. *PLoS ONE* 7(11): e49118. <https://doi.org/10.1371/journal.pone.0049118>
- Prakash, V., R.E. Green, D.J. Pain, S.P. Ranade, S. Saravanan, N. Prakash, R. Venkitachalam, R. Cuthbert, A.R. Rahmani & A.A. Cunningham (2007).** Recent changes in populations of resident Gyps vultures in India. *Journal of the Bombay Natural History Society* 104(2): 129–135.
- Prakash, V., T.H. Galligan, S.S. Chakraborty, R. Dave, M.D. Kulkarni, N. Prakash, R.N. Shringarpure, S.P. Ranade & R.E. Green (2019).** Recent changes in populations of Critically Endangered Gyps vultures in India. *Bird Conservation International* 29(1): 55–70. <https://doi.org/10.1017/S0959270917000545>
- Rasmussen, P.C. & S.J. Parry (2001).** The taxonomic status of the long-billed vulture *Gyps indicus*. *Vulture News* 44: 18–21.
- Sathyakumar, S., T. Bashir, T. Bhattacharya & K. Poudyal (2011).** Assessing mammal distribution and abundance in intricate eastern Himalayan habitats of Khangchendzonga, Sikkim, India. *Mammalia* 75(3): 257–268. <https://doi.org/10.1515/mamm.2011.023>
- SAVE (2025).** *Saving Asia's Vultures from Extinction Meeting Report 2025: Phnom Penh, Cambodia, 17–18 February; Siem Pang Wildlife Reserve, 19–21 February.* SAVE Partnership.
- Shafi, S., M. Anwar, T. Ahmed & V. Rawat (2020).** Summary of recent Vulture sightings at the Southern boundary of Corbett Tiger Reserve, Western Terai-arc Landscape, Uttarakhand, India. *Indian Forester* 146(10): 987–991. <https://doi.org/10.36808/if/2020/v146i10/155443>
- Sharma, N. (1995).** Bird community structure of the middle altitude oak forests of Ranikhet, Kumaon Himalayas: A preliminary study. [Master's dissertation]. Centre of Wildlife and Ornithology, Aligarh Muslim University, 23 pp.
- Thakur, M.L., V.K. Mattu, H. Lal, V.N. Sharma, H. Raj & V. Thakur (2018).** Avifauna of Arki Hills, Solan (Himachal Pradesh), India. *Indian Birds* 14(2): 37–49.





Nesting dynamics of Red-wattled Lapwing *Vanellus indicus* Boddaert, 1783 in urban and rural regions of Indore, India

Kratika Patidar¹ & Vipul Keerti Sharma²

^{1,2}Department of Zoology, Government Holkar (Model, Autonomous) Science College, Indore, Madhya Pradesh 452001, India.
¹kratikapatidar15@gmail.com (corresponding author), ²vipulkeertisharma@gmail.com

Abstract: With their ground-nesting habits, the Red-wattled Lapwing *Vanellus indicus* are particularly vulnerable to urbanization, which affects their nesting behaviour, reproductive success, and habitat use. The present study was designed to explore the adaptation strategies of the species in rural (Jamli), peri-urban (Rau) and urban (Holkar Science College) habitats of Indore, Madhya Pradesh, India. Forty-five nests were monitored for nesting success (March–July 2024), along with predation risks and microclimatic conditions during the breeding season. Nest site, clutch size, incubation, and fledgling success were observed. Nesting success was highest (93%) in peri-urban and rural areas (90%), but lowest (70%) in urban areas; a similar pattern was observed for reproductive success, which was highest in peri-urban and rural habitats and lowest in urban regions. Primarily found on rooftops, urban nests avoided many risks associated with terrestrial predators but introduced new risks, including high levels of human disturbance, altered predator communities, and extreme microclimates that negatively affected reproductive success. Nesting in rural areas provided optimal conditions, with less human interference, improved natural camouflage, and constant dynamics of the environment. Peri-urban areas showed great success, reflecting a balance between natural and anthropogenic influences. We, therefore, conclude that urban areas do show the adaptability of the species. To mitigate the impacts of urbanization, conservation efforts should prioritize protecting rural and peri-urban habitats, reducing human disturbance, and supporting artificial nesting platforms in urban areas.

Keywords: Anthropogenic disturbance, breeding ecology, breeding phenology, ground-nesting birds, habitat adaptation, nesting ecology, nest-site selection, nesting success, reproductive success.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

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

Citation: Patidar, K. & V.K. Sharma (2026). Nesting dynamics of Red-wattled Lapwing *Vanellus indicus* Boddaert, 1783 in urban and rural regions of Indore, India. *Journal of Threatened Taxa* 18(2): 28378–28386. <https://doi.org/10.11609/jott.10146.18.2.28378-28386>

Copyright: © Patidar & Sharma 2026. 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: This work was supported by the Council of Scientific and Industrial Research (CSIR), Government of India, through a Junior Research Fellowship (JRF), with additional support under the DST-FIST Program–2024 (Grant No. TPN-107420).

Competing interests: The authors declare no competing interests.

Author details: KRATIKA PATIDAR is a doctoral research scholar in the Department of Zoology at Government Holkar (Model, Autonomous) Science College, Indore, India. Her research focuses on the nesting ecology and bioacoustics of the Red-wattled Lapwing, with broader interests in avian ecology, behavioural ecology, and conservation biology. DR. VIPUL KEERTI SHARMA is professor and head of the Department of Zoology at Government Holkar (Model, Autonomous) Science College, Indore, India. He is a zoologist, wildlife filmmaker, author, and science communicator, and a recipient of three National Awards for wildlife films, with research interests in ornithology and biodiversity conservation.

Author contributions: KP: fieldwork, study design, observations, manuscript drafting. VKS: conceptualization, supervision, review, and proofreading.

Acknowledgements: This research was conducted with financial support from the Council of Scientific and Industrial Research (CSIR), India. We thank Harsh Vishwakarma, CCDH, IIT Indore, for his assistance in data analysis.



INTRODUCTION

Life-history trait estimates are integral to predicting population growth rates, assessing species' sensitivity to environmental changes, supporting conservation planning, and informing management decisions (Stahl & Oli 2006; Sládeček et al. 2021). In birds, life-history traits are key to understanding maximum population growth potential, and this knowledge is essential for evaluating species' responses to changing environments and for developing effective, targeted conservation strategies (Stahl & Oli 2006; Sládeček et al. 2021). The Red-wattled Lapwing *Vanellus indicus* (Image 1) is a wader in the family Charadriidae, widely distributed across the Indian subcontinent, and currently assessed as 'Least Concern' by IUCN. The Red-wattled Lapwing serves as an important ecological component of the habitat due to its role as both a predator and prey: it feeds on insects such as beetles, ants, termites, caterpillars, and small invertebrates, helping regulate insect populations, while its eggs, chicks, and occasionally adults are preyed upon by predators such as kites, crows, mongooses, dogs, snakes, and monitor lizards (Ali & Ripley 1998) and is characterized by its bold black-and-white plumage and familiar loud calls. When urbanization starts to encroach natural habitats, Red-wattled Lapwings nest on rooftops and under-construction building, which indicates habitat shift as traditional rural nesting sites are being lost due to landscape disturbances such as agricultural intensification, land-levelling, road and building construction, sand and soil extraction, removal of vegetation, heavy machinery movement, and increasing human activity (Kumar et al. 2022).

Red-wattled Lapwings predominantly nest in open, semi-arid habitats such as agricultural fields, riverbanks, fallow lands, and grasslands, as widely reported from different regions of India (Ali & Ripley 1998; Choudhary & Chishty 2022). Within these habitats, eggs are typically laid in shallow ground depressions or simple scrapes that closely resemble the surrounding substrate, providing camouflage against predators (Ali & Ripley 1998). Similar nesting preferences and ground-scraps nest structures have also been documented in recent regional studies across agro-ecosystems and semi-natural landscapes, reinforcing the species' dependence on open habitats for successful breeding (Arya et al. 2023; Gupta & Saxena 2023; Kadam & Jadhav 2023).

Urbanisation has a pronounced influence on nesting behaviour, egg viability, and habitat selection in birds, particularly among ground-nesting species. For the Red-wattled Lapwing, rural nests are generally rudimentary

scrapes on bare ground or gravelly substrates that blend with stones and soil. While this strategy enhances camouflage, it also exposes eggs and chicks to substantial risks from common predators such as mongooses, kites, crows, dogs, snakes, and monitor lizards, in addition to nest destruction caused by agricultural activities and livestock grazing (Hart et al. 2002; Whittingham & Evans 2004).

Urbanisation also alters ecological communities associated with Red-wattled Lapwing breeding habitats. While natural landscapes support relatively stable prey assemblages dominated by insects such as beetles, ants, termites, caterpillars, and other ground-dwelling invertebrates, urban habitats often experience changes in prey availability and composition due to surface sealing, pesticide use, artificial lighting, and modified vegetation structure (Newton 1998; Chen et al. 2023). Similarly, predator communities shift from predominantly terrestrial predators in rural areas to a greater influence of aerial predators such as crows and kites in urban settings, creating a distinct predation regime that can negatively affect egg viability and chick survival. Comparable patterns have been reported in other ground-nesting shorebirds in India, including the Little Ringed Plover *Thinornis dubius*, Hanuman Plover *Anarhynchus seebohmi*, and Crab Plover *Dromas ardeola*, where breeding success is increasingly constrained by habitat modification, human disturbance, and altered predator pressure in coastal and human-dominated landscapes (Byju et al. 2023a,b,c). These parallels highlight the broader vulnerability of ground-nesting birds to anthropogenic pressures and provide a comparative framework for interpreting the nesting adaptations and reproductive outcomes of the Red-wattled Lapwing across urban–rural gradients.



Image 1. Red-wattled Lapwing with its chick showing camouflage.

Although the Red-wattled Lapwing is currently listed as 'Least Concern' by the IUCN (IUCN 2025), its breeding habitats are increasingly subjected to pressures such as habitat degradation, urban expansion, agricultural intensification, and broader environmental change. Rather than indicating population declines, these pressures manifest as localised threats to nesting sites, breeding success, and habitat quality, underscoring the need to understand reproductive performance and habitat-specific responses of the species.

In the present study, we assessed new information on key aspects of Red-wattled Lapwing nesting ecology, including nest-site selection, clutch size, incubation characteristics, causes of nesting failure, and overall breeding success. Specifically, we examine differences in nesting and reproductive success across rural, peri-urban, and urban landscapes to assess how anthropogenic environments influence reproductive outcomes. By evaluating nesting success in relation to predation pressure and microclimatic conditions at nest sites, this study aims to identify habitat-specific factors that govern nest survival and breeding performance. Given the limited research on urban adaptations of ground-nesting birds in central India, this work addresses an important knowledge gap by examining how rapid land-use change in and around Indore, Madhya Pradesh, shapes the reproductive strategies of the Red-wattled Lapwing. The findings provide insights into life-history traits and habitat-specific constraints that can inform targeted conservation and habitat-management strategies in rapidly urbanising landscapes.

MATERIALS AND METHODS

Study Area

The study focused on three sites around Indore (Images 2–4), Madhya Pradesh, India, representing urban, peri-urban, and rural landscape types. The urban site was Holkar Science College (22.695° N, 75.871° E; 587 m elevation), characterised by dense built-up structures, high human activity, and frequent landscape modification typical of an urban environment. The peri-urban site, Rau (22.639° N, 75.803° E; ~587 m elevation), represents a low-density urban fringe dominated by agricultural fields interspersed with residential development, roads, and construction activity, reflecting a transitional landscape influenced by both natural and anthropogenic factors. The rural site was Jamli Village (22.524° N, 75.694° E; 577 m elevation), consisting primarily of agricultural farmland with limited infrastructure and minimal human disturbance, representing a predominantly natural rural setting. Together, these three sites form a gradient of increasing human influence, allowing assessment of how urbanisation affects the nesting ecology of the Red-wattled Lapwing.

Field Observations and Data Collection

During the breeding season (March–July 2024), field observations were conducted on alternate days. Study areas were systematically scanned using binoculars to locate nests, which were identified based on nesting cues such as adult incubation behaviour, alarm calls, or repeated site use. This visual scanning approach is



Image 2. Government Holkar Science College, Indore.



Image 3. Jamli Village Map.



Image 4. Rau Region Map.

commonly employed for ground-nesting or exposed-nesting birds (Escalona-Segura et al. 2022). A total of 45 nests were monitored during the study period, including 20 nests at Jamli, 15 at Rau, and 10 at Holkar Science College. Various breeding parameters, including nest size, egg size, and nest depth, were recorded (Figure 1),

following methodologies comparable to those used by Vanadzina et al. (2022). Nest and egg dimensions were measured using a 15-cm ruler carefully placed near the nest, ensuring minimal disturbance and prioritising the safety of eggs and chicks. These measurements allowed comparison of egg length and width across



Image 5. Eggs placement of Red-wattled Lapwing.

nests and habitats. Nests and eggs were photographed using a Nikon Coolpix P1000 camera to document nest structure, egg placement, and site characteristics for visual records (Image 5).

Data Analysis

Apparent nesting success was calculated for each habitat by dividing the number of successful nests by the total number of nests observed at each site. Reproductive success was assessed as the proportion of fledged chicks relative to the total number of eggs laid, following established methods described by Vijayan (1980) and Jehle et al. (2004). To obtain a more robust estimate of nest survival, Mayfield's (1975) method was applied to calculate daily survival rates (DSR) and overall nest survival across the incubation and nestling periods. Variance and standard errors of survival estimates were calculated following the approaches outlined by Johnson (1979) and Hensler (1985) to assess the precision of survival probabilities. Correlation analysis (Pearson's correlation coefficient) was used to examine the relationship between nest size, egg size, and fledgling success (see Data Analysis section). Reproductive performance metrics, including nesting success, reproductive success, and survival estimates, were summarised using descriptive statistics (mean, median, and range) and presented in tables and graphical form to facilitate comparison among rural, peri-urban, and urban habitats.

RESULT AND DISCUSSION

Breeding Phenology

The breeding season of the Red-wattled Lapwing began in March and continued until July across all habitats, consistent with reports from other regions of India (Ali & Ripley 1998; Kabir & Iqbal 2018; Arya et al. 2023). Egg-laying peaked in April at all sites, but the timing varied across habitats. In the rural site (Jamli), peak laying occurred in early April, whereas in the peri-urban (Rau) and urban (Holkar Science College) sites, it occurred in mid-April.

Previous studies indicate that egg laying in this species usually starts from late March to early April, with peak activity in April or early May, depending on regional conditions (Ali & Ripley 1998; Kabir & Iqbal 2018; Choudhary & Chishty 2022). The earlier peak observed in Jamli, therefore, corresponds to the expected breeding period under relatively undisturbed conditions. In contrast, the delayed peak in peri-urban and urban habitats likely reflects the influence of anthropogenic disturbance and altered microclimates. Similar habitat-related shifts in breeding timing have been reported in semi-urban and agricultural landscapes (Gupta & Saxena 2023; Kadam & Jadhav 2023). Earlier breeding in rural habitats may provide advantages by reducing exposure of eggs and chicks to extreme summer temperatures and disturbance later in the season (Chen et al. 2023).

Nesting Strategies

Red-wattled Lapwings showed different nesting strategies in the three habitats. Nests in rural Jamli were usually scraped into the ground in open fields or along riverbanks, where the eggs and chicks were camouflaged by soil, stones, and surrounding vegetation. This habitat had low human disturbance and relatively stable environmental conditions, which provided favourable conditions for nesting and chick survival. In suburban Rau, nests were recorded mainly in agricultural fields located near residential areas, roads, and construction sites (Table 1). This indicates an intermediate nesting strategy between rural and urban habitats. The presence of farmland provided suitable nesting sites, but increased human activity and higher predation pressure created additional risks compared to rural areas.

Urban nesting by Red-wattled Lapwings at Holkar Science College showed a clear behavioural adaptation, with several nests observed on rooftops and other elevated structures. This shift was likely due to increased pressure from terrestrial predators such as stray dogs and mongooses. Rooftop nesting introduced

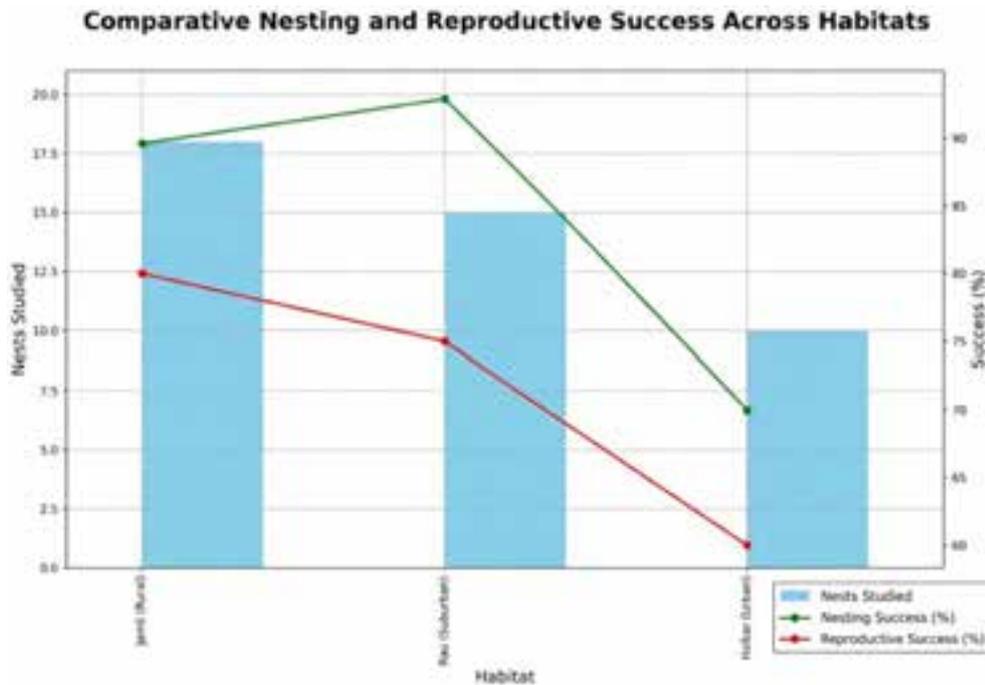


Figure 1. Nesting and reproductive success by habitat.

Table 1. Habitat-specific challenges and adaptations of Red-Wattled Lapwing.

Habitat	Challenges	Adaptations Observed
Jamli (Rural)	Minimal challenges, stable environment.	Traditional ground scrapes for natural camouflage.
Rau (Suburban)	Moderate human disturbance, increased predation pressure.	Nesting near transitional zones to balance rural and urban impacts.
Holkar (Urban)	Human interference, aerial predation, extreme microclimates, and the risk of eggs falling.	Rooftop nesting, use of pebbles to stabilize eggs.

Table 2. Comparative nesting and reproductive success across habitats.

Habitat	Nests studied	Nesting success (%)	Eggs laid	Chicks fledged	Reproductive success (%)
Jamli (Rural)	20	90	80	64	80
Rau (Suburban)	15	93.33	60	45	75
Holkar (Urban)	10	70	40	24	60

new threats, including frequent human disturbance, high surface temperatures, reduced shade, and strong exposure to sunlight, which together create extreme microclimatic conditions. In addition, urban nests were more vulnerable to aerial predators such as crows and kites. Behaviour such as placing pebbles around eggs to prevent them from rolling off the roof indicated the species' ability to adjust to urban conditions. Despite these adaptations, urban habitats remained less suitable for successful nesting due to continued disturbance, predation, and harsh microclimatic conditions (Gering &

Blair 1999; Sethi et al. 2014).

Reproductive Performance and Nest Success

Habitat type clearly influenced nesting and reproductive success (Table 2, Figure 2). In rural Jamli, nesting success was 90%, with 18 successful nests out of 20, and reproductive success was 80%, indicating favourable conditions for chick survival. Clutch size was generally four eggs per nest, and no damaged eggs or dead chicks were observed during monitoring. In suburban Rau, nesting success was slightly higher

Correlation of Nest and Egg Size with Fledgling Success Across Regions

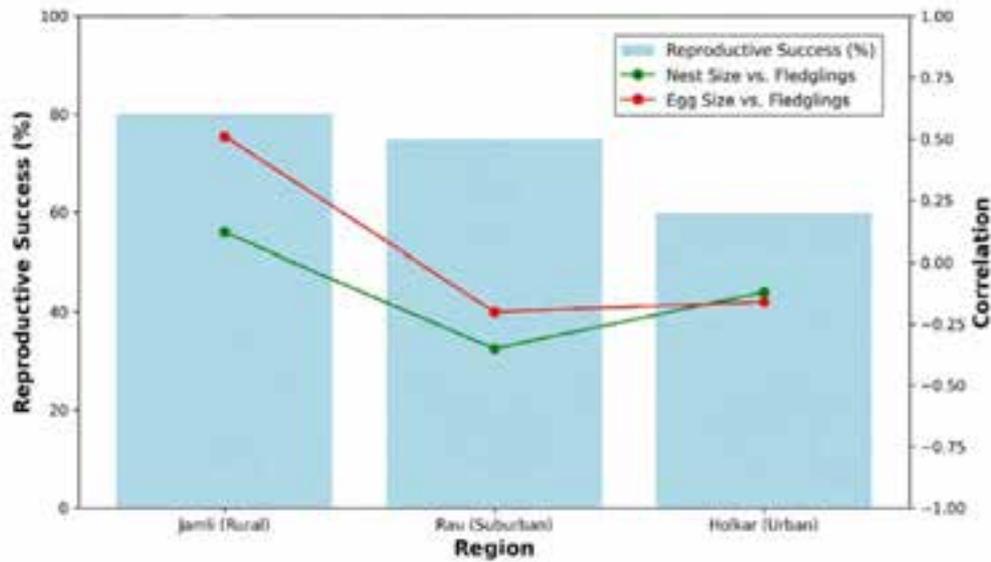


Figure 2. Correlations of nest and egg size with fledglings.

Table 3. Mean nest and egg parameters across habitats.

Habitat	Mean nest size (cm)	Mean egg size (cm)	Mean clutch size	Mean nest depth (cm)
Jamli (Rural)	11.18 ± 0.96	4.50	4.0 ± 0.00	1.14 ± 0.39
Rau (Suburban)	11.23 ± 1.45	4.30	4.0 ± 0.00	1.32 ± 0.27
Holkar Science College (Urban)	10.85 ± 0.88	4.00	4.0 ± 0.00	1.31 ± 0.32

Table 4. Correlation of nest and egg size with fledgling success across regions.

Region	Correlation (Nest Size vs. fledglings)	Correlation (Egg size vs. fledglings)	Reproductive success (%)
Jamli (Rural)	Weak positive (0.12)	Moderate positive (0.51)	80
Rau (Suburban)	Weak negative (-0.35)	Weak negative (-0.20)	75
Holkar (Urban)	Weak negative (-0.12)	Weak negative (-0.16)	60

(93.33%), with 14 successful nests out of 15, but reproductive success was lower (75%), suggesting higher chick loss before fledging. Clutch size in most nests was also four eggs, and no direct egg damage or chick mortality was recorded in the field, although human disturbance and predator presence were more frequent than in rural areas. Urban Holkar Science College showed the lowest nesting success (70%), with seven successful nests out of 10, and reproductive success was 60%. Most nests contained four eggs, with one nest having three eggs. Although no dead chicks or damaged eggs were directly observed, urban nests experienced greater human disturbance, higher exposure to aerial predators

(mainly crows and kites), and extreme microclimatic conditions such as high surface temperatures and direct sunlight. These results indicate that urban habitats are less suitable for successful reproduction than rural and peri-urban areas.

How Nest Size, Egg Size, and Fledgling Success Correlate

Nesting factors showed variable relationships with fledgling success depending on habitats (Table 3–4, Supplementary Tables S1–S3, Figure 2). In the rural site (Jamli), a moderate positive correlation was observed between egg size and fledgling success ($r = 0.51$), suggesting that larger eggs were associated with higher

chick survival under stable environmental conditions. A weak positive correlation was also found between nest size and fledgling success ($r = 0.12$), indicating that slightly larger nests may provide minor benefits in terms of protection and microclimate stability. Similar associations between egg size and chick survival have been reported in Red-wattled Lapwing and other ground-nesting birds, where larger eggs produce heavier and more viable chicks (Kabir & Iqbal 2018; Yadav & Sharma 2022).

In the suburban site (Rau), weak negative correlations were found between nest size and fledgling success ($r = -0.35$) and between egg size and fledgling success ($r = -0.20$). These results suggest that the potential advantages of larger nests or eggs may be offset by higher levels of human disturbance and predation pressure in peri-urban environments. In the urban site (Holkar Science College), weak negative correlations were observed between nest size and fledgling success ($r = -0.12$) and between egg size and fledgling success ($r = -0.16$). This indicates that environmental stressors in urban habitats, such as high surface temperatures, frequent human activity, and increased aerial predation, may reduce the benefits normally associated with larger nests and eggs. Similar reductions in reproductive advantages under urban conditions have been reported for other ground-nesting species, where microclimatic stress and disturbance limit chick survival regardless of egg or nest size (Gering & Blair 1999; Chen et al. 2023).

Conservation Implications

The Red-wattled Lapwing represents a clear example of how a ground-nesting bird has adapted to high levels of stress caused by urbanisation. However, urban habitats also pose considerable risks, including lower reproductive success and increased exposure to human disturbance and other environmental pressures. As nesting success was higher in rural and peri-urban habitats than in densely urbanised areas, these landscapes should be given priority in conservation planning to ensure long-term population persistence. Protection of natural nesting sites in farmlands and grasslands is essential, along with the restoration of degraded habitats within cities. In urban areas, management actions such as providing rooftop nesting platforms that mimic natural ground conditions may help reduce risks associated with human disturbance and extreme microclimatic conditions. Long-term monitoring of food availability, predator dynamics, and levels of human activity is necessary to better understand how the species responds to ongoing environmental change

and urban expansion (Sethi et al. 2014; Chen et al. 2023; Anand et al. 2025). Incorporating these factors into conservation strategies may improve breeding success and overall survival of the Red-wattled Lapwing across different habitat types.

CONCLUSION

The results show that outcomes of nest site selection in the Red-wattled Lapwing differ according to habitat type, reflecting how the species adjusts its breeding strategy across rural, peri-urban, and urban environments. The present findings underline the importance of conserving rural and semi-urban habitats through the protection of farmlands and grasslands and by restoring degraded sites. In urban areas, the development of wildlife-friendly structures such as artificial nesting platforms and green roofs may help support breeding populations. Beyond its relevance to this species, the study contributes to a broader understanding of how ground-nesting birds respond to human-dominated landscapes and limited adaptations. Given the continued loss of natural habitats, conservation measures that focus on maintaining suitable breeding environments are essential for sustaining biodiversity in increasingly urban regions.

REFERENCES

- Ali, S. & S.D. Ripley (1998). *Handbook of the birds of India and Pakistan* Vol. 2, Oxford University Press, UK, 277 pp.
- Anand, J., H. Byju, S. Sheela & H. Maitreyi (2025). A comprehensive review of the three uncommon breeding shorebirds in peninsular India. *Journal of Experimental Zoology India* 28(1): 1–13. <https://doi.org/10.51470/jez.2025.28.1.13>
- Arya, A.K., K.K. Joshi, D. Kumar & A. Bachheti (2023). A study on the breeding habits of Red-wattled Lapwing (*Vanellus indicus* Boddaert, 1783) (Aves: Charadriiformes: Charadriidae) in the agricultural landscape of Muzaffarnagar District, Uttar Pradesh, India. *Journal of Threatened Taxa* 15(4): 23119–23122. <https://doi.org/10.11609/jott.8066.15.4.23119-23122>
- Byju, H., Y. Natarajan, N. Raveendran & R. Kishore (2023a). Breeding record of Little Ringed Plover *Charadrius dubius jerdoni* Legge, 1880 (Charadriidae: Charadriiformes) from Tamil Nadu, India. *Journal of Threatened Taxa* 15(4): 23136–23138. <https://doi.org/10.11609/jott.8333.15.4.23136-23138>
- Byju, H., N. Raveendran & K.M. Aarif (2023b). From the Arabian Peninsula to Indian shores: Crab Plover *Dromas ardeola* Paykull, 1805 (Aves: Charadriiformes: Dromadidae) breeding at Point Calimere, India. *Journal of Threatened Taxa* 15(10): 23990–23995. <https://doi.org/10.11609/jott.8680.15.10.23990-23995>
- Byju, H., N. Raveendran, S. Ravichandran & R. Kishore (2023c). Additional breeding records of Hanuman Plover *Charadrius seebohmi* E. Hartert & A. C. Jackson, 1915 (Aves: Charadriiformes: Charadriidae) from southeastern coast of India. *Journal of Threatened Taxa* 15(4): 23114–23118. <https://doi.org/10.11609/jott.8066.15.4.23114-23118>

- jott.8317.15.4.23114-23118
- Chen, S., Y. Liu, S.C. Patrick, E. Goodale, R.J. Safran & E. Pagani-Núñez (2023). A multidimensional framework to quantify the effects of urbanization on avian breeding fitness. *Ecology and Evolution* 13(7): e10259. <https://doi.org/10.1002/ece3.10259>
- Choudhary, N.L. & N. Chishty (2022). Breeding behavior and threats of survival of Red-wattled Lapwing (*Vanellus indicus*) in Udaipur district, Rajasthan, India, pp. 27–45. In: *Current Research on Zoology and Entomology Sciences Vol. 2*. Scripown Publications, Delhi.
- Escalona-Segura, G., M.M. Borges-Ramírez, V. Estrella-Canul & J.R. Osten (2022). A methodology for the sampling and identification of microplastics in bird nests. *Green Analytical Chemistry* 3: 100045. <https://doi.org/10.1016/j.greeac.2022.100045>
- Gering, J.C. & R.B. Blair (1999). Predation on artificial bird nests along an urban gradient: Predatory risk or relaxation in urban environments? *Ecography* 22(5): 532–541.
- Gupta, S. & K. Saxena (2023). Seasonal variation and habitat role in distribution and activity patterns of Red-wattled Lapwing (*Vanellus indicus* Boddaert, 1783) (Aves: Charadriiformes: Charadriidae) in Udaipur, Rajasthan, India. *Journal of Threatened Taxa* 15(8): 23729–23741. <https://doi.org/10.11609/jott.8075.15.8.23729-23741>
- Hart, J., T. Milsom, A. Baxter, P. Kelly & W. Parkin (2002). The impact of livestock on Lapwing (*Vanellus vanellus*) breeding densities and performance on coastal grazing marsh. *Bird Study* 49(1): 67–78. <https://doi.org/10.1080/00063650209461246>
- Hensler, G.L. (1985). Estimation and comparison of functions of daily nest survival probabilities using the Mayfield method, pp. 289–301. In: Morgan, B.J.T. & P.M. North (eds.). *Statistics in Ornithology*, Springer-Verlag, New York.
- IUCN (2025). *The IUCN Red List of Threatened Species*. International Union for Conservation of Nature. <https://www.iucnredlist.org>. Accessed on 25.i.2026.
- Jehle, G., A.A.Y. Adams, J.A. Savidge & S.K. Skagen (2004). Nest survival estimation: A review of alternatives to the Mayfield estimator. *Ornithological Applications* 106(3): 472–484. <https://doi.org/10.1093/condor/106.3.472>
- Johnson, D.H. (1979). Estimating nest success: the Mayfield method and an alternative. *The Auk* 96(4): 651–661.
- Kabir, M.A. & T. Iqbal (2018). Seasonal variations in nest-building behaviour of the Red-wattled Lapwing (*Vanellus indicus*). *Bangladesh Journal of Zoology* 46(2): 215–222. <https://doi.org/10.3329/bjz.v46i2.40391>
- Kadam, N. & R. Jadhav (2023). Habitat use and nesting success of Red-wattled Lapwing in agroecosystems of Western Maharashtra. *Indian Journal of Ecology* 50(1): 65–72.
- Kumar, S., H. Singh & K. Chauhan (2022). Effect of temperature and predation on nesting success of Red-wattled Lapwing in semi-urban areas. *Journal of Ornithology and Ecology* 56(2): 95–104.
- Mayfield, H.F. (1975). Suggestions for calculating nest success. *The Wilson Bulletin* 87(4): 456–466.
- Newton, I. (1998). *Population Limitation in Birds*. Academic Press, London, 597 pp.
- Sethi, V.K., D. Bhatt & A. Kumar (2014). Adaptation of Red-wattled Lapwing (*Vanellus indicus*) to urban habitats: A case study from north India. *Indian Birds* 9(3): 75–78.
- Shaffer, T.L. (2004). A unified approach to analyzing nest success. *The Auk* 121(2): 526–540. <https://doi.org/10.1093/auk/121.2.526>
- Sládeček, M., M. Šálek, T. Albrecht & T. Grim (2021). Urbanization affects life-history traits and reproductive success in birds. *Journal of Avian Biology* 52(2): e02672. <https://doi.org/10.1111/jav.02672>
- Stahl, J.T. & M.K. Oli (2006). Relative importance of avian life-history variables to population growth rate. *Ecological Modelling* 198(1–2): 23–39. <https://doi.org/10.1016/j.ecolmodel.2006.04.001>
- Vanadzina, K., S.E. Street, S.D. Healy, K.N. Laland & C. Sheard (2023). Global drivers of variation in cup nest size in passerine birds. *Journal of Animal Ecology* 92: 338–351. <https://doi.org/10.1111/1365-2656.13815>
- Vijayan, V.S. (1980). Breeding biology of the Indian Black Ibis *Pseudibis papillosa*. *Journal of the Bombay Natural History Society* 77: 210–221.
- Whittingham, M.J. & K.L. Evans (2004). The effects of habitat structure on predation risk of birds in agricultural landscapes. *Animal Conservation* 7(4): 283–297. <https://doi.org/10.1017/S1367943004001515>
- Yadav, R.S. & M. Sharma (2022). Nesting ecology and chick survival of Red-wattled Lapwing in relation to environmental variables. *Journal of Avian Biology* 53(7): e02957. <https://doi.org/10.1111/jav.02957>



Assessing avian diversity and conservation status in Dhamapur Lake World Heritage Irrigation Structure, Sindhudurg, Maharashtra, India

Yogesh Koli¹ , Pravin Sawant²  & Mayuri Chavan³ 

^{1,2,3} Sant Rawool Maharaj Mahavidyalaya, Kudal, Maharashtra 416520, India.

¹dryjkoli@gmail.com (corresponding author), ²pravinsawant2615@gmail.com, ³chavanmayuri0320@gmail.com

Abstract: We present a preliminary checklist of bird species in the wetland of Dhamapur Lake, a World Heritage irrigation structure in Sindhudurg District, Maharashtra, derived from studies between July 2019 and November 2024. A total of 153 species belonging to 56 families, along with their IUCN Red List status, are documented. Family-wise analysis revealed that the Ardeidae (8 species) dominated, followed by the Accipitridae and Muscicapidae. We documented 102 residents, 21 migratory, and 30 local migratory species in the study area. Categorized according to the IUCN Red List, we documented six 'Near Threatened' species, *Coracias benghalensis*, *Ciconia episcopus*, *Anhinga rufa*, *Anthracoceros cornutus*, *Melanogaster fuscus*, and *Esacus recurvirostris*, and four 'Vulnerable' species, *Ocyrceros griseus*, *Buceros bicornis*, *Pluvialis squatarola*, and *Sterna aurantia*, highlighting the urgent need to conserve this site.

Keywords: Checklist, ecosystem, indicator, migratory, ornithology, residential, sustainable, threatened, vulnerable, wetland.

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

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

Citation: Koli, Y., P. Sawant & M. Chavan (2026). Assessing avian diversity and conservation status in Dhamapur Lake World Heritage Irrigation Structure, Sindhudurg, Maharashtra, India. *Journal of Threatened Taxa* 18(2): 28387–28398. <https://doi.org/10.11609/jott.10130.18.2.28387-28398>

Copyright: © Koli et al. 2026. 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: Self-funded.

Competing interests: The authors declare no competing interests.

Author details: DR. YOGESH KOLI (YK)—assistant professor, Department of Zoology, Sant Rawool Maharaj Mahavidyalaya, Kudal. He is a president of My Way Journey Organization, and has carried out his research in the field of entomology and published his work in national and international peer reviewed journals. He is currently working on biodiversity studies and conservation issues in Sindhudurg District. He has published one book entitled 'Birdlife of Sindhudurg' in 2018. PRAVIN SAWANT (PS)—research scholar at Sant Rawool Maharaj Mahavidyalaya, Kudal. He is a founder member of My Way Journey Organization, exclusively working in the field of biodiversity studies for the last six years. He is documenting bird diversity of the Sindhudurg region with Dr. Yogesh Koli. MAYURI CHAVAN (MC)—is a post graduate student, working as a researcher with a keen interest in observing insects and birds. She is highly motivated in conserving and protecting the wetlands.

Author contributions: YK & MC wrote the manuscript and collected data in the field by surveying birds at different locations. PS photographed all birds species. PS helped YK in collecting the data during field work.

Acknowledgements: We thank the principal, Sant Rawool Maharaj Mahavidyalaya, Kudal for providing necessary facilities for this research work; Mr. Tejas Sawant, Mr. Faiyz Talikot & Mr. Gurunath Kadam for their kind help during field work.



INTRODUCTION

Wetlands serve as a connecting link between land and water ecosystems (Havril et al. 2018), typically having a water table near the ground surface or submerged vegetation under shallow water (Mitsch & Gosselink, 2015). Often referred to as 'nature's kidney' and 'supermarket' as they manage the regulation of water supply, support a wide range of biodiversity, and filter polluted water (Mitsch & Gosselink 2015), protecting shorelines, and making them crucial habitats (Byju et al. 2025a). The high-yield ecosystems, covering 6% of land surface (Mitsch & Gosselink 2007) are crucial for many bird species, providing essential habitats for feeding, breeding, & resting and serve as stopover and wintering areas for migratory birds (Piersma & Lindström 2004; Grimmett et al. 2011; Byju et al. 2025b). Waterbirds are essential to the nutrient cycling of wetlands, occupying different trophic levels, and serve as important bioindicators of an ecosystem's ecological health (Byju et al. 2025c).

Dhamapur Lake is associated with ecologically rich wetlands having considerable biodiversity. It was the first wetland from Maharashtra to receive a World Heritage Irrigation Structure (WHIS) award (<https://icid-ciid.org/award>).

Prior ornithological studies in Sindhudurg District include a preliminary survey conducted in 2018, which recorded 247 bird species (Koli et al. 2018). A year later, this number increased to 307 species covering coastal and forest bird diversity (Rao et al. 2019). Along with this, one of the popular hotspots of biodiversity in Sindhudurg District, Amboli, was found to host 208 bird species (Satose et al. 2018). Altogether, these studies emphasize the avifaunal richness of Sindhudurg District, but the available literature is restricted to broad landscapes such as the coastal region, forest, and hill ecosystems. Though 57 wetlands had been officially recognized in the Sindhudurg District, one of the most productive ecosystems remains significantly understudied, except for a single study from Pat wetland, in which 39 bird species were recorded (Patil et al. 2015), and no detailed or updated assessment has been made for other wetlands. Therefore, the present study highlights the baseline data of the avian fauna of the Dhamapur wetland, and addresses potential environmental issues. Researchers and stakeholders can use these findings for management purposes and to develop sustainable growth strategies while protecting Dhamapur wetland.

MATERIALS AND METHODS

Study area

Dhamapur Lake (16.033° N 73.594° E), is located in the Sahyadri Hills of the Western Ghats at the southern tip of Maharashtra (Image 1). It supplies the largest wetland in Sindhudurg District, extending over 32 ha, with 21% is covered by forest, 72% by agriculture, and 5% by grassland and scrubland (ICID-CIID 2022). The lake was established almost 500 years ago with the construction of a dam using rice straw as fiber, mud as binding material, and tree trunks as pipes and conduits. This is testament to ancient methods of using knowledge of local geography to harvest water and ensure a year-round supply. The periphery of the wetland is covered by a reserve deciduous forest separating the Dhamapur and Kasle forests. Dhamapur Village has diverse habitats that include semi-evergreen forest, low-elevation terraced plateaus and grasslands. Sixty-one minor streams, along with water emerging from two major streams, the Kovadewadi Dam and the Guramwadi Dam, fill the wetland with water, supporting the needs of humans and wildlife. The old stream, which has provided water to the wetland for centuries, starts from the Kalse mountains. Major sites of the present study covered backwater areas of the wetlands of Pendur Bhatwadi, Mograne Kalse, and Dhamapur. The study area of the Dhamapur wetland is shown in Image 1.

The study was conducted for five years, from July 2019–December 2024. Field surveys were carried out in winter (November–February), summer (March–June), and monsoon (July–October) seasons, seven days a month, 0600–1100 h and 1500–1700 h. Direct observations were done with binoculars (Olympus 80X) and photographs of birds taken by Canon 200D and Canon R10, lens Tamron 150–600 mm and 55–250 mm. All identification was done with the help of a standard field guide, Grimmett et al. (2011). The residential status of birds was classified as Migratory (M), Resident (R), and Local migratory (LM).

RESULTS

The 153 species belonging to 56 families that were recorded along with their IUCN Red List status, are listed in Table 1 and few rarely sighted Images present image 2 & 3. Family-wise, we recorded eight Ardeidae species, seven each for Accipitridae and Muscicapidae, and singles for, Aegithinidae, Anhingidae, Apodidae, Artamidae, Burhinidae, Coraciidae, Dicaeidae, Hirundinidae,



Image 1. Map of Dhamapur wetland study region.

Laridae, Passeridae, Pellorneidae, Pittidae, Ploceidae, Podargidae, Podicipedidae, Rostratulidae, Trogonidae, Turdidae, Tytonidae, and Zosteropidae consist of single species. An analysis of documented species indicates 102 resident species, 21 migrants and 30 local migrants (Figure 2). According to the IUCN (2025), six species, *Coracias benghalensis*, *Ciconia episcopus*, *Anhinga rufa*, *Anthracoceros cornutus*, *Melanogaster fuscus*, and *Esacus recurvirostris* are 'Near Threatened', and four species *Ocyrceros griseus*, *Buceros bicornis*, *Pluvialis squatarola*, and *Sterna aurantia* are categorized as 'Vulnerable' globally (Figure 1). The remaining 144 species fall under the 'Least Concern' category. During the observation period, the Dhamapur wetland exhibited a rich assemblage of avifauna, highlighting its ecological significance as a key habitat for both aquatic and terrestrial birds. Among the waterbirds, five species were particularly dominant in terms of abundance and frequency of occurrence. These included the Lesser Whistling-duck *Dendrocygna javanica* (n = 534) and the Little Cormorant *Microcarbo niger* (n = 360). The Indian Pond Heron *Ardeola grayii* (n = 266) were commonly

seen foraging in the shallow margins and vegetated zones of the wetland. The Asian Openbill *Anastomus oscitans* and Painted Stork *Mycteria leucocephala* (n = 252 each) were other prominent species, often found in shallow margins, moving in small flocks across open water.

In addition to these aquatic species, the surrounding terrestrial habitats supported a variety of landbirds, four of which were notably abundant. The Red-wattled Lapwing *Vanellus indicus* (n = 217) was regularly recorded along the exposed part of the grassland. The White-throated Kingfisher *Halcyon smyrnensis* (n = 175) was frequently observed perched near the waterbody's edge, preying on small fish and amphibians. The Asian Green Bee-eater *Merops orientalis* (n = 142) actively foraged in open areas around the wetland, while the Red-whiskered Bulbul *Pycnonotus jocosus* (n = 134) was also a regular inhabitant, often observed scavenging near human settlements adjacent to the wetland.

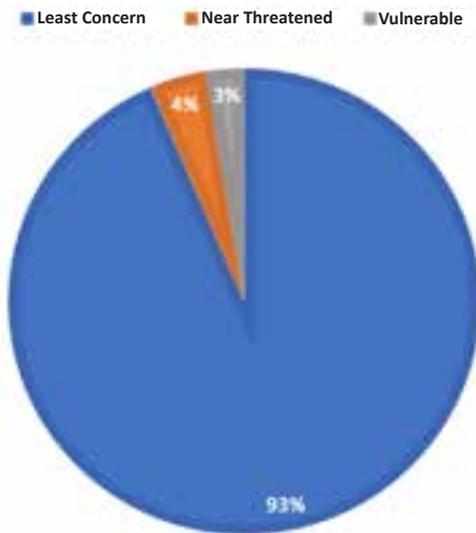


Figure 1. Representation of the IUCN Red List status of the avian fauna of Dhamapur.

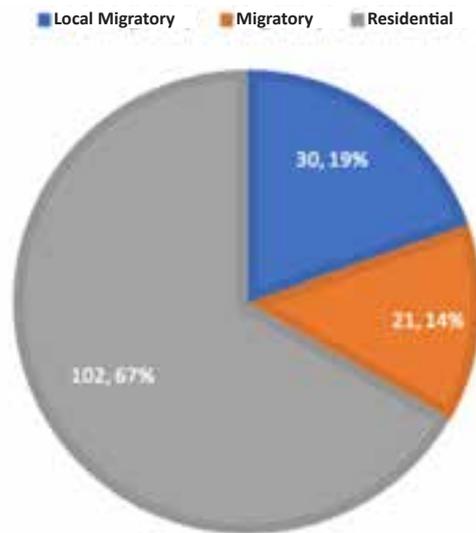


Figure 2. Migratory status of avian species documented from Dhamapur.

DISCUSSION

The present study is a baseline study of avian diversity of the Dhamapur wetland of Sindhudurg. Among the recorded bird families in the study area, the Ardeidae family is found to be dominant. Furthermore, all species within this family are typically resident, except for *Nycticorax nycticorax*, which migrates locally, suggesting that Dhamapur wetland serves as a suitable and stable resource throughout the year.

After assessment of recorded bird species, it indicates a strong presence of residential bird species, i.e., 102, indicating that Dhamapur wetland and its surrounding areas offer consistent and reliable resources. This underscores that the wetland serves as a permanent area for breeding, nesting, and foraging (Byju et al. 2023). Furthermore, the presence of 21 migratory birds highlights the importance of Dhamapur wetland as a wintering ground and stopover location (Anand et al. 2023). Also, with the presence of 30 local migratory species shows the seasonal movement within the Konkan region, implying an additional habitat in conjunction with nearby wetlands like rivers and coastal areas (Rao et al. 2019). The existence of six ‘Near Threatened’ and four ‘Vulnerable’ bird species showcases the ecological significance of Dhamapur wetland and indicates its role as a critical habitat for species of global concern.

Human activities such as land reclamation, pollution, and excessive withdrawal of water resources have negatively impacted Indian wetlands (Gopi et al. 2014; Byju et al. 2024), which shows the significant risks for

birds. Such concerns are also rising in our study area. The increase in tourism around Dhamapur has led to heightened physical disruptions, such as trampling along the banks and increased noise levels, as well as more on-water activities, like boating. These changes due to anthropogenic activities can drive birds away from their feeding and resting spots, disturb sediments in the water, diminish water clarity, and ultimately impact the quality of their habitats which leads to reduced species richness, loss of habitat specialists with a rise in generalists, disrupted migration and greater migratory mortality, reduced fitness, limited food & foraging efficiency, heightened competition, and decreased nest success (Patil et al. 2015).

In 2021, the water quality of Dhamapur wetland showed deviations in key physicochemical parameters (Yogesh Koli pers. obs. 2021). The slightly acidic pH (6.38) and elevated COD (78 mg/L), and BOD (24 mg/L) (Table 2) values indicate high organic pollution and oxygen depletion. These changes are mainly attributed to anthropogenic inputs, particularly idol immersion activities involving plaster of paris and chemical paints. Due to these changes and a sudden increase in water temperature in 2022, dead fish were sighted in Dhamapur wetland (Joshi 2022).

It not only threatens the quality of the habitat and food sources within the wetland but also endangers the diversity of bird species that rely on these ecosystems. Additionally, there has been a growing number of houses being built around the lake, the reclamation of wetland areas, and the annual practice of immersing

Table 1. Checklist of avian fauna of Dhamapur wetlands.

	Family	Common name	Scientific name	Local name	Status	IUCN Red List status
1	1. Accipitridae	Black-winged Kite	<i>Elanus caeruleus</i>	कापशी घार	Residential	LC
2		Brahminy Kite	<i>Haliastur indus</i>	समुद्री घार	Residential	LC
3		White-bellied Sea Eagle	<i>Ichthyophaga leucogaster</i>	समुद्री गरुड	Residential	LC
4		Black Kite	<i>Milvus migrans</i>	घार	Residential	LC
5		Oriental Honey-buzzard	<i>Pernis ptilorhynchus</i>	मधुवाज	Local Migratory	LC
6		Crested Serpent Eagle	<i>Spilornis cheela</i>	तुरेवाला सर्पगरुड	Residential	LC
7		Shikra	<i>Tachyspiza badia</i>	शकिरा	Residential	LC
8	2. Aegithinidae	Common Iora	<i>Aegithina tiphia</i>	सुभग	Residential	LC
9	3. Alcedinidae	Common Kingfisher	<i>Alcedo atthis</i>	सामान्य धीवर	Residential	LC
10		Blue-eared Kingfisher	<i>Alcedo meninting</i>	नळिया कानाचा धीवर	Local Migratory	LC
11		Oriental Dwarf Kingfisher	<i>Ceyx erithaca</i>	तीबोटी धीवर	Migratory	NT
12		Pied Kingfisher	<i>Ceryle rudis</i>	कवड्या धीवर	Residential	LC
13		White-throated Kingfisher	<i>Halcyon smyrnensis</i>	पांढर्या छातीचा धीवर	Residential	LC
14		Stork-billed Kingfisher	<i>Pelargopsis capensis</i>	बलाकचोच धीवर	Residential	LC
15	4. Anatidae	Common Teal	<i>Anas crecca</i>	चक्राग	Local Migratory	LC
16		Indian Spot-billed Duck	<i>Anas poecilorhyncha</i>	हळदीकुंकू बदक	Local Migratory	LC
17		Lesser Whistling-duck	<i>Dendrocygna javanica</i>	अडई	Local Migratory	LC
18		Knob-billed Duck	<i>Sarkidiornis melanotos</i>	नंदीमुखी	Migratory	LC
19		Northern Shoveler	<i>Spatula clypeata</i>	थापट्या बदक	Migratory	LC
20		Ruddy Shelduck	<i>Tadorna ferruginea</i>	चक्रवाक	Migratory	LC
21	5. Anhingidae	Oriental Darter	<i>Anhinga melanogaster</i>	तरिदाज	Local Migratory	LC
22	6. Apodidae	Little Swift	<i>Apus affinis</i>	पेंसीफकि पाकोळी	Residential	LC
23	7. Ardeidae	Great Egret	<i>Ardea alba</i>	मोठा बगळा	Residential	LC
24		Grey Heron	<i>Ardea cinerea</i>	राखी बगळा	Residential	LC
25		Western Cattle Egret	<i>Ardea ibis</i>	गाय बगळा	Residential	LC
26		Medium Egret	<i>Ardea intermedia</i>	मध्यम बगळा	Residential	LC
27		Purple Heron	<i>Ardea purpurea</i>	जांभळा बगळा	Residential	LC
28		Indian Pond Heron	<i>Ardeola grayii</i>	ढोकरी	Residential	LC
29		Little Egret	<i>Egretta garzetta</i>	छोटा बगळा	Residential	LC
30		Black-crowned Night Heron	<i>Nycticorax nycticorax</i>	रात ढोकरी	Local Migratory	LC
31	8. Artamidae	Ashy Woodswallow	<i>Artamus fuscus</i>	राखी रानपाकोळी	Migratory	LC
32	9. Bucerotidae	Malabar Pied Hornbill	<i>Anthracoceros coronatus</i>	मलबारी कवड्या धनेश	Residential	VU
33		Great Hornbill	<i>Buceros bicornis</i>	महाधनेश	Residential	VU
34		Malabar Grey Hornbill	<i>Ocyrceros griseus</i>	मलबारी राखी धनेश	Residential	NT
35	10. Burhinidae	Great Thick-knee	<i>Esacus recurvirostris</i>	मोठा करवानक	Local Migratory	NT
36	11. Campephagidae	Small Minivet	<i>Pericrocotus cinnamomeus</i>	छोटा गोमेट	Residential	LC
37		Orange Minivet	<i>Pericrocotus flammeus</i>	नारंगी गोमेट	Residential	LC
38	12. Caprimulgidae	Indian Nightjar	<i>Caprimulgus asiaticus</i>	रानरातवा	Residential	LC
39		Jerdon's Nightjar	<i>Caprimulgus atripennis</i>	जेरडनचा रातवा	Residential	LC

	Family	Common name	Scientific name	Local name	Status	IUCN Red List status
40	13. Charadriidae	Kentish Plover	<i>Anarhynchus alexandrinus</i>	कॅंटीश चखिल्या	Migratory	LC
41		Pacific Golden Plover	<i>Pluvialis fulva</i>	सोन चखिल्या	Migratory	LC
42		Grey Plover	<i>Pluvialis squatarola</i>	राखी चखिल्या	Local Migratory	VU
43		Little Ringed Plover	<i>Thinornis dubius</i>	छोटा कंठेरी चखिल्या	Migratory	LC
44		Red-wattled Lapwing	<i>Vanellus indicus</i>	टटिवी	Local Migratory	LC
45		Yellow-wattled Lapwing	<i>Vanellus malabaricus</i>	माळटटिवी	Local Migratory	LC
46		14. Ciconiidae	Asian Openbill	<i>Anastomus oscitans</i>	उघड्या चोचीचा करकोचा	Residential
47	Woolly-necked Stork		<i>Ciconia episcopus</i>	पांढऱ्या मानेचा करकोचा	Local Migratory	NT
48	Painted Stork		<i>Mycteria leucocephala</i>	रंगीत करकोचा	Migratory	LC
49	15. Cisticolidae	Common Tailorbird	<i>Orthotomus sutorius</i>	शप्पी	Residential	LC
50		Gray-breasted Prinia	<i>Prinia hodgsonii</i>	राखी छातीचा वटवट्या	Residential	LC
51		Ashy Prinia	<i>Prinia socialis</i>	राखी वटवट्या	Residential	LC
52		Jungle Prinia	<i>Prinia sylvatica</i>	रान वटवट्या	Residential	LC
53	16. Columbidae	Emerald Dove	<i>Chalcophaps indica</i>	पाचू होला	Residential	LC
54		Rock Pigeon	<i>Columba livia</i>	पारवा	Residential	LC
55		Spotted Dove	<i>Spilopelia chinensis</i>	ठपिकेवला होला	Residential	LC
56		Grey-fronted Green Pigeon	<i>Treron affinis</i>	राखी कपाळाची हरीळी	Residential	LC
57		Yellow-footed Green Pigeon	<i>Treron phoenicopterus</i>	पविळ्या पायाची हरीळी	Residential	LC
58	17. Coraciidae	Indian Roller	<i>Coracias benghalensis</i>	भारतीय नीलपंख	Residential	NT
59	18. Corvidae	Indian Jungle Crow	<i>Corvus macrorhynchos</i>	डोमकावळा	Residential	LC
60		House Crow	<i>Corvus splendens</i>	कावळा	Residential	LC
61		Rufous Treepie	<i>Dendrocitta vagabunda</i>	टकाचोर	Local Migratory	LC
62	19. Cuculidae	Greater Coucal	<i>Centropus sinensis</i>	भारदवाज	Residential	LC
63		Pied Cuckoo	<i>Clamator jacobinus</i>	चातक	LM	LC
64		Asian Koel	<i>Eudynamys scolopaceus</i>	कोकीळ	Residential	LC
65		Common Hawk Cuckoo	<i>Hierococcyx varius</i>	पावश्या	Local Migratory	LC
66	20. Dicaeidae	Thick-billed Flowerpecker	<i>Pachyglossa agilis</i>	जाड चोचीचा फुलटोचा	Local Migratory	LC
67	21. Dicruridae	Ashy Drongo	<i>Dicrurus leucophaeus</i>	राखी कोतवाल	Residential	LC
68		Black Drongo	<i>Dicrurus macrocercus</i>	कोतवाल	Residential	LC
69		Greater Racket-tailed Drongo	<i>Dicrurus paradiseus</i>	भृंगराज कोतवाल	Residential	LC
70	22. Estrilidae	Red Avadavat	<i>Amandava amandava</i>	-	Residential	LC
71		Black-throated Munia	<i>Lonchura kelaarti</i>	काळ्या गळ्याची मनोली	Residential	LC
72		Scaly-breasted Munia	<i>Lonchura punctulata</i>	ठपिकेवली मनोली	Residential	LC
73		White-rumped Munia	<i>Lonchura striata</i>	पांढऱ्या पुठ्याची मनोली	Residential	LC
74	23. Hirundinidae	Wire-tailed Swallow	<i>Hirundo smithii</i>	तारवाली भगिरी	Residential	LC
75	24. Jacanidae	Pheasant-tailed Jacana	<i>Hydrophasianus chirurgus</i>	लांब शेपटीचा कमळपक्षी	Local Migratory	LC
76		Bronze-winged Jacana	<i>Metopidius indicus</i>	कांस्यपंखी कमळपक्षी	Local Migratory	LC

	Family	Common name	Scientific name	Local name	Status	IUCN Red List status
77	25. Laniidae	Brown Shrike	<i>Lanius cristatus</i>	तपकरी खाटकि	Residential	LC
78		Long-tailed Shrike	<i>Lanius schach</i>	लांब शेपटीचा खाटकि	Residential	LC
79		Bay-backed Shrike	<i>Lanius vittatus</i>	उदपिठीचा खाटकि	Residential	LC
80	26. Laridae	River Tern	<i>Sterna aurantia</i>	नदी सुरय	Local Migratory	VU
81	27. Leiothrichidae	Common Babbler	<i>Argya caudata</i>	सामान्य सातभाई	Residential	LC
82		Large Grey Babbler	<i>Argya malcolmi</i>	राखी सातभाई	Residential	LC
83		Jungle Babbler	<i>Argya striata</i>	जंगली सातभाई	Residential	LC
84	28. Megalaimidae	Coppersmith Barbet	<i>Psilopogon haemacephalus</i>	तांबट	Residential	LC
85		White-cheeked Barbet	<i>Psilopogon viridis</i>	पांढर्या गालाचा कुदर्या	Residential	LC
86		Brown-headed Barbet	<i>Psilopogon zeylanicus</i>	तपकरी डोक्याचा कुदर्या	Residential	LC
87	29. Meropidae	Blue-bearded Bee-eater	<i>Nyctornis athertoni</i>	दाढीवाला राघू	Local Migratory	LC
88		Asian Green Bee-eater	<i>Merops orientalis</i>	वेडाराघू	Residential	LC
89		Blue-tailed Bee-eater	<i>Merops philippinus</i>	नळिया शेपटीचा राघू	Local Migratory	LC
90	30. Monarchidae	Black-naped Monarch	<i>Hypothymis azurea</i>	काळ्या मानेची आकाशी माशीमार	Residential	LC
91		Asian Paradise Flycatcher	<i>Terpsiphone paradisi</i>	सवर्णीय नर्तक	Local Migratory	LC
92	31. Motacillidae	Paddyfield Pipit	<i>Anthus rufulus</i>	धान तीरचमिणी	Local Migratory	LC
93		White Wagtail	<i>Motacilla alba</i>	पांढरा धोबी	Migratory	LC
94		Citrine Wagtail	<i>Motacilla citreola</i>	पवळ्या डोक्याचा धोबी	Migratory	LC
95		Yellow Wagtail	<i>Motacilla flava</i>	पवळा धोबी	Migratory	LC
96	32. Muscipidae	Indian Robin	<i>Copsychus fulicatus</i>	चीरक	Residential	LC
97		White-rumped Shama	<i>Copsychus malabaricus</i>	शामा	Residential	LC
98		Oriental Magpie Robin	<i>Copsychus saularis</i>	दयाळ	Residential	LC
99		Tickell's Blue Flycatcher	<i>Cyornis tickelliae</i>	टकिलची नळी माशीमार	Residential	LC
100		Bluethroat	<i>Luscinia svecica</i>	शंकर	Migratory	LC
101		Malabar Whistling Thrush	<i>Myophonus horsfieldii</i>	मलबार शीळ कसूर	Residential	LC
102		Siberian Stonechat	<i>Saxicola maurus</i>	सामान्य गप्पीदास	Local Migratory	LC
103	33. Nectariniidae	Vigors's Sunbird	<i>Aethopyga vigorsii</i>	वगोरचा शजीर	Residential	LC
104		Little Spiderhunter	<i>Arachnothera longirostra</i>	छोटा कोळीखाऊ	Residential	LC
105		Purple Sunbird	<i>Cinnyris asiaticus</i>	जांभळा शजीर	Residential	LC
106		Crimson-backed Sunbird	<i>Leptocoma minima</i>	छोटा शजीर	Residential	LC
107		Purple-rumped Sunbird	<i>Leptocoma zeylonica</i>	जांभळ्या पुठ्याचा शजीर	Residential	LC
108	34. Oriolidae	Indian Golden Oriole	<i>Oriolus kundoo</i>	हळदया	Residential	LC
109		Black-hooded Oriole	<i>Oriolus xanthornus</i>	बुरख्याधारी हळदया	Residential	LC
110	35. Passeridae	House Sparrow	<i>Passer domesticus</i>	चमिणी	Residential	LC
111	36. Pelloroneidae	Puff-throated Babbler	<i>Pellorneum ruficeps</i>	ठपिकेवाला सातभाई	Residential	LC
112	37. Phalacrocoracidae	Little Cormorant	<i>Microcarbo niger</i>	छोटा पाणकावळा	Residential	LC
113		Indian Cormorant	<i>Phalacrocorax fuscicollis</i>	भारतीय पाणकावळा	Residential	LC

	Family	Common name	Scientific name	Local name	Status	IUCN Red List status
114	38. Phasianidae	Grey Junglefowl	<i>Gallus sonneratii</i>	राखी रानकॉबडी	Residential	LC
115		Red Spurfowl	<i>Galloperdix spadicea</i>	लाल चकोत्री	Residential	LC
116		Indian Peafowl	<i>Pavo cristatus</i>	मोर	Residential	LC
117		Jungle Bush Quail	<i>Perdica asiatica</i>	जंगली लावा	Residential	LC
118	39. Picidae	Lesser Goldenback	<i>Dinopium benghalense</i>	छोटा सोनपाठी सुतार	Residential	LC
119		Yellow-crowned Woodpecker	<i>Leiopicus mahrattensis</i>	पविल्या मुकुटाचा सुतार	Residential	LC
120		Rufous Woodpecker	<i>Micropternus brachyurus</i>	तांबूस सुतार	Residential	LC
121	40. Pittidae	Indian Pitta	<i>Pitta brachyura</i>	नवरंग	Migratory	LC
122	41. Ploceidae	Baya Weaver	<i>Ploceus philippinus</i>	सुगरण	Residential	LC
123	42. Podargidae	Sri Lanka Frogmouth	<i>Batrachostomus moniliger</i>	बेडकलॉइया	Residential	LC
124	43. Podicipedidae	Little Grebe	<i>Tachybaptus ruficollis</i>	टबिकली	Residential	LC
125	44. Psittaculidae	Vernal Hanging Parrot	<i>Loriculus vernalis</i>	पचि पोपट	Residential	LC
126		Plum-headed Parakeet	<i>Psittacula cyanocephala</i>	टोई पोपट	Residential	LC
127		Rose-ringed Parakeet	<i>Psittacula krameri</i>	पोपट	Residential	LC
128	45. Pycnonotidae	Yellow-browed Bulbul	<i>Acritillas indica</i>	पविल्या भुवईचा बुलबुल	Residential	LC
129		Red-vented Bulbul	<i>Pycnonotus cafer</i>	लालबुड्या बुलबुल	Residential	LC
130		Red-whiskered Bulbul	<i>Pycnonotus jocosus</i>	शपिई बुलबुल	Residential	LC
131	46. Rallidae	White-breasted Waterhen	<i>Amaurornis phoenicurus</i>	पांढर्या छातीची पाणकोबडी	Residential	LC
132		Eurasian Coot	<i>Fulica atra</i>	वारकरी	Local Migratory	LC
133		Grey-headed Swampen	<i>Porphyrio poliocephalus</i>	जांभळी पाणकोबडी	Local Migratory	LC
134		Slaty-legged Crane	<i>Rallina eurizonoides</i>	मातकट पायाची फटाकडी	Residential	LC
135	47. Rostratulidae	Great Painted-snip	<i>Rostratula benghalensis</i>	भेंडलावा	Migratory	LC
136	48. Scolopacidae	Common Sandpiper	<i>Actitis hypoleucos</i>	सामान्य तुतारी	Local Migratory	LC
137		Common Snipe	<i>Gallinago gallinago</i>	पानलावा	Migratory	LC
138	49. Strigidae	Spotted Owllet	<i>Athene brama</i>	ठपिकेवला पगिळा	Residential	LC
139		Brown Fish Owl	<i>Ketupa zeylonensis</i>	मासेमार घुबड	Residential	LC
140		Brown Wood Owl	<i>Strix leptogrammica</i>	तपकरी वनघुबड	Residential	LC
141	50. Sturnidae	Jungle Myna	<i>Acridotheres fuscus</i>	जंगली मैना	Residential	LC
142		Common Myna	<i>Acridotheres tristis</i>	साळुंकी	Residential	LC
143		Chestnut-tailed Starling	<i>Sturnia malabarica</i>	करड्या डोक्याची मैना	Migratory	LC
144	51. Threskiornithidae	Eurasian Spoonbill	<i>Platalea leucorodia</i>	चमच्या	Migratory	LC
145		Glossy Ibis	<i>Plegadis falcinellus</i>	मोर शराटी	Local Migratory	LC
146		Red-naped Ibis	<i>Pseudibis papillosa</i>	काळा शराटी	Local Migratory	LC
147		Black-headed Ibis	<i>Threskiornis melanocephalus</i>	काल्या डोक्याचा शराटी	Local Migratory	LC
148	52. Trogonidae	Malabar Trogon	<i>Harpactes fasciatus</i>	मलबारी करणा	Migratory	LC
149	53. Turdidae	Orange-headed Thrush	<i>Geokichla citrina</i>	नारंगी डोक्याचा कसूर	Residential	LC
150	54. Tytonidae	Barn Owl	<i>Tyto alba</i>	गव्हाणी घुबड	Residential	LC
151	55. Vangidae	Bar-winged Flycatcher Shrike	<i>Hemipus picatus</i>	कवड्या माशीमार-खाटक	Migratory	LC
152		Common Woodshrike	<i>Tephrodornis pondicerianus</i>	रानखाटक	Migratory	LC
153	56. Zosteropidae	Indian White-eye	<i>Zosterops palpebrosus</i>	चपमेवाला	Residential	LC

Table 2. Physicochemical parameters of Dhamapur Wetland.

Parameter	Observed value	Normal range (Freshwater standard)	Remarks
pH	6.38	6.5–8.5	Slightly acidic, near lower limit
Chemical Oxygen Demand (COD)	78 mg/L	< 20 mg/L	Significantly higher, indicates organic pollution
Biochemical Oxygen Demand (BOD)	24 mg/L	< 3 mg/L	Very high, suggests heavy organic load
Sulphate (SO ₄ ²⁻)	1.75 mg/L	< 200 mg/L	Well within safe limit
Iron (Fe)	< 0.687 mg/L	< 0.3 mg/L	Within permissible limit
Lead (Pb)	< 0.035 mg/L	< 0.05 mg/L	Within permissible limit but close to upper range
Nickel (Ni)	< 0.075 mg/L	< 0.1 mg/L	Within acceptable range
Zinc (Zn)	< 0.0096 mg/L	< 5 mg/L	Well below permissible limit
Copper (Cu)	0.054 mg/L	< 1.5 mg/L	Within safe limit
Chromium (Cr)	< 0.035 mg/L	< 0.05 mg/L	Within acceptable range

*Normal ranges are based on BIS (IS:10500–2012) and WHO standards for freshwater and drinking water quality.

Ganesh idols, which adds considerable amounts of Shadu soil into the water. During the Sustainable Ganesh Idol Immersion Campaign in 2023, run by a few NGOs and college students, around four tons of accumulated shadu soil from the immersion 'kund' were collected and measured. This data highlights a huge amount of shadu soil accumulated in the wetland over the past decades. This accumulation of clay from shadu soil binds with sand particles at the bottom of the wetland and alters the water filtration process. This clay contains metals like silica, magnesium, and iron, which eventually enter aquatic pathways and contribute to ecological changes (Federal 2021). In 2018, the Sindhudurg Wetland Brief Documentation Committee had reported 12 Violations at Dhamapur Lake in its report (Joshi 2022). Out of these 12 violations, only one violation, which was constructed by the government itself, was demolished after the intervention of the National Green Tribunal (NGT 2018).

As a result of these pressures, the Dhamapur wetland was assigned a C+ rating in the 2019 National Wetland Health Report Card, which was compiled using data from the Ministry of Environment, Forest and Climate Change (MoEF&CC). The report indicated that this poor rating can be largely attributed to the government's insufficient conservation efforts.

This study serves as essential and valuable baseline data on avian species in the need to conserve and manage this region.

REFERENCES

- Anand, J., H. Byju, A. Nefla, S. Abhijith, O.R. Reshi & K.M. Aarif (2023). Conservation significance of Changaram wetlands - a key wintering site for migratory shorebirds and other waterbirds in the western coast of Kerala, India. *Journal of Threatened Taxa* 15(1): 22410–22418. <https://doi.org/10.11609/jott.8089.15.1.22410-22418>
- Byju, H., N. Raveendran, S. Ravichandran & R. Vijayan (2023). A checklist of the avifauna of Samanatham tank, Madurai, Tamil Nadu, India. *Journal of Threatened Taxa* 15(9): 23857–23869. <https://doi.org/10.11609/jott.8419.15.9.23857-23869>
- Byju, H., H. Maitreyi, N. Raveendran & R. Vijayan (2024). Avifaunal diversity assessment and conservation significance of Therthangal Bird Sanctuary, Ramanathapuram, Tamil Nadu: insights about breeding waterbirds. *Journal of Threatened Taxa* 16(9): 25802–25815. <https://doi.org/10.11609/jott.8999.16.9.25802-25815>
- Byju, H., H. Maitreyi, R. Natarajan, R. Vijayan & B.A.V. Maran (2025a). The avifauna of Ramanathapuram, Tamil Nadu along the Southeast coast of India: waterbirds assessments and conservation implication across key sanctuaries and Ramsar sites. *PeerJ* 1–30. <http://doi.org/10.7717/peerj.18899>
- Byju, H., H. Maitreyi, K.M. Aarif, K.A. Rubeena & S. Ravichandran (2025b). Temporal Patterns in Shorebird Diversity and Abundance at Dhanushkodi Lagoon: A Critical Wintering Ground along India's Southeast Coast. *Thalassas* 41: 151. <https://doi.org/10.1007/s41208-025-00908-1>
- Byju, H., H. Maitreyi, K.M. Aarif & N. Raveendran (2025c). Disappearing colonies: temporal decline in abundance and nesting of waterbirds in a key Indian wetland. *Wetlands Ecology & Management* 33: 47. <https://doi.org/10.1007/s11273-025-10067-y>
- Federal (2021). <https://thefederal.com/analysis/maharashtra-eco-friendly-ganesh-utsav-needs-course-correction>. Accessed on 9.x.2025.
- Gopi, K.S., A.S. Chauhan, S. Kittur & S. Babu (2014). Wetland loss and waterbird use of wetlands in Palwal District, Haryana, India: The role of agriculture, Urbanization and Conversion to fish ponds. *Wetlands* 35(1): 1–11. <https://doi.org/10.1007/s13157-014-0600-8>
- Grimmett, R., C. Inskipp & T. Inskipp (2011). *Birds of the Indian Subcontinent*. Christopher Helm Publishers Ltd., London, United Kingdom, 528 pp.
- Havril, T., Á. Tóth & J.W. Molson (2018). Impacts of predicted climate change on groundwater flow systems: can wetlands disappear due to recharge reduction? *Journal of Hydrology* 563: 1169–1180. <https://doi.org/10.1016/j.jhydrol.2017.09.020>



Image 2. A—*Ceyx erithaca* | B—*Anhinga melanogaster* | C—*Ocyeros griseus* | D—*Esacus recurvirostris* | E—*Ciconia episcopus* | F—*Mycteria leucocephala*. © Yogesh Koli.

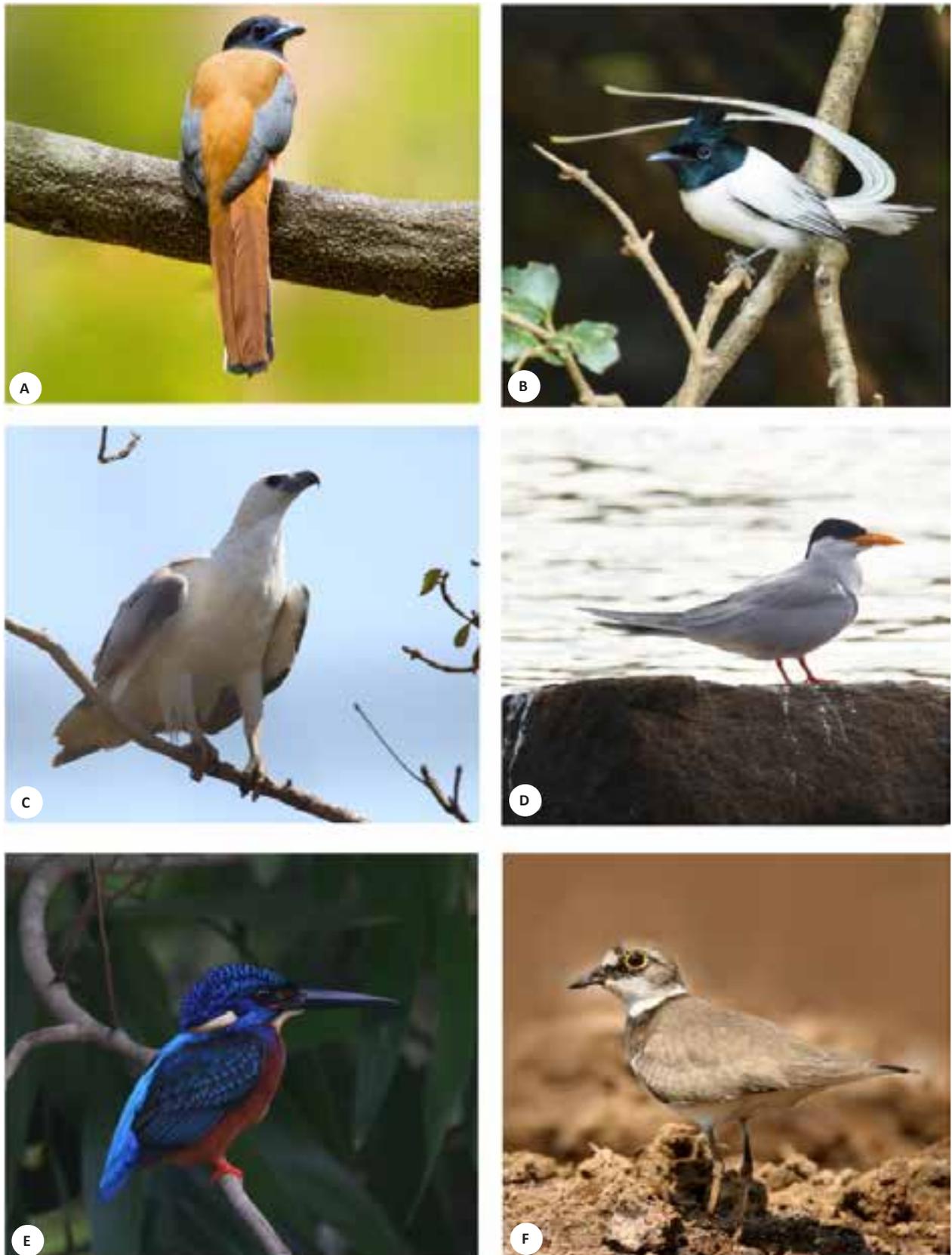


Image 3. A—*Harpactes fasciatus* | B—*Terpsiphone paradise* | C—*Ichthyophaga leucogaster* | D—*Sterna aurantia* | E—*Alcedo meninting* | F—*Thinornis dubius*. © Pravin Sawant.

- ICID-CIID (2022).** International Commission on Irrigation & Drainage Commission Internationale des Irrigation et du Drainage. <https://icid-ciid.org>. Accessed on 09.x.2025.
- IUCN (2025).** The IUCN Red List of Threatened Species. Version 2025–26. <https://www.iucnredlist.org>. Accessed on 9.x.2025.
- Joshi, P. (2022).** <https://www.indiejournal.in/article/dead-fish-sightings-at-heritage-lake-reflect-govt-neglect>
- Koli, Y.J., B.K. Parab & P.S. Sawant (2018).** Birdlife of Sindhudurg. Bhumi Publication, 214 pp.
- Mitsch W.J. & J.G. Gosselink (2007).** *Wetlands*. Wiley, New York, 582 pp.
- Mitsch, W.J. & J.G. Gosselink (2015).** *Wetlands*, 5th ed. Hoboken. John Wiley & Sons, New Jersey, 736 pp.
- NGT (2018).** <https://www.greentribunal.gov.in>
- Patil, A.J., G.B. Rao, B. Shirke, S. Babu & G. Quadros (2015).** Diversity of Avifauna In The Shallow Pat Lake In Kudal Taluka Of Sindhudurg District, Maharashtra. Proc UGC Sponsored National Seminar on Wetlands-Present Status, Ecology & Conservation 20-25.
- Piersma, T. & Å. Lindström (2004).** Migrating shorebirds as integrative sentinels of global environmental change. *IBIS* 146 (Suppl.1): 61–69. <https://doi.org/10.1111/j.1474-919X.2004.00329.x>
- Rao, G.B., S. Babu, G. Quadros & V. Anoop (2019).** Bird diversity in the coastal talukas of Sindhudurg District, Maharashtra, India. *Journal of Threatened Taxa* 11(9): 14166–14186. <https://doi.org/10.11609/jott.4007.11.9.14166-14186>
- Satose, V., V. Choursiya, R. Deulkar & S. Menon (2018).** Avian fauna of Amboli Ghat, Sindhudurg District, Maharashtra State, India. *Journal of Threatened Taxa* 10(13): 12805–12816. <https://doi.org/10.11609/jott.2886.10.13.12805-12816>



Population status and habitat use of Indian Grey Wolf *Canis lupus pallipes* in Pench Tiger Reserve, Madhya Pradesh, India

Iqra Rabbani¹ & Sharad Kumar²

^{1,2}Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, Uttar Pradesh, India.

¹rajputiqrarabbani@gmail.com, ²sharadamu@gmail.com (corresponding author)

Abstract: Wolves, once one of the most widely distributed carnivores on Earth, have experienced drastic population declines and range contractions due to anthropogenic pressures. We studied the population status and habitat utilization of the Indian Grey Wolf in Pench Tiger Reserve (PTR). Both direct and indirect evidence were used to assess wolf presence, and Bonferroni confidence intervals were calculated to analyze habitat utilization. Wolf distribution was found to be restricted to the Khawasa Range of PTR, with the Khawasa Beat showing the highest encounter rate (0.154/km). Most wolf signs were recorded in mixed habitats (miscellaneous), underscoring the importance of these areas for the species' long-term conservation. A significant positive correlation was observed between tree-cutting and wolf encounter rate ($r = 0.976$, $p = 0.024$, $df = 3$), suggesting that habitat changes associated with tree removal may influence wolf activity.

Keywords: Anthropogenic pressures, Bonferroni confidence intervals, buffer zone, camera trap, carnivores, correlation, direct and indirect evidence, encounter rate, grazing, tree-cutting.

Editor: Murali Krishna Chatakonda, Amity University, Noida, India.

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

Citation: Rabbani, I. & S. Kumar (2026). Population status and habitat use of Indian Grey Wolf *Canis lupus pallipes* in Pench Tiger Reserve, Madhya Pradesh, India. *Journal of Threatened Taxa* 18(2): 28399–28405. <https://doi.org/10.11609/jott.10059.18.2.28399-28405>

Copyright: © Rabbani & Kumar 2026. 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: None.

Competing interests: The authors declare no competing interests.

Author details: IQRA RABBANI is a PhD research scholar in the Department of Wildlife Sciences at Aligarh Muslim University, Aligarh, Uttar Pradesh, India. Her research focuses on wolf ecology and habitat studies, species distribution, and conservation. DR. SHARAD KUMAR is working as assistant professor in Department of Wildlife Sciences at Aligarh Muslim University. He has conducted long-term research on tiger ecology in Corbett Tiger Reserve. He has also been actively involved in various wildlife research and conservation programs across Uttarakhand, Madhya Pradesh, Gujarat, and Assam, contributing significantly to large carnivore conservation efforts in India.

Author contributions: Concept and design of study IR and SK. Supervision: SK. Data collection: IR. Analysis: IR and SK. Manuscript writing IR, Manuscript review and comments: IR and SK.

Acknowledgements: We sincerely express our gratitude to the Forest Department of Pench Tiger Reserve for their continuous support and cooperation during my study. We are especially grateful to Shri Rajnish Singh, IFS, Deputy Director granting permission to conduct research and for his constant guidance and logistical support throughout fieldwork. We also extend our sincere thanks to Shri Sumit Rega, Shri Rahul Upadhyaya, and S.K. Ukiye from Forest Department. I (Iqra Rabbani) also thankful to all the faculty members of Department of Wildlife Sciences at Aligarh Muslim University, Aligarh, for their guidance, encouragement, and valuable teachings throughout my academic journey. Finally, I wholeheartedly thankful to Vikrant Sharma, Ananya Prasad, Nishat Fatima for their endless support and encouraging me at every step.



INTRODUCTION

The Grey Wolf *Canis lupus*, the largest member of the canid family, inhabits a wide range of terrestrial ecosystems (Mech 1974; Jhala & Giles 1991). Its global distribution spans across 68 countries, making it one of the most widely distributed terrestrial mammals (Boitani et al. 2020). Among the 10 subspecies of Grey Wolf recognized worldwide (Boitani et al. 2020; Werhahn 2020), India harbors two distinct subspecies: the Himalayan or Tibetan Wolf *Canis lupus chanco* and the Indian Grey Wolf or Indian Peninsular Wolf *Canis lupus pallipes* (Aggarwal et al. 2003; Sharma et al. 2004). The Indian Grey Wolf is a keystone carnivore of India's semi-arid and grassland ecosystems. Despite its ecological significance, the taxon remains one of the least studied large carnivores in the country, often overshadowed by charismatic megafauna such as the elephant, tiger, and leopard. In India, the Indian Grey Wolf is protected under Schedule I of the Wildlife (Protection) Act, 1972 and is listed as 'Vulnerable' by the IUCN as its populations are considered fragmented and declining due to increasing anthropogenic pressures (IUCN 2025).

Over the past few decades, the global decline of large carnivores has emerged as a critical conservation issue, with many species experiencing significant range contractions and population losses (Weber & Rabinowitz 1996; Ripple et al. 2014; Fernández-Sepúlveda & Martín 2022). The Indian Grey Wolf is no exception, having suffered a substantial decline across much of its historical distribution (Mech 1970). This decline has been largely attributed to habitat degradation, increasing human-wolf negative interactions, low public awareness, and in some areas, targeted persecution and extermination campaigns (Habib 2007). The estimated population of the Indian Grey Wolf in India is around 3,170 individuals (Jhala et al. 2022), distributed across fragmented habitats with little to no connectivity between metapopulations. This highlights the urgent need for region-specific conservation strategies tailored to local ecological and sociopolitical contexts. It is estimated that India has a total of 89,138 km² suitable habitats for breeding packs; the largest continuous breeding habitat is located in the Central Indian landscape (Jhala et al. 2022). The remaining populations of the Indian Grey Wolf are small, fragmented, and increasingly isolated, making them highly vulnerable to local extinction. Without targeted management interventions and scientific understanding of their population status and habitat needs, the long-term viability of these populations remains at risk (Singh & Kumara 2006; Becker et al. 2008).

Reliable information on population size and habitat use is essential for the effective conservation of any threatened species (Sousa-Silva et al. 2014). Acquiring such data is particularly challenging for species like the Indian Grey Wolf, which occur at low densities and inhabit vast, human-dominated landscapes (Mahajan et al. 2022a). Although several studies have assessed the species' status at local and regional scales (Jhala & Giles 1991; Kumar & Rahmani 1997; Kumar 1998; Singh & Kumara 2006), and a few at the national level (Shahi 1982; Jhala 1993, 2003; Karanth et al. 2009; Srivathsa et al. 2020; Jhala 2022), knowledge gaps still persist regarding their ecological preferences across different landscapes.

Pench Tiger Reserve (PTR), located in the Satpura-Maikal landscape of central India, is a known stronghold for apex predators like the Bengal Tiger *Panthera tigris* and Leopard *Panthera pardus*. However, its role as a habitat for lesser-known carnivores such as the Indian Grey Wolf is poorly understood. Understanding the population status and habitat utilization patterns of the Indian Grey Wolf in a multi-use landscape of PTR is crucial for informed conservation and management efforts. This study aims to assess the current distribution and habitat preferences of the Indian Grey Wolf within Pench Tiger Reserve, Madhya Pradesh. By identifying key habitats and anthropogenic influences, the findings will contribute to evidence-based strategies for the conservation of this ecologically important yet vulnerable carnivore.

MATERIAL AND METHODS

Study Area

The study was conducted in PTR, located in the central Indian state of Madhya Pradesh (Figure 1). The Reserve spans an area of 1,179.63 km² and falls within the Seoni and Chhindwara districts. Geographically, PTR lies between 78.916–79.583 °E and 21.583–22.000 °N. The elevation ranges 425–600 m. Although some areas like the Karmajhiri Range are plains, the majority of PTR's terrain is characterized by gently undulating landscapes interspersed with seasonal streams and 'nallahs'. The region experiences a wide temperature range, from 0°C in winter to 45°C in summer (Sankar et al. 2000), with an average annual rainfall of approximately 1,300 mm. The climate is marked by four distinct seasons: summer (March–June), monsoon (July–August), post-monsoon (September–November), and winter (December–February).

The vegetation in Pench Tiger Reserve is

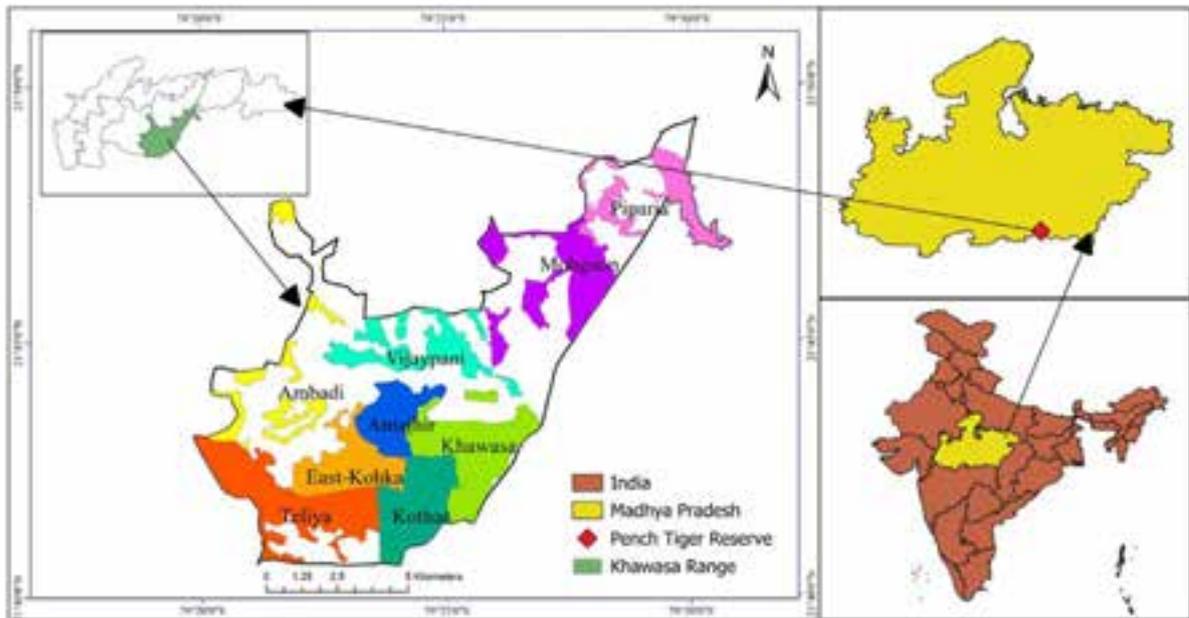


Image 1. Map depicting the location of study area: Khawasa Range, Pench Tiger Reserve, Madhya Pradesh.

predominantly composed of dry deciduous forests, comprising pure Teak *Tectona grandis* forest, Teak-mixed forest, mixed forests, bamboo forest, and open grasslands. The reserve supports a diverse assemblage of carnivores, including the Tiger, Leopard, Dhole *Cuon alpinus*, Jungle Cat *Felis chaus*, Small Indian Civet *Viverricula indica*, Sloth Bear *Melursus ursinus*, Golden Jackal *Canis aureus*, Indian Grey Wolf, and Common Palm Civet *Paradoxurus hermaphroditus*. The herbivore community includes species such as the Sambar *Rusa unicolor*, Chital or Spotted Deer *Axis axis*, Gaur *Bos gaurus*, Nilgai *Boselaphus tragocamelus*, and Chousingha or Four-horned Antelope *Tetracerus quadricornis*. In addition to mammals, the reserve hosts a rich diversity of birdlife, with over 250 recorded species.

Methods

Camera-trapping data in 2019–2023 were collected from the forest department of Pench Tiger Reserve. Data analysis revealed the presence of the Indian Grey Wolf exclusively in the Khawasa Range of the Reserve. Accordingly, the Khawasa Range was selected for further data collection (January–March 2023) on population status and habitat use of wolves. The range is a multi-use area of the Reserve and predominantly characterized by tropical dry deciduous forest. The vegetation is dominated by Teak along with associated species such as Mahua *Madhuca indica*, Saja *Terminalia tomentosa*, and Tendu *Diospyros melanoxylon*. The range experiences

moderate level of human disturbance like livestock grazing, tree-logging, and the seasonal collection of forest products like Mahua flowers and Tendu leaves. The range comprises nine forest beats, each of which was chosen as a sampling unit to assess the population status and habitat utilization patterns of the species.

Wolf status and habitat use across forest beats were assessed by systematically searching for and recording both direct and indirect evidences of wolves. Surveys were conducted along all trails, roads, and nallahs within the different beats, as these features are commonly used by wolves for movement within their home ranges. Survey efforts involved walking 171 km² across these features. This approach increases the probability of detecting wolf evidence compared to random surveys (Mahajan et al. 2022b). To minimize bias arising from misidentification, only fresh signs were recorded during the survey.

Whenever direct or indirect evidence of wolves was encountered, data on evidence type, location, habitat, terrain and status of anthropogenic pressures were collected. To differentiate indirect evidence of the Indian Grey Wolf from those of related sympatric species such as the Domestic Dog *Canis familiaris* and Golden Jackal *Canis aureus*, we compared pugmarks, scats, and associated field signs during surveys. Wolf pugmarks are large (7–10 cm in length), oval and symmetrical shape with a straight posterior margin of the heel pad, whereas dog tracks are more variable in

size, often rounder and asymmetrical with prominent claw impressions, and jackal tracks are smaller (4.5–6 cm), compact, and narrower (Talwar & Usmani 2005; Mahajan et al. 2022b). Scats were distinguished based on size, shape, and contents. The wolf scats are thick (2–3 cm diameter), rope-like, and generally contained hair, bones, and prey remains; dog scats are irregular, softer, and often contained anthropogenic matter; jackal scats are smaller (1.5–2 cm diameter), segmented, and frequently contained fruit seeds in addition to hair (Jhala 2003; Rather 2021; Mahajan et al. 2022b). Data from camera-trapping and evidence surveys were used for the analysis of habitat use.

To quantify habitat conditions and habitat use, random sampling plots were laid in each beat. For the tree-layer assessment, a circular plot with a 10-m radius was used. Within this, a nested 5-m radius circular plot was laid to assess the shrub layer following Haleem & Ilyas (2023). The data collected from these plots were used to quantify vegetation characteristics, including species density, diversity, richness, and evenness, which were then used to understand patterns of wolf habitat utilization. The area under different habitat types was determined using Remote sensing and geographic information system (GIS) analysis based on the land use and land cover (LULC) map of the study area.

Analysis

The trails were monitored once, covering a total distance of 171 km. Beat-wise encounter rates were calculated by dividing the total number of wolf evidence recorded in each beat by the total distance travelled within that beat (Table 1). To evaluate the relationship between anthropogenic pressures and wolf presence, non-parametric correlation analysis was conducted using SPSS version 22.0 (IBM Corp 2013). Vegetation attributes, including tree and shrub diversity, richness, and evenness, were computed using PAST software.

Data on direct and indirect wolf evidence were segregated by habitat type. A chi-square test was performed to examine whether the distribution of wolf evidence differed significantly among the various

habitat types. To assess habitat use patterns by wolves, Bonferroni confidence intervals were calculated (Neu et al. 1974; Byres et al. 1994). Habitat preferences and avoidance were determined based on these intervals.

RESULTS

Over the past five years, a total of 27 camera-trap captures of the Indian Grey Wolf were recorded in the Khawasa Range. The camera trap data revealed the presence of wolves in six out of nine beats of Khawasa range: Kothar, Amajhiri, Amabari, Teliya, Vijaypani, and Khawasa. No wolf detections were recorded in East Kohka, Mohgaon, and Pipariya beats. Among the beats where wolves were captured, Kothar Beat recorded the highest number of captures, while Amajhiri and Teliya had the lowest (Figure 2).

A total of 13 direct and indirect signs of Indian Grey Wolf presence were recorded during the sign survey, confirming their occurrence in only four out of the nine beats of the Khawasa Range. The highest encounter rate was recorded in the Khawasa Beat (0.15 evidences/km), while the lowest was in Pipariya Beat (0.12 evidences/km) (Table 1). The analysis of anthropogenic pressures in beats with wolf presence revealed varying intensities of human activities. The highest tree-logging was recorded in Pipariya Beat (95 trees/ha) while the lowest was in Khawasa Beat. The highest tree-cutting was recorded in Khawasa (81.9 trees/ha), whereas Pipariya Beat had the lowest tree-cutting. The highest intensity of grazing was recorded in Vijaypani while there was no grazing in Aamajhiri (Table 1). No significant correlation was observed between the wolf encounter rate and most anthropogenic pressures, except for tree-cutting, which showed a strong positive correlation with encounter rate ($r = 0.976, p = 0.024, df = 3$).

In terms of shrub composition, Ambari had the highest shrub diversity (1.673), while East Kohka showed the highest shrub richness (1.593), and Ambari again had the highest shrub evenness (0.7608). Conversely,

Table 1. Status of the anthropogenic pressures in beats with wolf presence in Pench Tiger Reserve.

Beats	Wolf encounter rate (evidence/km)	Tree-logging density (ha)	Tree-cutting density (ha)	Cattle dung piles density (ha)
Khawasa	0.154	40.9	81.9	22.7
Aamajhiri	0.137	47.8	15.9	0.0
Pipariya	0.121	95.5	15.9	79.6
Vijaypani	0.141	63.7	31.8	111.5

the lowest shrub diversity was observed in Kothar (1.022), lowest richness in Mohgaon (1.027), and lowest evenness in Kothar (0.3968) (Table 2).

Habitat-wise comparison of vegetation parameters revealed that the mixed habitat (Miscellaneous Forest) had the highest tree diversity (2.84), richness (4.345) and evenness (0.5351), which indicates species in mixed habitats are more evenly distributed than in Teak and Teak-mixed habitat (Table 3). Analysis of 40 wolf evidences (including camera-trap captures) across three habitat types – mixed, teak mixed, and teak – revealed that the majority of evidence (32) was recorded from mixed habitat, while Teak and Teak-mixed habitats each had four evidences. A chi-square test indicated no statistically significant difference in habitat utilization by the Indian Grey Wolf ($\chi^2 = 4.9$, $df = 2$, $p = 0.05$), although the test statistic was close to the critical value. To further assess habitat preference, Bonferroni confidence intervals were calculated (Table 3). The results suggested that Teak habitat was utilized less than its availability, whereas mixed and Teak-mixed habitats were used in proportion to their availability.

DISCUSSION

This study revealed that the distribution of the Indian Grey Wolf in PTR is restricted to the Khawasa Range, which lies in the buffer zone, with most sightings occurring near human settlements. Their absence from the core area and exclusive presence in the buffer zone aligns with findings by Jhala et al. (2022), who suggest that wolves prefer habitats with low to moderate densities of dominant predators such as tigers and leopards. This avoidance may be attributed to the high density of tigers and leopards in the core zone of the

study area, indicating that wolves actively avoid areas dominated by larger carnivores. The proximity of wolf sightings to human settlements suggests opportunistic behaviour, likely driven by availability of livestock carcasses and anthropogenic waste near human settlements, an adaptive trait also documented in other studies (Jethva & Jhala 2004; Becker et al. 2008; Sharma et al. 2019). By utilizing consistent and energy-efficient food sources such as livestock carcasses and human waste, wolves may compensate for limited access to wild prey resulting from interference or competition with dominant carnivores (Becker et al. 2008).

Habitat composition also plays a significant role in influencing wolf distribution in the study area. Results of the study indicate a preference for mixed and Teak-mixed forest types, which provide both concealment and prey opportunities. These habitats tend to support higher densities of herbivores due to their diverse ground vegetation and structural complexity (Karanth & Sunquist 1995), thereby indirectly benefiting wolves.

The significant positive correlation between tree-cutting and wolf encounter rate indicates that higher tree felling is associated with increased wolf activity. Tree-cutting creates open spaces and such areas also have more dirt roads and trails, which may facilitate wolf movement and improve hunting efficiency by increasing prey visibility and accessibility. Additionally, tree-cutting can enhance the growth of ground vegetation (shrub and herb layers). This improved ground cover may further contribute to habitat suitability by supporting higher prey abundance and enhancing foraging opportunities for wolves. This pattern highlights the species' ability to exploit human-modified habitats. Similar findings have been reported in other studies, where wolves were observed to use logging roads, clear-cuts, and other disturbed habitats to optimize travel and foraging

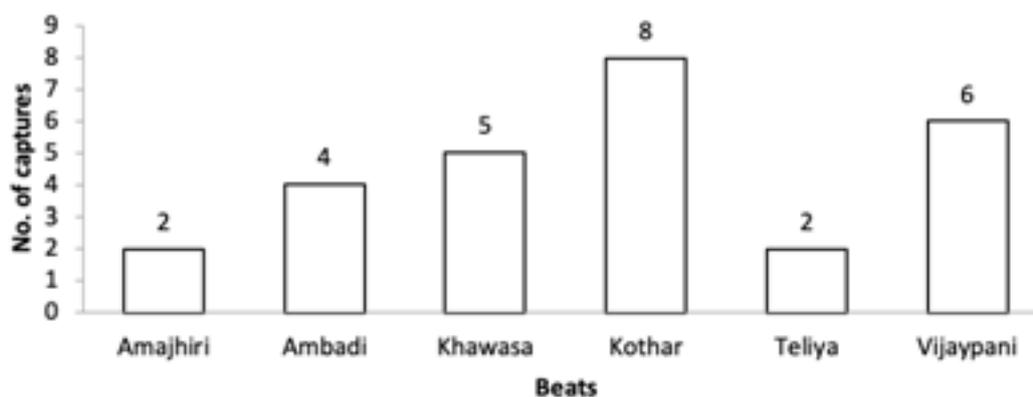


Figure 2. Beat-wise number of captures of the Indian Grey Wolf in the Khawasa range of Pench Tiger Reserve.

Table 2. Habitat-wise tree and shrub indices and counts of wolf evidence in Pench Tiger Reserve.

Habitat	Tree diversity	Tree richness	Tree evenness	Shrub diversity	Shrub richness	Shrub evenness	Wolf evidence
Mixed	2.84	4.345	0.5351	0.811	1.957	0.5144	32
Teak	1.687	3.049	0.2843	0.8107	2.213	0.654	4
Teak Mixed	2.02	3.717	0.3428	0.5522	0.9128	0.5508	4

Table 3. Availability and expected proportional usage with 95% Bonferroni confidence intervals.

Habitat	Observed usage	Expected usage	Actual proportional use (Pi)	Expected proportional use (Pio)	Bonferroni confidence interval	Remark
Mixed	32	26.96	0.8	0.67	$0.654 \leq Pi \leq 0.945$	0
Teak	4	10.02	0.1	0.25	$-0.009 \leq Pi \leq 0.209$	-
Teak mixed	4	3.005	0.1	0.07	$-0.009 \leq Pi \leq 0.209$	0

—Avoided | +—Preferred | 0—used in accordance to availability.

efficiency (Whittington et al. 2005; Houle et al. 2010). Therefore, the observed relationship may reflect a functional response of wolves to human-mediated habitat changes, demonstrating their adaptability in human-dominated landscapes.

Study findings highlight that buffer zones are not merely peripheral spaces but serve as critical habitats for many wildlife species, including wolves. These areas must be recognized for their ecological value and managed accordingly. An effective conservation strategy should integrate habitat management, scientific research, and active community participation to ensure the protection of wildlife across the landscape. To ensure the long-term conservation of wolves in the region, it is essential to adopt a landscape-level conservation approach. Given that wolf packs require large home ranges, ranging 150–300 km² (Jhala 2003; Habib 2007), focusing solely on small habitat patches is insufficient. Conservation efforts should prioritize the protection of natural habitat features and the maintenance of wildlife corridors, enabling free movement between areas and promoting population connectivity (Sharma et al. 2019; Gubbi et al. 2020).

REFERENCES

- Aggarwal, R.K., J. Ramadevi & L. Singh (2003). Ancient origin and evolution of the Indian wolf: Evidence from mitochondrial DNA typing of wolves from Trans-Himalayan region and Peninsular India. *Genome Biology* 4: 1–30.
- Becker, M.S., R.A. Garrott, P.J. White, C.N. Gower, E.J. Bergman & R. Jaffe (2008). Wolf prey selection in an elk–bison system: Choice or circumstance? *Terrestrial Ecology* 3: 305–337.
- Boitani, L., M. Phillips & Y.V. Jhala (2020). *Canis lupus*. The IUCN Red List of Threatened Species. <https://doi.org/10.2305/IUCN.UK.2018-2.RLTS.T3746A163508960.en>

Fernández-Sepúlveda, J. & C.A. Martín (2022). Conservation status of the world's carnivorous mammals (order Carnivora). *Mammalian Biology* 102(5–6): 1911–1925. <https://doi.org/10.1007/s42991-022-00305-8>

Government of India. (1972). The Wildlife (Protection) Act, 1972 (Act No. 53 of 1972). Ministry of Law, Justice and Company Affairs, New Delhi, India.

Gubbi, S., S. Ramesh, A.M. Menon, M.N. Girish & H.C. Poornesha (2020). The lone wolf: new distribution update of the Indian Grey Wolf (*Canis lupus pallipes*) in southern India. *Canid Biology & Conservation* 22(6): 21–24.

Habib, B. (2007). Ecology of Indian wolf (*Canis lupus pallipes* Sykes, 1831) in the Great Indian Bustard Sanctuary, Maharashtra, India. Ph.D. Thesis. Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, India, xi+264 pp.

Habib, B. & S. Kumar (2007). Den shifting by wolves in semi-wild landscapes in the Deccan Plateau, Maharashtra. *Journal of Zoology* 272: 259–265.

Haleem, A. & O. Ilyas (2023). Status distribution and factors affecting the habitat selection by Sambar Deer (*Rusa unicolor*) in Pench Tiger Reserve, Madhya Pradesh, India. *Journal of Threatened Taxa* 15(1): 22371–22380. <https://doi.org/10.11609/jott.7597.15.1.22371-22380>

Houle, M., D. Fortin, C. Dussault, R. Courtois & J.-P. Ouellet. (2010). Cumulative effects of forestry on habitat use by Gray Wolf (*Canis lupus*) in the boreal forest. *Landscape Ecology* 25(3): 419–433. <https://doi.org/10.1007/s10980-009-9420-2>

IBM Corp. (2013). *IBM SPSS Statistics for Windows, Version 22.0*. IBM Corp., Armonk, NY.

International Union for Conservation of Nature (IUCN) (2025). The IUCN Red List of Threatened Species (Version 2025-2). <https://www.iucnredlist.org>

Jethva, B.D. & Y.V. Jhala (2004). Foraging ecology, economics and conservation of Indian wolves in the Bhal region of Gujarat, Western India. *Biological Conservation* 116: 351–357. [https://doi.org/10.1016/S0006-3207\(03\)00218-0](https://doi.org/10.1016/S0006-3207(03)00218-0)

Jhala, Y.V. (1991). The habitat and population dynamics of wolves and blackbuck in Velavadar National Park, Gujarat, India. Ph.D. Thesis. Virginia Polytechnic Institute and State University, 199 pp.

Jhala, Y.V. (1993). Predation on blackbuck by wolves in Velavadar National Park. *Conservation Biology* 7(4): 874–881.

Jhala, Y.V. (2003). Status, ecology and conservation of the Indian wolf (*Canis lupus pallipes*). *Journal of the Bombay Natural History Society* 100: 293–307.

Jhala, Y.V. & R.H. Giles Jr. (1991). The status and conservation of the wolf in Gujarat and Rajasthan, India. *Conservation Biology* 5(4):

- 476–483. <https://doi.org/10.1111/j.1523-1739.1991.tb00354.x>
- Jhala, Y.V., S. Saini, S. Kumar & Q. Qureshi (2022).** Distribution, status, and conservation of the Indian peninsular wolf. *Frontiers in Ecology and Evolution* 10: Article 814966. <https://doi.org/10.3389/fevo.2022.814966>
- Karanth, K.U. & M.E. Sunquist (1995).** Prey selection by tiger, leopard, and dhole in tropical forests. *Journal of Animal Ecology* 64(4): 439–450. <https://doi.org/10.2307/5647>
- Karanth, K.K., J.D. Nichols, J.E. Hines, K.U. Karanth & N.L. Christensen (2009).** Patterns and determinants of mammal species occurrence in India. *Journal of Applied Ecology* 46(6): 1189–1200. <https://doi.org/10.1111/j.1365-2664.2009.01710.x>
- Kumar, S. (1998).** Ecology and behaviour of Indian Grey Wolf (*Canis lupus pallipes*) in the Deccan Grasslands of Solapur, Maharashtra. Ph.D. Thesis. Centre of Wildlife and Ornithology, Aligarh Muslim University, Aligarh, India, 261 pp.
- Kumar, S. & A.R. Rahmani (1995).** Conservation of the Grey Wolf in Great Indian Bustard Sanctuary at Nannaj, Maharashtra, India, pp. 364–367. In: Bissonette, J.A. & P. R. Krausman (eds.). Proceedings of the international symposium on ecology and management of ungulates in India.
- Mahajan, P., R. Chaudhary, A. Kazi & D. Khandal (2022a).** Spatial determinants of livestock depredation and human attitude toward wolves in Kailadevi Wildlife Sanctuary, Rajasthan, India. *Frontiers in Ecology and Evolution* 10: 855084. <https://doi.org/10.3389/fevo.2022.855084>
- Mahajan, P., D. Khandal & K. Chandrawal (2022b).** Factors influencing habitat-use of Indian Grey Wolf in the semiarid landscape of western India. *Mammal Study* 47(1): 23–37. <https://doi.org/10.3106/ms2021-0029>
- Mech, L.D. (1974).** *Canis lupus*. *Mammalian Species* 37: 1–6. <https://doi.org/10.2307/3503924>
- Morrison, M.L., B.G. Marcot & R.W. Mannan (1992).** *Wildlife–Habitat Relationships: Concepts and Applications*. University of Wisconsin Press, 520 pp.
- Neu, C.W., C.R. Byers & J.M. Peek (1974).** A technique for analysis of utilization–availability data. *The Journal of Wildlife Management* 38(3): 541–545. <https://doi.org/10.2307/3800887>
- Rather, T.A. (2021).** Ecology of carnivores in buffer zone of the Bandhavgarh Tiger Reserve, Madhya Pradesh, India. Ph.D. Thesis. Department of Wildlife Sciences, Aligarh Muslim University, Aligarh, India, xxiii+271 pp.
- Ripple, W.J., J.A. Estes, R.L. Beschta, C.C. Wilmers, E.G. Ritchie, M. Hebblewhite, J. Berger, B. Elmhagen, M. Letnic, M.P. Nelson, O.J. Schmitz, D.W. Smith, A.D. Wallach & A.J. Wirsing (2014).** Status and ecological effects of the world’s largest carnivores. *Science* 343(6167): 1241484. <https://doi.org/10.1126/science.1241484>
- Shahi, S.P. (1982).** Report of Grey Wolf (*Canis lupus pallipes*) in India: A preliminary survey. *Journal of the Bombay Natural History Society* 79: 493–502.
- Sharma, D.K., J.E. Maldonado, Y.V. Jhala & R.C. Fleischer (2004).** Ancient wolf lineages in India. *Proceedings of the Royal Society B: Biological Sciences* 271(Suppl. 3): S1–S4. <https://doi.org/10.1098/rsbl.2003.0071>
- Sharma, L.K., T. Mukherjee, P.C. Saren & K. Chandra (2019).** Identifying suitable habitat and corridors for Indian Grey Wolf (*Canis lupus pallipes*) in Chotta Nagpur Plateau and Lower Gangetic Plains: A species with differential management needs. *PLoS ONE* 14(4): e0215019. <https://doi.org/10.1371/journal.pone.0215019>
- Singh, M. & H.N. Kumara (2006).** Distribution, status and conservation of Indian Gray Wolf (*Canis lupus pallipes*) in Karnataka, India. *Journal of Zoology* 270(1): 164–169. <https://doi.org/10.1111/j.1469-7998.2006.00103>
- Sousa-Silva, R., P. Alves, J. Honrado & A. Lomba (2014).** Improving the assessment and reporting on rare and endangered species through species distribution models. *Global Ecology and Conservation* 2: 226–237. <https://doi.org/10.1016/j.gecco.2014.09.01>
- Talwar, R. & A. Usmani (2005).** *Reading pugmarks: A pocket guide for forest guards* (Revised ed.). Tiger & Wildlife Programme, WWF-India
- Weber, W. & A. Rabinowitz (1996).** A global perspective on large carnivore conservation. *Conservation Biology* 10: 1045–1054.
- Werhahn, G. (2020).** Phylogeny and ecology of the Himalayan wolf. Ph.D. Thesis. Wildlife Conservation Research, Unit Department of Zoology, University of Oxford, 437 pp.
- White, G.C. & R.A. Garrott (1990).** Habitat analysis, pp. 183–205. In: Analysis of wildlife radio-tracking data. Academic Press.
- Whittington, J., C.C.S. Clair & G. Mercer (2005).** Spatial responses of wolves to and road trails in mountain valleys. *Ecological Applications* 15(2): 543–553. <https://doi.org/10.1890/03-5317>



Activity budgets of a zoo-housed Mishmi Takin *Budorcas taxicolor taxicolor* (Mammalia: Artiodactyla: Bovidae) herd

Nabanita Ghosh¹ , Pranita Gupta² , Joy Dey³  & Basavaraj S. Holeyachi⁴ 

¹⁻⁴ Padmaja Naidu Himalayan Zoological Park, Darjeeling, West Bengal 734101, India.

¹ghosh.nabanita1695@gmail.com (corresponding author), ²pranita.gupta.subba@gmail.com, ³joydarjeeling@yahoo.co.in, ⁴basavifs@gmail.com

Abstract: The Himalayan Caprine *Budorcas taxicolor taxicolor*, generally known as the Mishmi Takin, is a globally 'Vulnerable' species per IUCN Red List and categorised under Schedule I of the Wildlife (Protection) Act, 1972. Information on their behaviour is limited, and this study was undertaken at Padmaja Naidu Himalayan Zoological Park, Darjeeling, to investigate the activity budgets of a herd of seven Mishmi Takin in captivity, with emphasis on reproductive and maternal behaviours. Ethograms developed based on a literature review and preliminary observations were used to observe animals for one year. Data analysis was conducted using descriptive statistics. It was observed that the takins spend the majority of their time feeding, standing, ruminating, resting or in locomotion. Reproductive behaviours comprised less than 1% of the activity budget. The study provides preliminary data on the behaviour of the Mishmi Takin in captivity, and could be utilised by zoo management to strategize animal enrichment and welfare.

Keywords: Behaviour, captivity, feeding, Himalayan Caprine, locomotion, observations, Padmaja Naidu Himalayan Zoological Park, ruminating, seasonality, zoo management.

Editor: Tiger Sangay, Ugyen Wangchuck Institute for Forestry Research and Training, Bumthang, Bhutan. **Date of publication:** 26 February 2026 (online & print)

Citation: Ghosh, N., P. Gupta, J. Dey & B.S. Holeyachi (2026). Activity budgets of a zoo-housed Mishmi Takin *Budorcas taxicolor taxicolor* (Mammalia: Artiodactyla: Bovidae) herd. *Journal of Threatened Taxa* 18(2): 28406–28412. <https://doi.org/10.11609/jott.9576.18.2.28406-28412>

Copyright: © Ghosh et al. 2026. 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 project was funded by West Bengal Zoo Authority. The grant number is 104/WBZA/T-18(j)/21-22 dated 15.06.2021.

Competing interests: The authors declare no competing interests.

Author details: NABANITA GHOSH, project fellow for the project. Affiliated to Padmaja Naidu Himalayan Zoological Park while working on the project. PRANITA GUPTA is the current zoo biologist in Padmaja Naidu Himalayan Zoological Park, Darjeeling. She is in charge of writing new projects and supervising them, overlooking animal records and education outreach. Joy Dey is the zoo veterinarian in charge of animal health. Basavaraj S. Holeyachi is the ex-director and one of the supervisors of this project.

Author contributions: NG: methodology, data collection, data analysis, manuscript writing and editing. PG: manuscript editing. JD: partial supervision. BSH: supervision.

Acknowledgements: I would like to acknowledge Barkha Subba (ex-zoo biologist) for the initial conceptualization of the project, Prishka Pariyar (ex-project fellow) for collecting the ad-libitum data and making the ethogram, zookeepers for their guidance during observations and data collections, Bedan Chettri (ex-assistant librarian) for providing study and reference material from the library and Shiwangi Rai (ex-project fellow) for helping with sampling the study.



INTRODUCTION

The Mishmi Takin *Budorcas taxicolor taxicolor*, is a large Himalayan even-toed member of the Bovidae, with three recognized subspecies: Bhutan Takin *B. t. whitei*, Grey or Sichuan Takin *B. t. tibetana*, and Golden or Shaanxi Takin *B. t. bedfordi* (Neas & Hoffmann 1987; Sharma et al. 2015). Elongated in structure with lunate horns, adult males weigh up to 350 kg and females up to 280 kg (Neas & Hoffman 1987). These generalist herbivores are primarily browsers, foraging on a wide variety of plants (Schaller et al. 1986). They occur in mountainous terrain and move in herds that typically migrate to higher elevations during summer (Schaller et al. 1986; Adkin et al. 2012). Breeding is observed in July–August, when they often inhabit higher altitudes (Allen 1940; Schaller et al. 1986; Zeng et al. 2008); the gestation period ranges 7–8 months (Neas & Hoffmann 1987).

The IUCN Red List categorizes the Takin as ‘Vulnerable’, and Wildlife (Protection) Act, 1972, identifies it as a Schedule I animal (Song et al. 2008; Sharma et al. 2015). In India, it is found in the remote hills of Mishmi in Arunachal Pradesh, most of which is not legally protected (Sharma et al. 2015). Information about its behaviour is scant in the literature, owing to the inaccessible, uneven, and rugged terrain takins occupy. Observational studies in zoo research programs have provided insights into animal habits and behaviour (Mench et al. 1997), and this study was an attempt to generate baseline behavioural data for a captive herd of Mishmi Takin at PNHZP. The activity budgets were specifically prepared based on observations made during the active daylight period, spanning from early morning to early evening hours for each herd member. Subsequently, the influence of seasonal variation were quantitatively evaluated on these activities. Reproductive behaviour of the group and maternal care of a pregnant female takin were also investigated as part of the research objective. This study hopes to provide data that can be utilised by zoo management to support effective animal welfare and maintain viable captive breeding populations.

METHODS

Observations of captive Mishmi Takins took place at the Padmaja Naidu Himalayan Zoological Park (PNHZP), Darjeeling, India (27.050 °N, 88.261 °E) from March 2022 to May 2023. The animals were housed in three

enclosures of similar design and area. All the enclosures were outdoor yards comprising a separate feeding and drinking area, makeshift wooden platforms and in-built shelters for extreme weather conditions (Figure 1). Takin feed comprised fodder from the forest and supplementary feed from the zoo animal feed section. Supplementary feed provided to the takins, to meet the nutritional requirements, included a mixture of crushed maize, crushed wheat, gram, barley, pulses, turmeric, salt, and molasses (during winters) and was fed daily during morning hours (0900 h) by the zookeepers. The takins were fed fodder twice a day, typically around 0930 h in the morning and 1500 h in the afternoon. It comprised of a variety of plants like *Cyathea chinensis* Copel., *Artemisia vulgaris* L., *Rhaphidophora glauca* (Wall.) Schott, *Selaginella pennata* (D. Don), *Tradescantia fluminensis* Vell, *Saurauia napaulensis* DC., *Hedychium gardnerianum*, *Piper suipigua* Buch.-Ham. ex D. Don, *Pouzolzia sanguinea* (Blume) Merr., *Acer laevigatum* Wall., *Maesa chisia* D. Don, and *Leucosceptrum canum* Sm.

Initially, Male 1, Male 3, Female 1, and Female 3 were housed together. Male 2 was housed alone. Female 2 and Female 4 were housed together. After three months, Male 1 was housed with Female 2 and Female 4. Male 3, Female 1 and Female 3 were shifted to Male 2’s enclosure. Female 3 and Female 4 were transferred to a different zoo six months after the initiation of the observation period (Table 1). The decision to shift the takins and reduce the enclosures occupied from three to two was a zoo management decision pertaining to logistics.

One-hundred-and-eight hours of preliminary observations were conducted on the captive herd of seven takins in March–April 2022 (Table 1). The ad libitum data from these observations, along with data provided in the literature was used to curate an ethogram for behavioural observations (Powell et al. 2012). A total of 37 behaviours were listed under five different categories, namely active, inactive, social affiliative, social aggression, and reproductive (Table 2).

To assess activity budgets, daily behavioural observations were collected on members of the captive herd using the instantaneous scan sampling method (Altman 1974). Hourly observations at 10-minute intervals were done by the observer from an elevated position. Observations were made 5–6 days per week, for 2–3 hours each day between 0700–1700 h. For the first three months, observations of the third enclosure were performed by a zookeeper after conducting an observer reliability test (Crockett 1996).

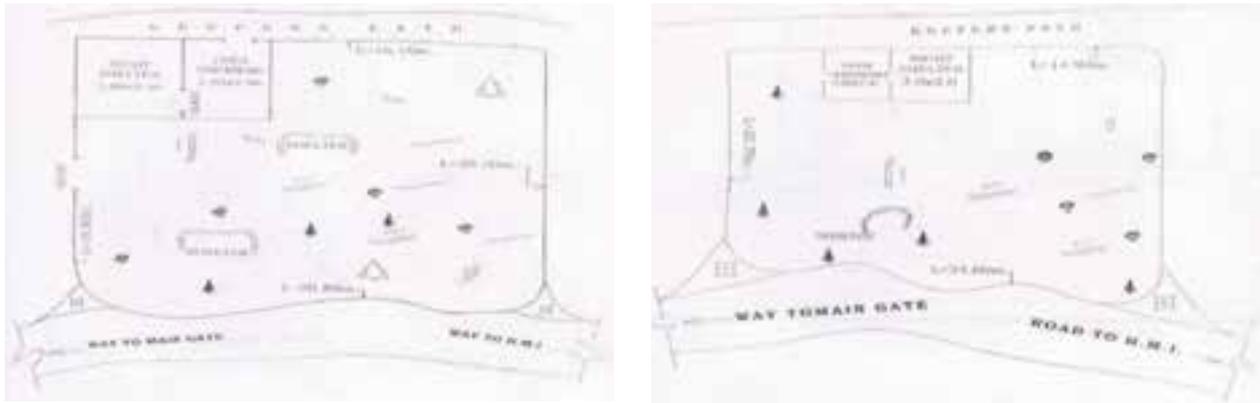


Figure 1. Takin enclosures at the Padmaja Naidu Himalayan Zoological Park.

Table 1. Mishmi Takin individuals housed at the Padmaja Naidu Himalayan Zoological Park.

	Animal	House name	Sex	Date of birth	Age as of 2023 (in years)	Stage	Dam	Sire	Date of acquisition
1.	Male 1	Danny	Male	19.iii.2016	7	Adult			20.i.2019
2.	Male 2	Rock	Male	11.ii.2016	7	Adult			20.i.2019
3.	Female 1	Claire	Female	18.iii.2016	7	Adult			20.i.2019
4.	Female 2	Ramona	Female	16.iii.2017	6	Adult			20.i.2019
5.	Female 3	Lucky	Female	29.iii.2020	3	Sub-adult	Claire	Danny	
6.	Female 4	Diana	Female	07.ii.2021	2	Calf	Ramona	Rock	
7.	Male 3	Canny	Male	25.i.2022	1	Calf	Claire	Danny	
8.	Female 5	Donna	Female	25.v.2023	0.5	Calf	Ramona	Danny	

The activity budgets of five takins (three males and two females) ranging 1–7 years old have been reported in this study. Female 2 got pregnant during the observation period and gave birth at the end of the observation period. Two female sub-adult takins (Females 3 & 4) were transferred to another zoo in the sixth month of the study period; hence, they couldn't be assessed further.

A total of 400 hours of behavioural data were collected in June 2022–May 2023, and subsequently categorised according to individual takins and seasons. Descriptive statistics were utilised to prepare activity budgets, which were represented graphically. The time that the members were out of sight has been excluded while calculating the time budgets, as the activities during that duration were not visible to the observer. The normality of the data was tested using the Shapiro-Wilk test. To examine potential differences between pregnant and non-pregnant females, the activity patterns of two adult females were compared using the Wilcoxon rank-sum test. For males, the Kruskal-Wallis test was applied to investigate potential age-related differences,

with post-hoc comparisons conducted by Bonferroni's method. Additionally, seasonal variations in activity patterns were assessed for the herd across four seasons: monsoon (June, July, August), autumn (September, October), winter (November, December, January), and summer-spring (March, April, May) using the Kruskal-Wallis test. February was excluded from the analysis to accommodate hormonal analysis conducted as part of the same study. Preliminary maternal care observations were made using ad libitum notes following Female 2's parturition in the last week of May 2023. Data compilation, sorting, and statistical analyses were done in MS Excel and R.

RESULTS

The overall activity budgets (Figure 2) of the zoo-housed Mishmi Takins showed that they spent 54.6% of their time in active behaviour, 42.2% in inactive behaviour, 2.4% in social affiliation, and 0.3% being socially aggressive and 0.3% of reproductive acts. Active

Table 2. Ethogram for behaviour observation of Mishmi Takin.

Behavior	Description
Inactive	
Ruminating	Movement of the mouth similar to chewing
Standing rest	Standing with its head lowered, facing the ground, or positioned straight
Sternal rest	Lying on the stomach, with head lowered or near ground level
Lateral rest	Completely resting on one side of its body, with head resting on the ground or on its back
Alert position	Being attentive with eyes open and fixated on the source
Bipedal stand	Standing on its hind limbs with forelimbs resting on the enclosure wall
Active	
Locomotion	Movement for a minimum of two steps
Foraging	Searching and sniffing foliage in the enclosure
Feeding	Actual consumption of food items and drinking water
Maintenance	Scratching the body with the hoof, licking the fur, rubbing the body against an erect object in the enclosure, shaking the head or entire body, self-nibbling, slowly rubbing the horns on an object without any force
Object manipulation	Investigates and moves around an object in the enclosure
Social aggression	
Head down	Displaying a lower head while drawing their rear legs forward, and arching their back
Head bud	Intertwining horns with force
Object horning	Thrashing vegetation, gouging large tree trunks with horns, and aggressively horning and manipulating inanimate objects inside the enclosures
Head shake	Shaking its head in the direction of another individual aggressively
Dominance posture	Standing rest position
Chasing	Pursuing another individual at a rapid pace
Submissive	Moving away from a charging individual
Social affiliation	
Social play	Juveniles running, jumping and head-butting each other
Contact with conspecifics	Face sniffing, nuzzling, licking and nudging
Snorting	Expelling air through the nose when threatened
Bellow	Sound coming from an open mouth as the call is produced deep in the throat
Maternal care	Suckling and protecting the calf
Facilitate nursing	Giving a call to the calf for nursing and allowing it to suckle
Allo-parenting	Non-maternal infant care, such as licking, protecting, nuzzling, and guiding by other members of the herd
Reproductive	
Flehmen	Sniffing the anogenital area, or urine, with head upright and nostrils flared
Mounting	Males attempting to mount females by throwing their forelegs onto the back of the females
Copulating	Occurs while mounting and is identified by agitated movements of the hind region
Following conspecific	Following the conspecific, especially after scent sampling
Others	Yawning, sneezing, defecating, and urinating
Out of sight	An animal cannot be observed from the data collector's location

behaviours entailed feeding (79.8%), locomotion (14%), maintenance (3.6%), and foraging (2.6%). Inactive behaviours included standing (43.14%), ruminating (31.2%), resting in sternal position (21.67%), resting in lateral position (1.52%), bipedal stands (0.96%), and alert (0.74%). In social aggression, there were 10 instances of head butt, six instances of chasing, one act of dominance and three acts of submission. Social affiliative behaviours included eight instances of social play, six instances of contact with conspecific, 18 instances of maternal care and two instances of female nursing. Vocalisations that were also included in social affiliation included 145 bellows and four snorts by the individuals. Reproductive behaviour included five instances of scent sampling, two instances of mounting and 15 instances of following.

Since feeding, resting, ruminating, and locomotion occupied the majority of the behaviours displayed, they were assessed further to examine whether these activities were affected by changing weather conditions (Figures 3 & 4). In the overall activity budget for the herd, feeding ($\chi^2 = 17.85$, $df = 3$, $p < 0.01$) and resting ($\chi^2 = 9.9$, $df = 3$, $p = 0.01$) showed a statistically significant difference across the four seasons. On assessing the time budgets of the members, comparatively, monsoons saw the highest percentage of time spent in feeding (females: 49% & males: 55%), followed by winters (females: 46.64% & males: 47.95%). This trend took a dip in autumn (females: 44% & males: 37%) and was the lowest in spring-summer (females: 40.97% & males: 39.42%). Herd members rested the highest percentage of time in spring-summer (females: 32.5% & males: 36%), followed by autumn (females: 30% & males: 31.7%). Monsoon saw a dip in resting (females: 26% & males: 31.4%), as did winters (females: 26% & males: 26.7%).

Wilcoxon rank-sum tests were conducted to compare the activity patterns (in percentage) between Female 1 and Female 2. Significant differences were observed in resting ($W = 0$, $p = 0.029$) and locomotion ($W = 16$, $p = 0.029$), indicating that the two females differed in the percentage of time spent on these activities. On examining their activity patterns, it was found that time utilised in resting was higher in Female 2 (33%) compared to Female 1 (24%), and time spent in locomotion was higher in Female 1 (14%) compared to Female 2 (6.6%). However, no significant differences were found for feeding ($W = 15$, $p = 0.057$) or ruminating ($W = 6$, $p = 0.68$).

For males, there were no significant differences among the three individuals except for locomotion patterns. The Kruskal-Wallis test revealed a statistically

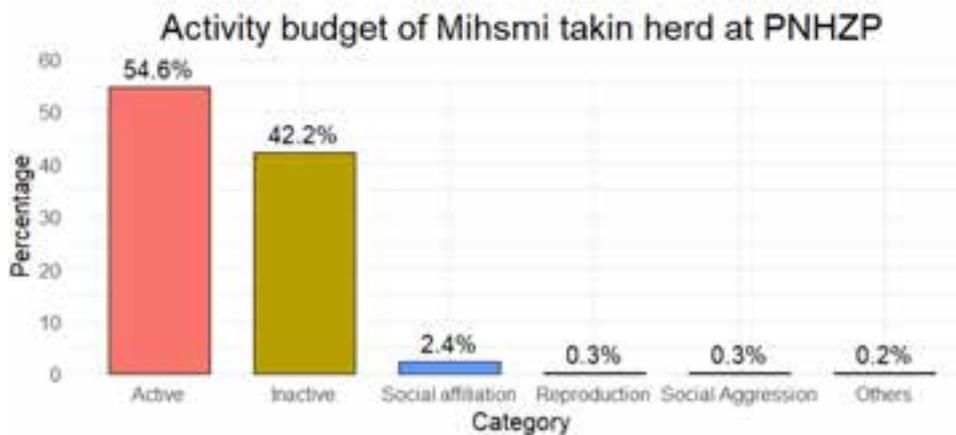


Figure 2. Activity budget of Mishmi Takin herd at the Padmaja Naidu Himalayan Zoological Park for one year.

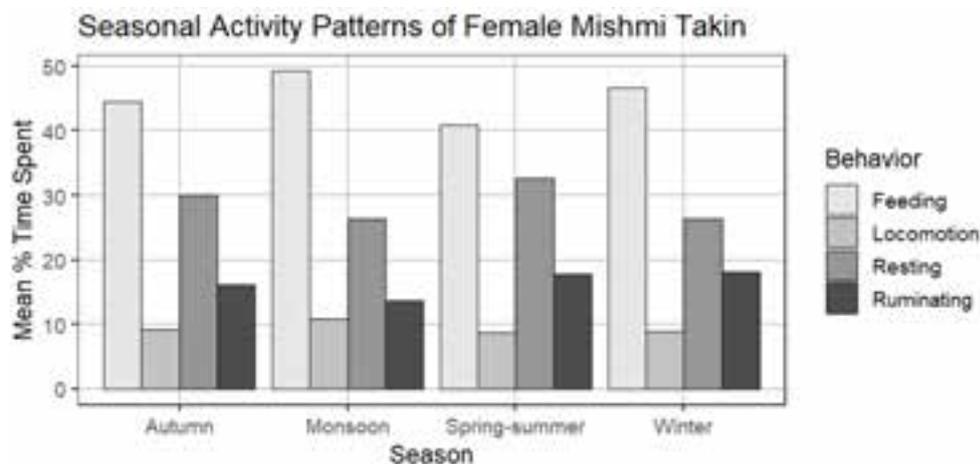


Figure 3. Selected behaviours for female takins at the Padmaja Naidu Himalayan Zoological Park.

significant difference in locomotion percentages among the three males ($\chi^2 = 6.5$, $df = 2$, $p = 0.03$). However, post-hoc pairwise comparisons using Dunn's test with Bonferroni adjustment found no statistically significant differences between any pairs of males (all adjusted p -values > 0.05). These results suggest that, while there maybe trends in locomotion activity in males, no specific pairwise differences were statistically robust after correcting for multiple comparisons.

Female 2 gave birth in the last week of May. After birthing, the mother immediately started licking the infant and kept guard. It sniffed the newborn takin from time to time. The infant stood up after almost 45 min and started suckling. It would spend time either sleeping or suckling. The mother was always in close vicinity of the newborn. These behaviours were prominent for 3–4 days after the takin's birth and began declining after a week.

DISCUSSION

The activity budgets of the captive herd of Mishmi Takin were assessed in this study at PNHZP. The study covers active daylight time observations. The individuals spent most of their time feeding, ruminating, resting and in locomotion. The effect of different seasons was also assessed and it was seen that feeding peaked during monsoons in both female and male members and females spent more time feeding as compared to males. This is in accordance with the findings of its wild counterpart, the Golden Takin, that spent 60–80% of their time feeding, resting and walking (Zeng & Song 2001) as well as its family group member, Bison *Bison bison*, in which lying, standing and feeding dominated 87.9% of the time budgets (Robitaille & Prescott 1993). Seasonal variations in feeding patterns can be attributed to availability of quality forage at different altitudes. Powell et al. (2013)

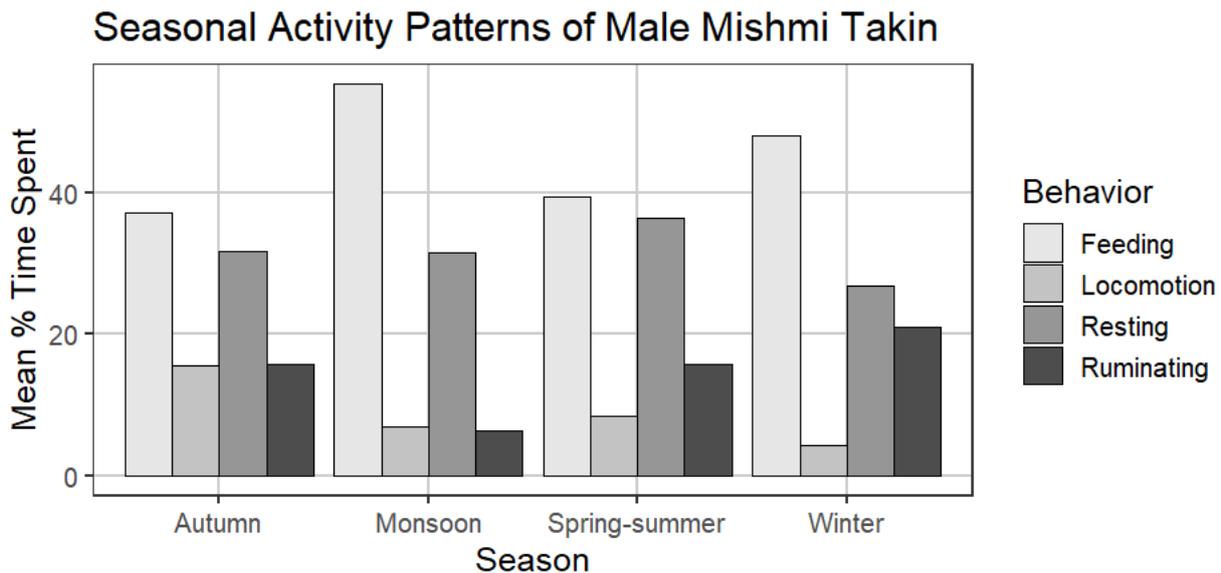


Figure 4. Selected behaviours for male takins at the Padmaja Naidu Himalayan Zoological Park.

reported that the captive takin herd in The Wilds in Cumberland, Ohio, spent 35% of their time feeding with females, comparatively spending more time than males in winter. Studies on activity budgets of the Bovidae family member, the Common Bushbuck *Tragelaphus scriptus decula*, revealed that they spent most of their time feeding, which was comparatively higher during the wet seasons as compared to the dry seasons (Bayih & Yihune 2018). Previous research on seasonal feeding patterns of another bovid family member, Bison *Bison bison*, has reported that diet quality and preferences peak from June to September in colder or wetter regions due to high abundance of quality forage (Craine 2021). In females, it was observed that the pregnant female (Female 2) spent comparatively more time resting than the non-pregnant female (Female 1). This could be attributed to a prepartum behavioural change, including increased transition from lying to standing or vice versa, among other tendencies such as seeking isolation, which facilitates a calm parturition and creates an optimal environment for birthing (Rørvang et al. 2018; Nervard et al. 2022).

Reproductive behaviour displayed by the takin herd in PNHZP constituted 0.3% of the annual activity budget, reflecting the limited temporal occurrence of reproductive activities outside the breeding season. Takins are seasonal breeders (Yoshida et al. 2024). The lack of display of reproductive behaviours could be attributed to the fact that these acts are only prominent during the breeding season. During the study period, 22 instances of such behaviours were recorded,

reflecting findings by Adkin et al. (2012), who observed that reproductive behaviours accounted for 0.01% to 1.1% of the time budget during a 2.5-year study of Sichuan Takin at Lincoln Park Zoo, Chicago. Flehmen is a common behaviour observed in bovids, such as Bison, characterised by lip curling while sniffing the vulva or urine of a female. Mounting in bovids, including Bison, is often the initial step of the copulatory sequence, typically followed by soft panting. However, this sequence is rarely completed as females often step away when the act begins (Estes 1974). In the observations conducted at PNHZP, these behaviours were exclusively performed by Male 1 and occasionally by Male 2. None of the females exhibited such behaviours during the study period.

Social aggression in the herd accounted for a small portion of the activity budget (0.3%), with only 20 instances recorded over a one-year period between Male 1 and adult female (Female 1) or juvenile male (Male 3). The low counts of aggression could be attributed to the captive conditions that are exceedingly different from wild conditions. Additionally, the placement of the two adult males into different enclosures could also lead to less aggressive counts. Aggressive behaviours are typically observed in bulls or bison during periods of male-male competition, often as part of dominance establishment. Serious fights are highly frequent, with passive avoidance frequently substituting physical confrontations, particularly during the rut (Estes 1974). In the current study, social affiliation, including vocalisations, made up 2.4% of the takins' activity budget. Similarly, in the study of the captive takin

herd at The Wilds, social behaviours were observed to constitute a very small percentage of the activity budget (<6%) (Powell et al. 2013).

This study at PNHZP had several limitations. Observations of the study sample were limited to behaviour in captive conditions. The sample size decreased from seven to five midway through the observation period due to the transfer of two sub-adult females. Additionally, the members were housed in separate enclosures, which prevented the exploration of collective herd behaviour, such as social hierarchical dynamics. The lactating and non-lactating females were also kept in separate enclosures, resulting in comparisons being divided by space and time. Furthermore, the maternal behaviour described in this study was based on ad libitum observation, limiting the depth of behavioural analysis. Future studies could focus on a more systematic investigation of mother-infant interactions to better understand this aspect of takin behaviour. The results of this study provide a preliminary understanding of the activity budgets of takins in captivity. Future research could further explore aspects such as diet preferences, enclosure utilisation, and social dynamics to create a more comprehensive framework for enrichment and welfare planning.

REFERENCES

- Adkin, A., D. Bernier & R.M. Santymire (2012). Characterizing the behavior and reproductive biology of zoo-housed Sichuan Takin *Budorcas taxicolor tibetana* using non-invasive techniques. *Theriogenology* 78(3): 483–494. <https://doi.org/10.1016/j.theriogenology.2012.02.006>
- Allen, G.M. (1940). The mammals of China and Mongolia. *American Museum of Natural History, New York* 2: 621–1350.
- Altmann, J. (1974). Observational study of behaviour: sampling methods. *Behaviour* 49: 227–67. <https://doi.org/10.1163/156853974X00534>
- Bayih, W. & M. Yihune (2018). Population status, feeding ecology and activity pattern of Common Bushbuck *Tragelaphus scriptus decula* in Sekele Mariam Forest, West Gojjam, Ethiopia. *Journal of Ecology and The Natural Environment* 10(5): 69–79. <https://doi.org/10.5897/JENE2018.0689>
- Crockett, C.M. (1996). Data collection in the zoo setting, emphasizing behavior, pp. 545–546. In: Kleiman, D. (ed.). *Wild Mammals in Captivity*. University of Chicago Press, Chicago.
- Craine, J.M. (2021). Seasonal patterns of bison diet across climate gradients in North America. *Scientific Reports* 11(1): 6829. <https://doi.org/10.1038/s41598-021-86260-9>
- Estes, R.D. (1974). Social organization of the African Bovidae. The behaviour of ungulates and its relation to management 1: 166–205.
- Lovari, S. & M. Apollonio (1994). On the rutting of the Himalayan Goral *Nemorhaedus goral*. *Journal of Ethology* 12: 25–34. <https://doi.org/10.1007/BF02350077>
- Mench, J.A. & G.J. Mason (1997). Behavior, pp. 127–142. In: Appleby, M.C. & B.O. Hughes (eds.). *Animal Welfare*. CAB International, Wallingford, CT.
- Neas, J.F. & R.S. Hoffmann (1987). *Budorcas taxicolor*. *Mammalian Species* No. 277. pp.1–7. <https://doi.org/10.2307/3503907>
- Nevard, R.P., S.D. Pant, J.C. Broster, S.T. Norman & C.P. Stephen (2022). Maternal behavior in beef cattle: The physiology, assessment and future directions—a review. *Veterinary Sciences* 10(1): 10. <https://doi.org/10.3390/vetsci10010010>
- Powell, D., B. Speeg, S. Li, E. Blumer & W. McShea (2013). An ethogram and activity budget of captive Sichuan Takin *Budorcas taxicolor tibetana* with comparisons to other Bovidae. *Mammalia* 77(4): 391–401. <https://doi.org/10.1515/mammalia-2012-0076>
- Robitaille, J.F. & J. Prescott (1993). Use of space and activity budgets in relation to age and social status in a captive herd of American Bison, *Bison bison*. *Zoo biology* 12(4): 367–379. <https://doi.org/10.1002/zoo.1430120407>
- Rørvang, M.V., B.L. Nielsen, M.S. Herskin & M.B. Jensen (2018). Prepartum maternal behaviour of domesticated cattle: a comparison with managed, feral, and wild ungulates. *Frontiers in Veterinary Science* 5: 45. <https://doi.org/10.3389/fvets.2018.00045>
- Reinhardt, V. (1985). Courtship behaviors among Musk-Ox males kept in confinement. *Zoo Biology* 4: 295–300. <https://doi.org/10.1002/zoo.1430040311>
- Song, Y.L., A.T. Smith & J. MacKinnon (2008). *Budorcas taxicolor*. The IUCN Red List of Threatened Species 2008: e.T3160A9643719. <https://doi.org/10.2305/IUCN.UK.2008.RLTS.T3160A9643719.en>. Accessed on 12 February 2026.
- Schaller, G.B., W. Pan Teng, Z. Qin, X.H. Wang & Shen'Heming (1986). Feeding behavior of Sichuan Takin *Budorcas taxicolor*. *Mammalia* 50: 311–322. <https://doi.org/10.1515/mamm.1986.50.3.311>
- Sharma, D., T. Wangchuk, G.S. Rawat & A.J.T. Johnsingh (2015). Takin, *Budorcas taxicolor*. In: Johnsingh, A.J.T. & N. Manjrekar (eds.). *Mammals of South Asia, Vol. 2*; Chapter 5. Orient BlackSwan, 766 pp.
- Yoshida, T., Y. Shimokawa, M. Ohta, M. Takayanagi & S. Kusuda (2024). Reproductive seasonality, estrous cycle, pregnancy, and the recurrence of postpartum estrus based on long-term profiles of fecal sex steroid hormone metabolites regarding zoo-housed female Golden Takins *Budorcas taxicolor bedfordi*. *Animals* 14(4): 571. <https://doi.org/10.3390/ani14040571>
- Zeng, Z.G., A.K. Skidmore, Y.L. Song, T.J. Wang & H.S. Gong (2008). Seasonal altitudinal movements of golden takin in the Qinling Mountains of China. *Journal Wildlife Management* 72: 611–617. <https://doi.org/10.2193/2007-197>
- Zeng Z. G., & Y.L. Song (2001). Daily activity rhythm and time budget of golden takin in spring and summer. *Acta Theriologica Sinica* 21(7): 13.





Extended distribution of *Nymphoides peltata* (S.G.Gmel.) Kuntze (Menyanthaceae) in Manipur, India

Aahen Chanu Waikhom¹ & Bimolkumar Singh Sadokpam²

^{1,2} Department of Life Sciences (Botany), School of Life Sciences, Manipur University, Canchipur, Manipur 795003, India.

¹ aahenchanu@manipuruniv.ac.in (corresponding author), ² bimolksadokpam1@gmail.com

Abstract: The present paper highlights the extended distribution of aquatic herb *Nymphoides peltata* (S.G.Gmel.) Kuntze and presents as a new addition to the flora of Manipur. This study also provides phenology, conservation status, and distribution of the recorded species.

Keywords: Aquatic herb, dimorphic leaves, invasive, new addition, perennial, Phayeng, phenology, rhizomatous herb.

Editor: Afroz Alam, Banasthali Vidyapith, Rajasthan, India.

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

Citation: Waikhom, A.C. & B.S. Sadokpam (2026). Extended distribution of *Nymphoides peltata* (S.G.Gmel.) Kuntze (Menyanthaceae) in Manipur, India. *Journal of Threatened Taxa* 18(2): 28413–28418. <https://doi.org/10.11609/jott.10056.18.2.28413-28418>

Copyright: © Waikhom & Sadokpam 2026. 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: None.

Competing interests: The authors declare no competing interests.

Author details: DR. AAHEN CHANU WAIKHOM is as guest faculty and working in the field of plant ecology and carbon sequestration in the Department of Life Sciences (Botany), Manipur University, Canchipur, Imphal. BIMOLKUMAR SINGH SADOKPAM is a research scholar working in the field of plant systematics and ethnobotany in the Department of Life Sciences (Botany), Manipur University, Canchipur, Imphal.

Author contributions: BSS—carried out field survey, manuscript drafting; ACW—carried out field survey, editing, conceptualization, revision and finalization of the manuscript.

Acknowledgements: The authors are grateful and express heartfelt gratitude to the head, Department of Life Sciences (Botany), School of Life Sciences, Manipur University, Canchipur for providing the necessary facilities for carrying out the present study. Lastly, we also would like to thank the villagers of Phayeng for their coordination rendering their help and support during the field survey.



INTRODUCTION

Nymphoides Ség., is a genus of truly freshwater aquatic dicot growing as a monospecific stand in the still water of ponds, lakes, and rivers, eutrophic, alkaline water (Ornduff 1966; van der Velde et al. 1979; Burks 2002; Mehrvarz & Nodehi 2016). It produces aerial flowers on stems and also has distinctive floating leaves. It is an aquatic genus comprising of 30–35 species (Cook et al. 1974), 40 species (Ho et al. 1995), and 50 species have been recorded so far across the globe (Tippery et al. 2008). Under the genus *Nymphoides*, 13 species and eight species been recorded from eastern Asia (Tippery et al. 2021), and India (Sivarajan & Joseph 1993), respectively. Till date, a total of 10 species have been reported so far from India: *Nymphoides peltata* (S.G.Gmel.) Kuntze, *N. aurantica* (Dalzell) (Kuntze), *N. parviflora* (Wall. ex G.Don) Tippery, *N. sivarajanii* K.T.Joseph, *N. indica* (L.) Kuntze, *N. macrosperma* K.V.Nair, *N. krishnakesara* K.T.Joseph & Sivar., *N. hydrophyllum* (Lour.) Kuntze, *N. balakrishnanii* P.Biju, Josekutty, Haneef & Augustine, *N. palyi* P.Biju, Josekutty, Haneef & Augustine (Sivarajan & Joseph 1993; Biju et al. 2016a,b; Tippery et al. 2021).

Most *Nymphoides* species occur in the tropical parts of the world (Wood 1983), but unlike other species, *N. peltata* is the only species occurring in moderately cold temperate areas (Meusal et al. 1978) and its distribution is restricted to temperate parts of Europe, Asia, and America. *Nymphoides peltata* is distributed in Europe (except the North), temperate regions of Asia, and also become naturalized in North America (Tutin 1972; Stuckey 1973; Smits et al. 1992). *Nymphoides peltata* is native to Eurasia but an invasive plant in the USA (Tippery et al. 2023). In India, *N. peltata* has been recorded from western Himalaya and Kashmir so far and it is well known for its distribution from India (Sivarajan & Joseph 1993). From Manipur, a total of two species under the genus *Nymphoides* have been reported, viz., *N. hydrophyllum* (Lour.) Kuntze and *N. indica* (L.) Kuntze (Agrawala et al. 2023) and the presently examined *Nymphoides peltata* is in addition to the flora of Manipur as the third species.

MATERIALS AND METHODS

Description of study site

Manipur is a part of the eastern Himalaya, lies in between 23.830–25.680 °N and 93.030–94.780 °E. Manipur separates India from Myanmar, which is a part of the northeastern corner of India. The state has a total geographical area of 22,327 km². Manipur is a hilly

state having two major regions as central valley and hilly region covering an area of about 10% and 90% of the total area, respectively.

Phayeng, the study site is located at 24.841 °N & 93.808 °E, Imphal West District, Manipur (Figure 1). This place is 14 km from Imphal, the capital of Manipur, at an altitude ranging 790–870 m. People of Phayeng were the aboriginal inhabitants of Manipur before the arrival of Meiteis and representing one of the indigenous people of Manipur (Parratt 1980). Forest of Phayeng is the largest sacred grove of Manipur, rich in biodiversity and a carbon neutral village, recognized as India's first carbon-positive settlement.

A brief field trip was carried out in Heiyu Park of Phayeng Village (Figure 1) of Manipur during 2024–2025. Herbarium specimens were prepared and mounted on a standard herbarium sheet following the standard procedure of Jain & Rao (1976). The prepared voucher specimens were deposited in Manipur University Museum of Plants (MUMP) and Botanical Survey of India (BSI), Eastern Regional Centre (Assam). Identification of the specimen was done by consulting relevant existing literature and databases (Nasir & Ali 1970–1995; Ho et al. 1995; POWO 2025; WFO 2025). Phenology, distribution along with conservation status were also provided briefly. Photographs of habits and dissected parts were captured from live specimens using SMZ160 Stereo Zoom Microscope and Sony Cyber-Shot DSC–HX10V.

RESULTS

Taxonomic Treatment

Nymphoides peltata (S.G.Gmel.) Kuntze, Revis. Gen. Pl. 2: 429. 1891; Ohwi, Fl. Jap. 742. 1965; Tutin in Tutin et al., Fl. Europ. 3: 68. 1972; Sivarajan & Joseph, Aquatic Bot. 45: 149. 1993; Ho & Ornduff, Fl. China 16: 141. 1995. (Menyanthaceae).

Description: Perennial aquatic rhizomatous herb; stem long, cylindrical, submerged, sometimes rooting from nodes; leaves dimorphic, floating, vegetative leaves alternate, ovate–orbicular, apex rounded, base deeply cordate, margin sinuate to entire, adaxially green, abaxially brownish red and glandular, 3–14 × 2–12 cm; petiole 30–280 cm; fertile leaves similar to vegetative leaves but smaller and subopposite or opposite, sheathing at base; petiole 5–10 cm; flowers clustered at node, 2–7 flowers in umbellate cluster, arising from axil, bisexual, distylous, pedicel 6.8–7 cm; sepals deeply 4–5 partite, elliptical–lanceolate, apex obtuse, abaxially purple

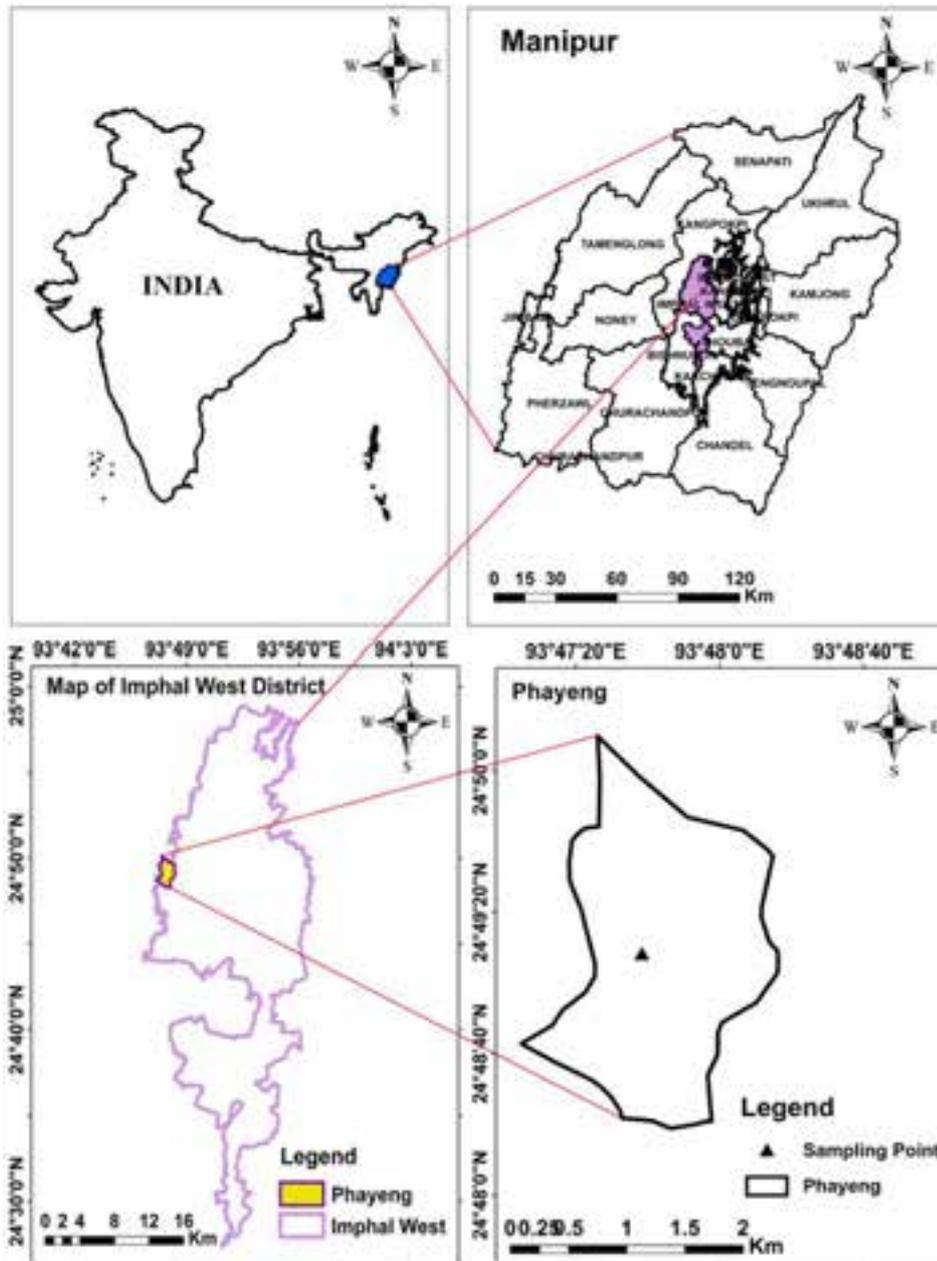


Figure 1. Geographical location of *Nymphoides peltata* (S.G.Gmel.) Kuntze (Menyanthaceae) in Manipur, India.

punctate, adaxially greenish, glabrous, 1.1–1.2 × 0.25–0.3 cm; petals as many as sepals, yellow, 2.7–2.8 × 1.4–1.5 cm, tube 0.6–0.7 cm long, whitish with tuft of hair at the middle, lobes 2.1 cm long, ovate, margins with broadly membranous and fimbriately toothed wings; stamens as many as corolla lobes, filaments 0.6–0.7 cm, inserted at the intersection of the lobes, anther bilobed, sagittate, basifixed, 0.4 cm long; pistil bottle-shaped, 1.6 cm long, style 0.9–1.0 cm, stigma bifid, folded irregularly at margins, ovary 0.4 × 0.3 cm, glandular, glands yellow, as many as petals, parietal placentation; capsule and

seed not known.

Flowering & Fruiting: May–October

Distribution: Algeria, China, Ghana, India (Western Himalaya, Kashmir, now in Manipur), Iran, Japan, Mongolia.

Specimen examined: India: Manipur, Imphal West District, Phayeng Village, Aahen Chanu Waikhom, 1.v.2025, 24.843 °N & 93.811 °E, altitude ca. 827 m, coll. No. 001.

Conservation Status: Least Concern (Lansdown 2014), Critically Endangered (de Bélair 2010).

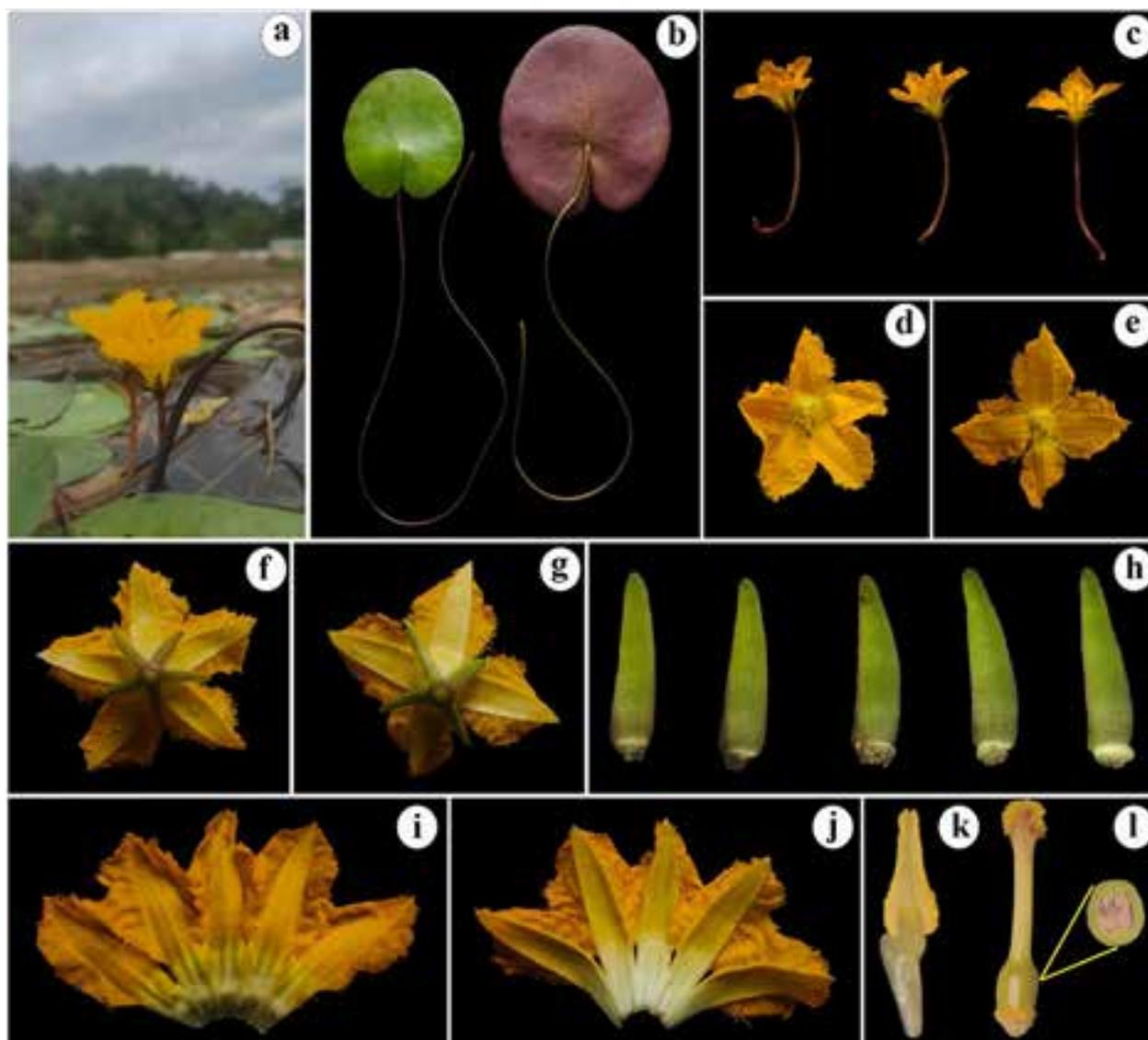


Image 1. *Nymphoides peltata* (S.G.Gmel.) Kuntze: a—Aquatic habit | b—adaxial and abaxial leaves | c—single flower | d & e—five and four petaled ventral view of flower respectively | f & g—five and four petaled dorsal view of flower, respectively | h—sepals | i—ventral view of corolla | j—dorsal view of corolla | k—anther | l—pistil along with T.S. of ovary. © Aahen Chanu Waikhom.

DISCUSSION

Nymphoides peltata possesses invasive nature; very difficult to control for having the potential to grow a new plant from rhizomes, stolons, detached leaves or seeds (Cook 1990). In 12 weeks, a single plant of *N. peltata* can produce over 100 new plants (Zhonghua et al. 2007). It has been declared as an invasive species in Sweden (NOBANIS 2005) and noxious weed in New Zealand and parts of North America (NWCB 2007). It is also known as yellow floating heart and fringed water lily which is a perennial hydrophyte of the Menyanthaceae family (Cheek 2018). It is also cultivated as an ornamental

plant in garden pools and aquaria (Allgayer & Teton 1987; Chester et al. 1996). *Nymphoides peltata* has the characteristic of a pioneer plant community which can colonise large areas through vegetative growth in a season (Brock et al. 1983). Bioactive compounds like 3,4,5-tri-O-caffeoylquinic acid (TCQA) isolated from the roots of *N. peltata* exhibit antioxidant and anti-wrinkling effects (Kim et al. 2023a). In India, the plant is used as a diuretic, anthelmintic, and antipyretic agent (Zhigzhitzhapova et al. 2021). Coumarin glycoside and iridoid glycosides derivatives isolated from the methanolic root extract of *N. peltata* shows the effect of wound healing (Kim et al. 2024).

CONCLUSION

Nymphoides peltata is native to some regions and has been introduced to other regions either accidentally or intentionally. It has been introduced to some part of the world like Sweden as an ornamental plant because of its beautiful yellow flower, even though it is native to regions like China and Japan to western Asia and central Europe (Weldon 2024). It is an invasive plant in the USA which is recognised as a noxious weed (Tippery et al. 2023). It can also form the dense stand like a mat, thus decreasing the water quality and reducing dissolved oxygen, thereby affecting the other associated species as well as in navigation and fishing (NatureServe 2008). *Nymphoides peltata* grows primarily in ponds, lakes producing both vegetative and reproductive propagules extensively in the easiest way. Introduction of this species in the present study site is not well known to the local people. *Nymphoides peltata* is invasive, posing serious threats to surrounding environments. This species produces profuse leaves covering almost the entire water surface, blocking sunlight, which creates a risk to other submerged aquatic plants and animals. Once introduced and naturalised in a particular habitat, the eradication of this plant is not an easy task. Community-based measures should be taken up so as not to disperse propagules to other habitats which might impose threats to other species.

Phytochemicals of *N. peltata* have been reported to be used as an ayurvedic medicine and in traditional Chinese medicine as a diuretic, antipyretic, or chloretic and to treat ulcers, snakebites, and edema. Moreover, it also has anti-inflammatory, anti-tumor, and anti-wrinkle properties (Kim et al. 2023b). Even though it has the ability to be invasive, it still has good phytochemical properties which can cure many diseases, so it can provide significant economic benefit not only for selling as an ornamental plant. People should be more practical in managing this plant in aquatic water bodies. Thus, we should be more aware of this species as a noxious weed or as a plant which have medicinal properties. We should explore more ethnobotanical aspects of *N. peltata*

REFERENCES

- Agrawala, D.K., R. Gogoi, S.S. Dash, J.S., Jalal, G. Krishna, A. Kumar, N. Odyuo, H.N. Sharma, P.K. Bhardwaj, L. Hepuni, A. Kar, B.B.T. Tham & L.R. Meitei (2023). Flora of Manipur—a pictorial guide. In: Mao, A.A. & P.K. Mukharjee (eds) Botanical Survey of India, Kolkata and Institute of Bio-resources & Sustainable Development, Ministry of Science and Technology. Govt. of India, New Delhi, 298 pp.
- Allgayer, R. & J. Teton (1987). *The Complete Book of Aquarium Plants*. Weidenfeld & Nicolson, Ward Lock, London, 157 pp.
- Biju, P., E.J. Josekutty, K.A.R.M. Haneef & J. Augustone (2016a). *Nymphoides balakrishnanii* sp. nov. (Menyanthaceae). A New Species from the Lateritic Plateau of Southern Western Ghats, India. *International Journal of Advanced Research* 4(7): 799–803. <https://doi.org/10.21474/IJAR01/945>
- Biju, P., E.J. Josekutty, K.A.R.M. Haneef & J. Augustone (2016b). A new species of *Nymphoides* Séguier (Menyanthaceae) from the lateritic plateau of South India. *Taiwania* 61(3): 218–220. <https://doi.org/10.6165/tai.2016.61.218>
- Brock, C.M., G.H.P. Arts, I.L.M. Goossen & A.H.M. Rutenfrans (1983). Structure and annual biomass production of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae). *Aquatic Botany* 17: 167–188. [https://doi.org/10.1016/0304-3770\(83\)90056-6](https://doi.org/10.1016/0304-3770(83)90056-6)
- Burks, K.C. (2002). *Nymphoides cristata* (Roxb.) Kuntze, a recent adventive expanding pest in Florida. *Castanea* 67: 206–211.
- Cheek, M.D. (2018). First confirmed record of *Nymphoides peltata* (SG Gmel.) Kuntze (Menyanthaceae) naturalised in southern Africa. *Bothalia–African Biodiversity & Conservation* 48(1): 1–4.
- Chester, E.W., B.E. Wofford, L.E. McKinney & D. Campbell (1996). Rare and noteworthy vascular plants from the Fort Campbell Military Reservation, Kentucky and Tennessee. *SIDA, Contributions to Botany* 17(1): 269–274.
- Cook, C.D.K. (1990). Seed dispersal of *Nymphoides peltata* (S.G.Gmelin) O. Kuntze (Menyanthaceae). *Aquatic Botany* 37: 325–340.
- Cook, C.D., B.J. Gut, E.M. Rix & J. Schneller (1974). *Water plants of the world: a manual for the identification of the genera of freshwater macrophytes*. Springer Science & Business Media.
- De Bélair, G. (2010). *Nymphoides peltata* (Pan–Africa assessment). The IUCN Red List of Threatened Species 2010: e.T164309A5821218. Accessed on 27.v.2025.
- Ho, T.N., R. Ornduff, Z.Y. Wu, P.H. Raven & D.Y. Hong (1995). Menyanthaceae Eds Flora of China 16 Science Press, Beijing, and Missouri Botanical Garden Press St.
- Jain, S.K. & R.R. Rao (1976). *A Handbook of Field and Herbarium Methods*. Today & Tomorrow's Printers and Publishers, New Delhi, 158 pp.
- Kim, T.Y., N.J. Park, H. Jegal, J.H. Paik, S. Choi, S.N. Kim & M.H. Yang (2023a). *Nymphoides peltata* root extracts improve atopic dermatitis by regulating skin inflammatory and anti-oxidative enzymes in 2, 4-dinitrochlorobenzene (DNCB)-induced SKH-1 hairless mice. *Antioxidants* 12(4): 873.
- Kim, T.Y., N.J. Park, B.G. Jo, B.S. Lee, M.J. Keem, T.H. Kwon, K.H. Kim, S.N. Kim & M.H. Yang (2023b). Anti-Wrinkling Effect of 3,4,5-tri-O-caffeoylquinic Acid from the Roots of *Nymphoides peltata* through MAPK/AP-1, NF- κ B, and Nrf2 Signaling in UVB-Irradiated Cells. *Antioxidants* 12: 1899. <https://doi.org/10.3390/antiox12101899>
- Kim, T.Y., B.S. Lee, B.G. Jo, S.P. Heo, Y.S. Jung, S.N. Kim, K.H. Kim & M.H. Yang (2024). Iridoid glycosides and coumarin glycoside derivatives from the Roots of *Nymphoides peltata* and their in vitro wound healing properties. *International Journal of Molecular Sciences* 25: 1268. <https://doi.org/10.3390/ijms25021268>
- Lansdown, R.V. (2014). *Nymphoides peltata*. The IUCN Red List of Threatened Species 2014: e.T164309A42398483. <https://doi.org/10.2305/IUCN.UK.2014-1.RLTS.T164309A42398483.en>. Accessed on 27.v.2025.
- Mehrvarz, S.S. & M.A. Nodehi (2016). A review of the genus *Nymphoides* (Menyanthaceae) in Iran. *Phytotaxa* 257(3): 261–270. <https://doi.org/10.11646/phytotaxa.257.3.4>
- Meusel, H., E.J. Jäger, S. Rauschert & E. Weinert (eds.). (1978). *Vergleichende Chorologie der zentraleuropäischen Flora: Karten*. VEB Gustav Fischer Verlag.
- Nasir, E. & S.I. Ali (eds.) (1970–1995). *Flora of West Pakistan*. Islamabad, Karachi, 131 pp.
- NatureServe (2008). NatureServe Explorer: An online encyclopedia of life, Version 7.0. Arlington, VA: Nature Serve. <http://www.natureserve.org/explorer>
- NOBANIS (2005). Regional portal on invasive alien species. North European and Baltic Network on Invasive Alien Species. <http://www.nobanis.org>

- www.nobanis.org/speciesInfo.asp?taxalD=3461
- NWCB (2007)**. Written Findings of the State Noxious Weed Control Board – Class B – B– Designate Weed: Yellow Floating Heart (*Nymphoides peltata*) (Gmel.) Kuntze. Olympia, WA: Washington State Noxious Weed Control Board. Olympia, USA. http://www.nwcb.wa.gov/weed_info/yfloatingheart.html
- Ornduff, R. (1966)**. The origin of dioecism from heterostyly in *Nymphoides* (Menyanthaceae). *Evolution* 20: 309–314.
- Parratt, S.N. (1980)**. *The Religion of Manipur: Beliefs, Rituals and Historical Development*. Firma KLM (Pvt.) Ltd., Calcutta, India, 218 pp.
- POWO (2025)**. Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. Published on the Internet; <https://powo.science.kew.org/>. Retrieved 10.vii.2025.
- Sivarajan, V.V. & K.T. Joseph (1993)**. The genus *Nymphoides* Séguier (Menyanthaceae) in India. *Aquatic Botany* 45(2–3): 145–170.
- Smits, A., G. Schmitz & G. van der Velde (1992)**. Calcium-dependent lamina production of *Nymphoides peltata* (S.G. Gmel.) O. Kuntze (Menyanthaceae): implications for distribution. *Journal of Experimental Botany* 43: 1273–1281. <https://doi.org/10.1093/jxb/43.9.1273>
- Stuckey, R.L. (1973)**. The introduction and distribution of *Nymphoides peltatum* (Menyanthaceae) in North America. *Bartonia* 42: 14–23. <https://doi.org/10.2307/41610364>
- Tippery, N.P., D.H. Les, D.J. Padgett & S.W.L. Jacobs (2008)**. Generic circumscription in Menyanthaceae: a phylogenetic evaluation. *Systematic Botany* 33: 598–612. <https://doi.org/10.1600/036364408785679851>
- Tippery, N.P., K.C. Pawinski & A.J. Jeninga (2021)**. Taxonomic evaluation of *Nymphoides* (Menyanthaceae) in eastern Asia. *Blumea–Biodiversity, Evolution and Biogeography of Plants* 66(3): 249–262. <https://doi.org/10.3767/blumea.2021.66.03.08>
- Tippery, N.P., N.E. Harms, M.F. Purcell, S.H. Hong, P. Häfliger, K. Killoy & R.A. Thum (2023)**. Assessing the genetic diversity of *Nymphoides peltata* in the native and adventive range using microsatellite markers. *Biological Invasions* 25(12): 3949–3963. <https://doi.org/10.1007/s10530-023-03151-y>
- Tutin, T.G. (1972)**. *Nymphoides* Séguier pp. 67–68. In: Tutin, T.G., Heywood, V.H., Burges, N.A., Moore, D.M., Valentine, D.H., Walters, S.M. & Webb, D.A. (eds.) *Flora Europaea* 3. Cambridge University Press, Cambridge, UK.
- van der Velde, G., T.G. Giesen & L. van der Heijden (1979)**. Structure, biomass and seasonal changes in biomass of *Nymphoides peltata* (Gmel.) O. Kuntze (Menyanthaceae), a preliminary study. *Aquatic Botany* 7: 279–300.
- Weldon, J. (2024)**. Modelling the risks of *Nymphoides peltata* spread in Swedish lakes. Rapport/Sveriges lantbruksuniversitet, Institutionen för vatten och miljö, (2024): 15).
- WFO (2025)**. World Flora Online. Published on the Internet; <http://www.worldfloraonline.org>. Accessed on 10.vii.2025.
- Wood, C. E. (1983)**. The genera of Menyanthaceae in the southeastern United States. *Journal of the Arnold Arboretum* 64(3): 431–445. <https://doi.org/10.5962/bhl.part.27411>
- Zhigzhitzhapova, S.V., E.P. Dylenova, E.P. Nikitina, Z.A. Tykheev, E.T. Pintaeva, L.D. Radnaeva & G.T. Tsybekmitova (2021)**. Composition of Fatty Acids from *Nymphoides peltata*. *Chemistry of Natural Compounds* 57(4): 743–745. <https://doi.org/10.1007/s10600-021-03463-2>
- Zhonghua, W., Y. Dan, T. Manghui, W. Qiang & X. Wen (2007)**. Interference between two floating-leaved aquatic plants: *Nymphoides peltata* and *Trapa bispinosa*. *Aquatic Botany* 86(4): 316–320. <https://doi.org/10.1016/j.aquabot.2006.11.008>



Impatiens chamchumroonii (Balsaminaceae), a new record for the flora of Vietnam

Cuong Huu Nguyen¹ , Diep Quang Dinh² , Dinh Duc Nguyen³  & Keooudone Souvannakhoummane⁴ 

¹Vietnam National University of Forestry, Xuan Mai, Hanoi, 100000, Vietnam.

²Nong Lam University - Hochiminh City, Linh Xuan, Hochiminh City, 700000, Vietnam.

³Faculty of Agriculture and Forestry, Tay Nguyen University, Dak Lak, 630000, Vietnam.

⁴Faculty of Natural Science, National University of Laos, Dongdok Campus, Xaythany District, Vientiane Capital, 01000, Laos.

¹nguyenhuucuong.tvr@gmail.com (corresponding author), ²dqdiep@gmail.com, ³nddinh@ttn.edu.vn,

⁴k.souvannakhoummane@nuol.edu.la

Abstract: The plant species *Impatiens chamchumroonii* of the Balsaminaceae family was recorded for the first time in Vietnam. They are collected from Dak Lak province hill areas in 2023. The voucher specimens of this species are housed in the herbarium of the Vietnam National University of Forestry (VNF). The species is presented with a taxonomic description, ecology, geographical distribution, occurrence in Vietnam, and field photographs of new records.

Keywords: Dak Lak Province, flowering plant, geographical distribution, new country record, plant taxonomy.

The genus *Impatiens* L. (Balsaminaceae) comprises about over 1,000 species, ranking as the 18th largest genus among flowering plants (Mabberley 2017; POWO 2025). Its distribution extends across tropical and subtropical Africa and Asia, with the centre of diversity and probable origin in southern China (Grey-Wilson 1980; Chen et al. 2007). In Vietnam, the recognized diversity within the genus *Impatiens* has expanded significantly over the past two decades, as evident from recent studies reported with eight species *I. purpureifolia* S.H.Huang & Y.M.Shui (Shui et al. 2011), *I. kamtilongensis* Toppin (Vu et al. 2015), *I. parvisepala* S.X.Yu & Y.T.Hou (Hoang et al. 2015), *I. napoensis* Y.L.Chen (Nguyen et al. 2018), *I.*

siculifera Hook.f. (Pham et al. 2019), *I. monticola* Hook.f. (Nguyen et al. 2021), *I. lobulifera* (Quan et al. 2024), and *I. damrongii* (Ha et al. 2025), which raised the number to 44 species in Vietnam (Tardieu 1944; Nguyen et al. 2000; Pham 2003). A field survey in primary and secondary evergreen broad-leaved lowland forests of central highland area in September 2023, the second and third authors collected an unusual species of *Impatiens*. After careful morphological examination of the species and analysis of available literature as well as collections of different herbaria, namely, HN, LE, VNF, and VNM (all acronyms following Thiers (2024), we identified this plant as *Impatiens chamchumroonii* Suksathan & Ruchis., which was previously reported from Thailand (Suksathan & Ruchisansakun 2022). This is the first record of this species in the flora of Vietnam, the data for which are presented below.

MATERIAL AND METHODS

All newly collected and studied herbarium specimens are presently stored in the herbarium of the Vietnam National University of Forestry (VNF). Color photos of plants were taken in natural habitats. Morphological

Editor: Inocencio Buot Jr., University of the Philippines Los Banos, Laguna, Philippines.

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

Citation: Nguyen, C.H., D.Q. Dinh, D.D. Nguyen & K. Souvannakhoummane (2026). *Impatiens chamchumroonii* (Balsaminaceae), a new record for the flora of Vietnam. *Journal of Threatened Taxa* 18(2): 28419–28423. https://doi.org/10.11609/jott.9719.18.2.28419-28423

Copyright: © Nguyen et al. 2026. 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: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: Authors would like to thank Mr. Tran Quoc An for his kind help during the fieldwork.

observations and measurements were made on living plants, dried specimens, and alcohol-preserved materials. Morphological characters were described using the terminology proposed by Shui et al. (2011) and Ruchisansakun et al. (2018).

RESULTS

Impatiens chamchumroonii Suksathan & Ruchis.; *Impatiens* Thailand 57 (2022). – Type: *R. Pooma*. W.J.J.O. de Wilde, B.E.E. Duyffjes, V. Chamchumroon & K Phattarahirankanok 2506 (holo BKF; iso L.). Thailand, Mukdahan province, Dong Luang, Ban Nalak, mixed deciduous forest slope, 160 m elevation, 24.viii.2001.

Description (Images 1 & 2): Lithophytic annual herb, 20–70 cm tall. Stem erect, glabrous or finely pubescent, when young: hypocotyl simple, elongate, 1–2 cm in diameter, epicotyl laxly branched, sometimes slightly zigzag in upper parts. Leaves spirally arranged, more or less congested at top of stem when young; petiole 1–3 cm long; lamina membranaceous, elliptic, 9–12 × 3.5–6.6 cm, apex acute, base rounded to cuneate, often asymmetric, with a pair of ellipsoid glands at or above the base, red to purple or with a white band along midrib adaxially, pale green abaxially, finely pubescent on both surfaces, margin crenate- serrate. Lateral main veins 12–14 pairs. Inflorescences axillary. Flowers solitary or in 2-flowered fascicles; bracts minute, linear. Flowers white with pinkish purple lower petals, often distorted, 1.5–2 cm wide, lower sepal and lateral united petals well-spaced and forming an elliptic window on each side: pedicel 10–27 mm long. Finely pubescent. Lateral sepals 4: outer pair yellowish white, obliquely oblong-obovate, 9.5–12.5 × 5–6 mm, apex apiculate, upper margins connate almost to the tip, glabrescent: inner pair minute, falcate, ca 1.5 mm long. Lower sepal bucciniform, yellowish, inside with many orange red cross-stripes that are visible through the open lateral windows, ca 9 × 7.5 mm, ca 5 mm deep, apex apiculate, abruptly constricted then hooked and inflated into a ca 5 mm long, white bilobed spur, each lobe scorpion tail-like with an acute, knob-like gland at apex. Dorsal petal white, broadly elliptic to obovate, 7–11 × 5–7 mm, apex emarginate-mucronate, midvein with a low, indistinct crest in the middle. Lateral united petals connate, clawed to 3.6 mm long upper petals white (or slightly yellow) with yellow base, often subequal, broadly obovate to suborbicular, 5–5.5 × 4.3–7.3 mm, apex rounded. Lower petals white to purplish blue, base white with two red stripes, broadly ovate to compressed obovate in outline, 13.5–17 × 12–18 mm, apex bilobed to 1/3–1/2 of its length, lobe apex emarginate, base with a white, low,

triangular keel. Stamen ca 5.3–5.5 mm long; anthers pale yellow. Ovary 4-carpellate, glabrous, ca 3.3 mm long. Fruit oblong-clavate, ca 2 cm long.

Distribution: Thailand (Mukdahan), Vietnam (Dak Lak province, Nam Ka commune).

Habitat: This species is found in Thailand, at elevations of 160 m, in mixed deciduous forest slope. In Vietnam it was observed in secondary evergreen broad-leaved forests, grows in areas with many exposed rocks, next to paths with a canopy cover of 0.1–0.3, near the forest along streams in association with *Lagerstroemia calyculata*, *Cratoxylon formosum*, *Vitex pinnata*, *Colona thorelli*, *Canarium subulatum*, *Irvingia malayana*, *Walsura robusta*, *Wrightia annamensis*, *Aporosa villosa*, *Ficus racemosa*, *Draceana cambodiana* at elevations of 400–450 m.

Specimens examined: Vietnam, Dak Lak province, Nam Ka commune, grows in moist shady places near waterfalls, along streams and occasionally on the rocky crevices covered by evergreen broad-leaved forests, around point 12.298 °N, 108.040 °E, at elevations of about 450 m, 12 September 2023, Dinh Quang Diep, Nguyen Duc Dinh (VNF: NK35).

Note: *Impatiens chamchumroonii* was first described in 2001, with its distribution initially reported as being endemic to the Dong Luang counties in Mukdahan Thailand. *Impatiens chamchumroonii* is somewhat similar to *I. calcicola* Craib in morphology of stem, leaves but differs in having distorted flower (vs. never distorted in *I. calcicola*), lower sepal and lateral united petals well-spaced and forming an elliptic window on each side (vs. no window in *I. calcicola*) and different spur shapes (slender with ellipsoid gland at apex in *I. calcicola* vs scorpion tail-like with an acute, knob-like gland at apex in *I. chamchumroonii*). Plants of *I. chamchumroonii* in Vietnam have minor differences from the Thailand type specimens, including lower petals white to purplish blue (vs. pinkish purple to purplish blue), flowers in September–October (vs. July–August), and habitat in the mountainous area around 450 m elevation (vs. 145–160 m alt.).

REFERENCES

- Chen, Y.L., S. Akiyama & H. Ohba (2007). Balsaminaceae, pp. 43–113. In: Wu, Z.Y., P.H. Raven & D.Y. Hong (eds.). *Flora of China, 12 (Hippocastanaceae through Theaceae)*. Science Press, Beijing & Missouri Botanical Garden Press, St. Louis, USA, 475 pp.
- Chen, Y., J. Chen, Q.Q. Yong, T.H. Yuan, Q. Wang, M.J. Li, S.W. Long & X.X. Bai (2023). Species diversity and geographical distribution patterns of Balsaminaceae in China. *Diversity* 15: 1012. <https://doi.org/10.3390/d15091012>
- Grey-Wilson, C. (1980). *Impatiens of Africa*. Balkema, Rotterdam, Netherlands, viii + 235 pp.



Image 1. *Impatiens chamchumroonii* Suksathan & Ruchis.: A—Plants in natural habitat | B—Plant (pressed specimen) . C, D, E, F, G—Flowers. views from different sides. Photos by Diep Dinh Quang, correction & design by Cuong Huu Nguyen.



Image 2. *Impatiens chamchumroonii* Suksathan & Ruchis. Flowers (pressed specimen). Photos by Diep Dinh Quang, correction & design by Cuong Huu Nguyen.

- Dang, V.H., L.V. Averyanov & C.H. Nguyen (2025). *Impatiens damrongii* (Balsaminaceae), a new record for the flora of Vietnam. *Journal of Threatened Taxa* 17(4): 26558–26561. <https://doi.org/10.11609/jott.9172.17.2.26558-26561>
- Hoang, T.S., N.B. Trinh, Q.H. Nguyen, V.V. Pham & T.V.A. Nguyen (2015). *Impatiens parvisepala* (Balsaminaceae): a newly recorded from Vietnam. *Vietnam Journal of Forest Science* 4: 4018–4020.
- Mabberley, D.J. (2017). *Mabberley's Plant Book—A Portable Dictionary of Plants, their Classification and Uses, 4th Edition*. Cambridge University Press, Cambridge, 1102 pp.
- Nguyen, H.C., L.V. Averyanov, A.A. Egorov & V.L. Nguyen (2021). *Impatiens monticola* (Balsaminaceae), a newly recorded species for the flora of Vietnam. *Botanicheskii Zhurnal (Moscow & St. Petersburg)* 106(10): 1036–1040.
- Nguyen, S.K., Y.H. Tong & N.H. Xia (2018). *Impatiens napoensis* (Balsaminaceae): a newly recorded species for the flora of Vietnam. *Journal of Tropical and Subtropical Botany* 26: 545–548. <https://doi.org/10.11926/jtsb.3905>
- Nguyen, T.H & R. Kiew (2000). New and interesting plants from Ha Long Bay, Vietnam. *The Gardens' Bulletin, Singapore* 52: 185–202.
- Pham, H.H. (2003). *An Illustrated Flora of Vietnam, Vol. 2*. Ho Chi Minh, Vietnam, 298–306.
- Pham, T.T., V.T. Do, T.T. Nguyen, T.T. Phung & V.T. Pham (2019). *Impatiens siculifera* (Balsaminaceae): a new record for the flora of Vietnam. *Acta Phytotaxonomica et Geobotanica* 70: 63–66. <https://doi.org/10.18942/apg.201817>
- Plants of the World Online (2022). *Impatiens chamchumroonii* Suksathan & Ruchis.: The world list of Impatiens species. <https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:77336882-1>. Accessed on 21.ii.2026
- Quan, N.C., L.V. Averyanov, H.D. Vo, D.H. Nguyen, H.V. Dang, Y.T. Nguyen, L.V. Nguyen & C.H. Nguyen (2024). New species, *Impatiens lobulifera* (Balsaminaceae) in the flora of Vietnam. *Vietnamese Academy of Forest Sciences* 1: 3–9.
- Ruchisansakun, S., P. Suksathan, T. van der Niet, E.F. Smets, Saw-Lwin & S.B. Janssens (2018). Balsaminaceae of Myanmar. *Blumea* 63: 199–267. <https://doi.org/10.3767/blumea.2018.63.03.01>
- Shinobu A., O. Hideaki & S.K. Wu (1996). Further Notes of *Impatiens* (Balsaminaceae) from Yunnan, China. *Bulletin of the National Museum of Nature and Science Series B* 22(4): 135–144.
- Shui, Y.M., S. Janssens, S.H. Huang, W.H. Chen & Z.G. Yang (2011). Three new species of *Impatiens* L. from China and Vietnam: preparation of flowers and morphology of pollen and seeds. *Systematic Botany* 36(2): 428–439. <https://doi.org/10.1600/036364411X569615>
- Suksathan, P. & S. Ruchisansakun (2022). *Impatiens of Thailand*. Natural History Publications, Borneo, Thailand, 396 pp.
- Tardieu, B.M. (1944). Les *Impatiens* d'Indochine, repartition, affinités et description d'espèces nouvelles. *Notulae Systematicae* 11: 169–185.
- Thiers, B.M. (2024). Index Herbariorum available at <http://sweetgum.nybg.org/science/ih/>. Accessed on 04 August 2025. (all acronyms following Thiers 2024).
- Vu, T.C., T.T.H. Nguyen, H.Q. Bui & P. Suksathan (2015). A new record of *Impatiens kamtilongensis* Toppin (Balsaminaceae) for Vietnam flora. *Academia Journal of Biology* 37(3): 332–335. <https://doi.org/10.15625/0866-7160/v37n3.6967>



known distribution of this fern group in the Indian subcontinent.

Collection of plant materials

The collection was made during the period from June 2023–December 2025 from different locations (Tilhari Nagar, Amboli, Panhala, Gargoti, Radhanagari, Mahabaleshwar, and Lonavala) of the northern Western Ghats. However, the collection of *Arachniodes sledgei* was made exclusively from the forests of Gargoti in the Kolhapur District of Maharashtra.

Identification

The collected plant materials were processed in the laboratory by cleaning, pressing, and preparing herbarium specimens following standard botanical methods. Identification was carried out through detailed morphological examination of vegetative and reproductive characters such as rhizome scales, frond architecture, pinnae & pinnule morphology, venation pattern, sori arrangement, and indusium characteristics under a stereomicroscope. The specimens were identified by consulting relevant taxonomic literature, including Manickam & Irudayaraj (1992) and Fraser-Jenkins et al. (2018), and further confirmed by comparison with authenticated voucher specimens available at the JCB herbarium. The voucher specimens: SMPJAP 1001 and 1002 were deposited in the BARO herbarium of the Department of Botany, The Maharaja Sayajirao University of Baroda and SMPJAP 1003 and 1004 at BJB, Herbarium of the Department of Botany, Hon. Balasaheb Jadhav Arts, Commerce and Science College, Ale.

RESULTS

Taxonomic treatment

Arachniodes sledgei Fraser-Jenk., Taxon. Revis. Three Hundred Indian Subcont. Pterid. 323–324. 2008; Fraser-Jenkins et al., An Annot. Check. Ind. Pterid. Part-II. 205–206. 2018.

Type: from Sri Lanka, Corbet's Gap, 1,320 m, W.A. Sledge 559, 9.12.1950, BM.

Arachniodes tripinnata (Goldm.) Sledge, Bull. Brit. Mus. (Nat. Hist.), Bot. 5: 41. 1973; Manickam & Irudayaraj, Pterid. Fl. W. Ghats. 219. 1992 & Pterid. Flora Nilgiris, 2003; Madhusoodanan., Handb. Ferns and Fern allies Kerala. 2015; Rajagopal & Bhat, Pterid. Karnataka St., Ind. 2016.

Arachniodes coniiifolia (T.Moore) Ching, Acta Bot. Sin. 10: 257 (1962); Nair et al., J. Econ. Taxon. Bot. 18: 449–476. 1994; Nayar & Geevarghese, *Fern F. Malabar*, 1993.

Plant terricolous or saxicolous, medium-sized herb, reaching a height up to 120 cm; rhizome 2–3 cm long, 5–15 mm thick, erect, dark brown, densely scaly; scales 5–10 mm long, 2–3 mm broad, concolorous, brown-black, linear-lanceolate, apex long acuminate, base broad, margin toothed; fronds monomorphic, ovate-deltoid, dark green; stipe 30–40 cm long, green when young, becoming brown at maturity, adaxially grooved, abaxially round, covered with brown scales; stipe scales same as of rhizome; lamina 70–80 cm long, 15–20 cm wide, bipinnate-tripinnate, ovate-deltoid, dark green, glossy above, with 10–12 pairs of pinnae; *rachis* adaxially grooved, abaxially round, covered with brown scales; *rachis* scales similar to that of rhizome; pinnae 7–10 cm long, 3–5 cm wide, ovate-deltoid, alternately arranged, apex acuminate, base cuneate, margin lobed, 5–8 pairs or pinnules; pinnules 1–1.5 cm, 5–8 mm wide, oblong-lanceolate, dark green, acroscopically lobed, basiscopically less lobed; texture coriaceous; *veins* forked, free, 2–3 pairs, reaching up to margin; *sori* at the base of lobe, 8–12 per pinnae, reniform or orbicular, indusiate; indusium reniform or orbicular, thin, membranaceous, pale green at young, brown at maturity, more or less persistent; spores 30 x 35 µm in diameter, trilete, brown, ellipsoid or planoconvex with thinly folded perine.

Global distribution: India, Indonesia, Sri Lanka (Fraser-Jenkins et al. 2018).

India: Maharashtra (present report), Karnataka, Kerala, and Tamil Nadu.

Ecology: It is a common element of the forests of southern India. At the present study site, the species was observed growing as a terricolous and saxicolous fern along the edges of rocky hill slopes and within caves, at altitudes ranging from 600–1,100 m. More than 300 individuals were recorded within a 1 km² area in the Gargoti region of Kolhapur District. The population occurs in dense forest habitats and is commonly associated with *Asplenium inaequilaterale*, *Thelypteris dentata*, and *Pteris biaurita*.

Specimens examined: INDIA, Karnataka, Chickmanglur District, Bagavathi to Gangamula, 08.x.1979, C.J. Saldanha, KFP 9720 (JCB!); Hasan Dt., Devarunde & Devalkere, 26.x.1970, F.M. Jarrett & T.P. Ramamoorthi, 1048 (JCB!); Maharashtra, Kolhapur District, Gargoti, Berry Land near Pal, 16.396° N, 74.191° E, 14.xii.2024, S.M. Patil & J.M. Patil, 1001, 1002 (BARO); 23.ii.2025, S.M. Patil & J.M. Patil, 1003, 1004 (BJB).



Image 1. *Arachniodes sledgei* Fraser-Jenk.: a— Habit | b— enlarged view of rhizome covered with dense brown scales | c— enlarged view of rachis and costa covered with scales | d— dorsal surface of pinnae showing sori arrangement. © Sachin Patil.

DISCUSSION

Fraser-Jenkins et al. (2018) reported four species of *Arachniodes* from southern India, namely *A. amabilis*, *A. cornu-cervi*, *A. palmipes*, and *A. sledgei*. However,

no representatives of the genus were previously documented from the northern Western Ghats of Maharashtra. The present collection, therefore, represents the first confirmed occurrence of *A. sledgei* in

this region, significantly extending its known distribution range northwards within the Western Ghats.

The species has historically been confused with *A. tripinnata* and *A. conifolia*. However, Fraser-Jenkins (2008) and Fraser-Jenkins et al. (2018) clarified that true *A. tripinnata* is restricted to the Malesian region and that earlier Indian records under this name correspond to *A. sledgei*. Similarly, *A. conifolia* does not occur in southern India, and previous reports were based on misidentifications. The morphological characters observed in the present specimens, particularly the bipinnate–tripinnate fronds, glossy lamina, auriculate pinnae, and reniform indusia, are consistent with the diagnostic features of *A. sledgei*, confirming its identity.

In southern India, the genus *Arachniodes* is largely confined to the Western Ghats, highlighting this mountain system as an important centre of diversity. The occurrence of *A. sledgei* in the Gargoti region of Maharashtra suggests floristic continuity between the southern and northern segments of the Western Ghats and indicates that suitable habitats for the species may be more widespread than previously recognised.

The taxonomic ambiguity and nomenclatural status of *Arachniodes sledgei* were thoroughly examined and resolved by Fraser-Jenkins (2008) and Fraser-Jenkins et al. (2018) through detailed morphological comparisons and critical evaluation of earlier literature. Their studies

provided a stable taxonomic framework for the genus in the Indian subcontinent.

From a conservation perspective, the discovery of a relatively large population (>300 individuals within 1 km²) indicates that the species may be locally well established in suitable habitats. However, comprehensive population data across its range remains insufficient. Further surveys are therefore necessary to more accurately evaluate its conservation status.

Thus, the present record not only adds to the fern diversity of Maharashtra but also contributes to a better understanding of the distribution, taxonomy, and biogeography of *Arachniodes* in India.

REFERENCES

- Benniamin, A. & M.S. Sundari (2020). *Pteridophytes of Western Ghats – A Pictorial Guide*. Bishen Singh Mahendra Pal Singh, Dehradun, India, 203 pp.
- Fraser-Jenkins, C.R., K.N. Gandhi & B.S. Kholia (2018). *An Annotated Checklist of Indian Pteridophytes Part-II (Woodsiaceae to Dryopteridaceae)*. Bishen Singh Mahendra Pal Singh, Dehra Dun, 582 pp.
- Lu, N.T., Ebihara, A., Hec, H., Zhang, L., Zhou, X.-M., Knapp, R., Kamau, P., Lorence, D., Gao, X.-F. & L.-B. Zhang (2019). A plastid phylogeny of the fern genus *Arachniodes* (Dryopteridaceae). *Molecular Phylogenetics and Evolution* 133: 214–245.
- Manickam, V.S. & V. Irudayaraj (1992). *Pteridophyte Flora of Western Ghats, South India*. B. I. Publication, New Delhi, 635 pp.
- POWO (2026). Plants of the World Online. Facilitated by the Royal Botanic Gardens, Kew. <https://powo.science.kew.org/>. Accessed on 18.ii.2026.





A note on the Petal-less Caper *Maerua apetala* (B.Heyne ex Roth) Jacobs (Capparaceae)

Shamsudheen Abdul Kader¹ & Bagavathy Parthipan²

¹Department of Plant Biology & Plant Biotechnology, Presidency College (Autonomous), Chennai, Tamil Nadu 600005, India.

²South Travancore Hindu College, Kottar, Nagercoil, Tamil Nadu 629001, India.

¹sakfri@rediffmail.com (corresponding author), ²parthipillai64@gmail.com

A Capparaceae family member, the Petal-less Caper *Maerua apetala* (B.Heyne ex Roth) Jacobs (= *Capparis apetala* B.Heyne ex Roth), was first reported as a small unarmed tree, endemic to the dry forest in the Eastern Ghats in Krishna, Kurnool, and Cuddapah districts, and southern Western Ghats in Tirunelveli (Gamble & Fischer 1935; Ahmedullah & Nayar 1987). Later, it was reported to be a medium-sized deciduous tree, endemic to southeastern India, especially in Eastern Ghats (Pullaiah & Rao 2002; Kumar & Raju 2021; Narasimhan & Sheeba 2021; POWO 2024), and Kanniyakumari coast (Kader 2015). In this paper, we report it as a large-canopied but short dry evergreen tree. In Tamil Nadu, it was reported from the districts of Kanniyakumari, Tirunelveli, Virudhunagar, Madurai, and Namakkal (Narasimhan & Sheeba 2021). The first author already reported five small trees in Kanniyakumari Railway Station (Kader 2015) which were removed for extending the railway track during December 2020–January 2022. In this paper, we report that *M. apetala* is also distributed in Vattakottai Fort in Kanniyakumari, Kavalkinaru in Tirunelveli District, in the hills of Thirupparanuntram and Kidaripatti in Madurai.

Maerua apetala is a rare, large-canopied but usually a short, unarmed, dry evergreen tree with

pinnately trifoliolate dimorphic leaves, small dark greenish-purple fragrant flowers in axillary and terminal racemes, and long-stalked ovoid berries (Image 1). It is an ethnobotanically important tree species. In Andhra Pradesh the Chenchu and Lambadi people use root bark paste and root extract to treat leucoderma. The tender leaves are ground with spices and the paste obtained is made into pills which are given orally for nervous disorders and foot pain (Flowers of India 2023). It has been reported to grow up to 4 m (Pullaiah 2000), up to 5 m (Pullaiah & Rao 2002), and up to 10 m height (Kumar & Raju 2021) at 0–300 m elevation, however, none of them reported its girth. During our field visit on 15 January 2022, we noticed a large tree with 3.30 m GBH and 10 m height inside Vattakottai Fort near Kanniyakumari (Image 1). It is the largest known tree of *M. apetala* and is under the control of Tamil Nadu State Department of Archeology. Extensive explorations to similar habitats in the adjacent localities are required to estimate its threat status for conservation assessment. Its flowering occurs during December–February and fruiting during February–April.

Editor: A.J. Solomon Raju, Andhra University, Visakhapatnam, India.

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

Citation: Kader, S.A. & B. Parthipan (2026). A note on the Petal-less Caper *Maerua apetala* (B.Heyne ex Roth) Jacobs (Capparaceae). *Journal of Threatened Taxa* 18(2): 28428–28429. <https://doi.org/10.11609/jott.9485.18.2.28428-28429>

Copyright: © Kader & Parthipan 2026. 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: Self-funded.

Competing interests: The authors declare no competing interests.

Acknowledgements: The authors are thankful to the anonymous reviewers and the editors for their valuable comments in improving the earlier version of the manuscript.

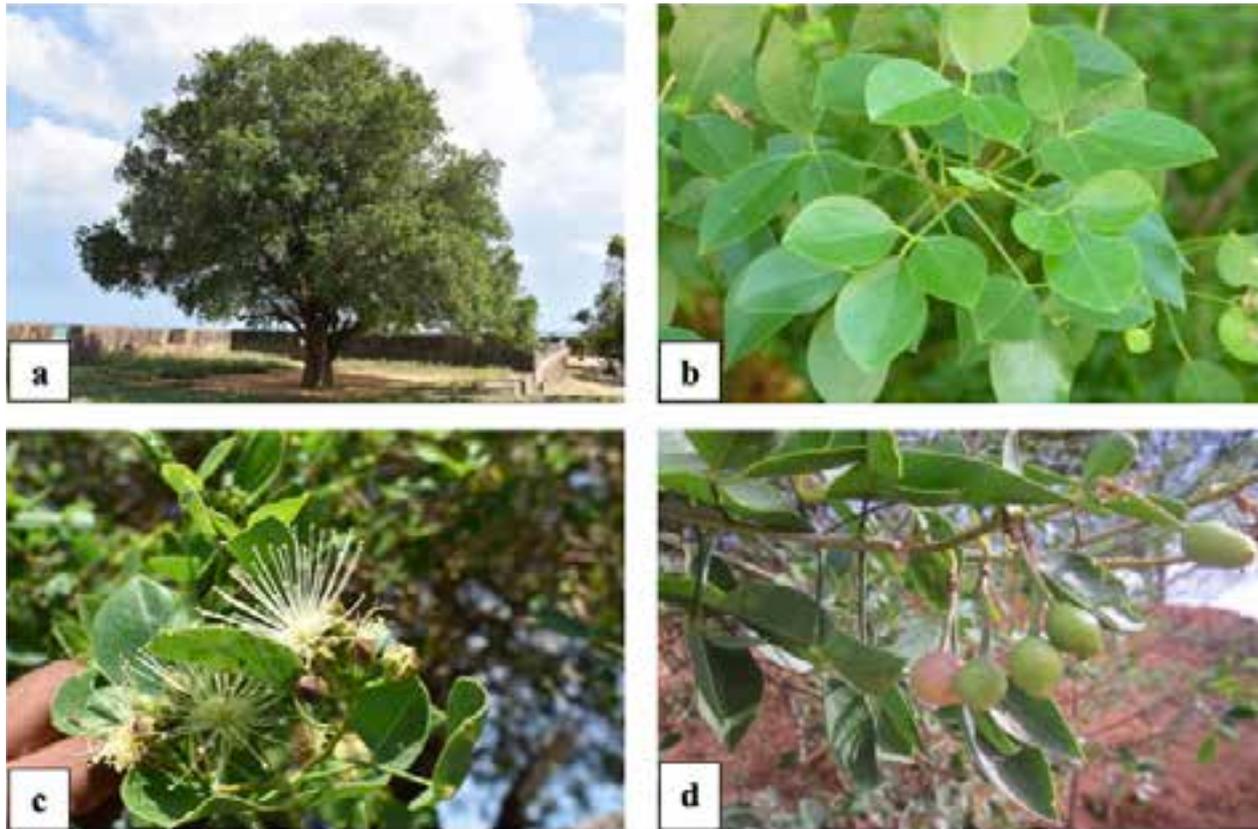


Image 1. *Maerua apetala*: a—habit | b—leaves | c—flowering twig | d—fruits. © Kader S.A.

References

- Ahmedullah, M. & M.P. Nayar (1987). *Endemic Plants of the Indian Region. Vol. 1. Peninsular India*. Botanical Survey of India, Calcutta, 261 pp.
- Kader, S.A. (2015). Taxonomical studies on *Niebuhria apetala* Dunn (Capparidaceae) – A Lesser Known Tree, Endemic to Southern India. *Journal of Economic and Taxonomic Botany* 39(3–4): 460–462.
- Flowers of India (2023). <http://m.flowersofindia.net>. Accessed on 30.ix.2023.
- Gamble, J.S. & C.E.C. Fischer (1935). *Flora of the Presidency of Madras (Reprint)*. Vol. I. Bishen Singh Mahendra Pal Singh, Dehra Dun, India, 577 pp.

- Narasimhan, D. & J.I. Sheeba (2021). *Flowering Plants of Tamil Nadu*. A Compendium, Tamil Nadu Biodiversity Board, Chennai, 1114 pp.
- POWO (2024). *Maerua apetala*. <http://powo.science.kew.org>. The Royal Botanic Gardens. Accessed on 07.xi.2024.
- Pullaiah, T. (2000). *Flora of Guntur District, Andhra Pradesh, India*. Daya Books, New Delhi, 417 pp.
- Pullaiah, T. & D.M. Rao (2002). *Flora of Eastern Ghats: Hill Ranges of South East India*. Vol. 1, Regency Publications, New Delhi, 346 pp.
- Kumar, S.S. & A.J.S. Raju (2021). Pollination ecology of the rare tropical deciduous tree species, *Maerua apetala* (Roth) Jacobs (Capparaceae) in the Southern Eastern Ghats forest of Andhra Pradesh, India. *Annali Di Botanica (Roma)* 11: 33–42.



Record of *Euploea mulciber* (Cramer, [1777]) (Lepidoptera: Nymphalidae) in Delhi, India: evidence of range extension in a restored urban ecosystem

Aisha Sultana¹ , Mohammad Shah Hussain²  & Balwinder Kaur³ 

^{1–3} Biodiversity Parks Programme, CEMDE, University of Delhi, Delhi 110007, India.

¹ aishasultana28@yahoo.com (corresponding author), ² mshahhussain@rediffmail.com, ³ smilewidballi@rediffmail.com

Butterflies (Lepidoptera) are important indicators of ecosystem health, as their distribution reflects environmental conditions and habitat quality (Pollard & Yates 1994). Range extensions in butterfly species often signal ecological changes, such as habitat restoration or climate shifts, providing insights into biodiversity dynamics. The Striped Blue Crow *Euploea mulciber*, a nymphalid butterfly (subfamily Danainae), has an established range that includes Jammu & Kashmir to northeastern India and the Andaman Islands (Varshney & Smetacek 2015), as well as Punjab and northwestern India.

Delhi's urban landscape supports a diverse butterfly fauna, with past surveys recording 115 species and more recent studies documenting 91 species in areas such as Jawaharlal Nehru University campus (Prakash et al. 2022). Despite extensive documentation (e.g., Jandu 1941, 1942, 1943; Donahue 1966, 1967; Ashton 1973; Anonymous 1991; Ghosh & Varshney 1997; Gupta 1997; Mondal et al. 1997; Kunte 2000; Larsen 2002; Zaidi 2010), *E. mulciber* had not been reported in Delhi. The closest previous records were from Bijnor and the foothills of the western Himalaya, approximately 200–300 km away (iNaturalist 2026). This study presents new evidence of *E. mulciber* in Delhi, suggesting a possible

range extension facilitated by urban green spaces (Paul & Sultana 2020).

The DDA's Aravalli Biodiversity Park (ABP) in Vasant Vihar, southern Delhi (28.557° N, 77.147° E), spans 692 ac along the Aravalli Hill range. Formerly a quartzite mining site, it has undergone ecological restoration since 2004. The Park now supports a diverse array of flora and fauna, including a butterfly conservatory established in 2005. This area provides key resources for Lepidoptera, with over 300 larval host plants (*Ficus racemosa*, *Nerium oleander*), nectar sources (*Ageratum*, *Vitex*, *Tagetes*, etc.) and microhabitats such as space for mud puddling, litter, rotten fruits, with water and shade (Paul & Sultana 2021a).

The observation of *E. mulciber* was an opportunistic sighting within the ABP's Butterfly Conservatory. It is an open conservatory, and no butterfly species has ever been deliberately introduced here. The identification of the butterfly relied on direct visual observation, confirmed by photographs capturing diagnostic features, adhering to the ethical standards of ABP, and was authenticated against standard references, including Smetacek (2000). *Euploea mulciber* is distinguished from similar species like the Common Crow *Euploea core*, present in the area, by its deep iridescent blue upperside (absent in *E.*

Editor: Anonymity requested.

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

Citation: Sultana, A., M.S. Hussain & B. Kaur (2026). Record of *Euploea mulciber* (Cramer, [1777]) (Lepidoptera: Nymphalidae) in Delhi, India: evidence of range extension in a restored urban ecosystem. *Journal of Threatened Taxa* 18(2): 28430–28432. <https://doi.org/10.11609/jott.9826.18.2.28430-28432>

Copyright: © Sultana et al. 2026. 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: Delhi Development Authority, Delhi, India.

Competing interests: The authors declare no competing interests.

Acknowledgements: Thanks to the anonymous reviewer for useful suggestions. We are grateful to the Delhi Development Authority for the financial help. Thanks are also due to the Aravalli Biodiversity Park staff for their cooperation.





Image 1. Striped Blue Crow *Euploea mulciber* (male) in DDA's Aravalli Biodiversity Park, Delhi, India.



Image 2. Striped Blue Crow *Euploea mulciber* (male) feeding on *Chromolaena odorata* in DDA's Aravalli Biodiversity Park, Delhi, India.

core's duller brown), specific white spot/streak patterns, and more elongated forewings; *E. core* generally has a rounder wing shape and lacks the vibrant blue and prominent hindwing streaks of *E. mulciber*. This species also derives chemical defences from larval feeding on toxic plants such as *Ficus* sp. and Apocynaceae (Kehimkar 2008). Three male *E. mulciber* were sighted in November

2013, 2018, and 2022 under mild winter conditions (temperature 23–28°C, 55–60% relative humidity), which are conducive to butterfly activity at the same location and habitat. Adults were observed basking and nectaring on *Chromolaena odorata*. Photographs (Images 1 & 2) verified key features, including a 60–70 mm wingspan, dark brown wings with iridescent blue

stripes, and the slow, gliding flight typical of Danainae (Kehimkar 2008).

The occurrence of *E. mulciber* in ABP as documented on iNaturalist (2026), confirm the species' persistence in that area. The presence of host plants like *Ficus* sp. and *Nerium oleander* within the conservatory likely supports the occurrence of this species.

These records represent a notable range extension into Delhi from its known forested habitats. The repeated November sightings suggest seasonal movement, possibly linked to post-monsoon conditions (after rainfall, vegetation conditions). Since 2004, restoration efforts at ABP have created a favourable habitat with host plants and nectar sources, potentially enabling this expansion. This aligns with research showing that urban green spaces promote butterfly diversity (Blair & Launer 1997; Paul & Sultana 2020). Climate change (Parmesan et al. 1999) and habitat connectivity (Paul & Sultana 2021b) may also play a role, though the species' limited flight capability suggests a gradual spread. The repeated sightings suggest a potential establishment, but the small sample size and lack of systematic surveys prevent definitive conclusions. Further monitoring in other areas of Delhi and host plant mapping are recommended to better understand this range expansion.

References

- Anonymous (1991).** *The Delhi Ridge Forest - Decline and Conservation*. Kalpavriksha Foundation, New Delhi, 56 pp.
- Ashton, R. (1973).** Butterflies of New Delhi (Papilionoidea). *Journal of the Bombay Natural History Society* 69(3): 502–509.
- Blair, R.B., & A.E. Launer (1997).** Butterfly diversity and human land use: Species assemblages along an urban gradient. *Biological Conservation* 80(1): 113–125. [https://doi.org/10.1016/S0006-3207\(96\)00056-0](https://doi.org/10.1016/S0006-3207(96)00056-0)
- Donahue, J.P. (1966).** An annotated list of the Butterflies of Delhi, India. *Journal of the Bombay Natural History Society* 63(2): 235–269.
- Donahue, J.P. (1967).** An annotated list of the Butterflies of Delhi, India. *Journal of the Bombay Natural History Society* 64(1): 22–48.
- Ghosh, S.K. & R.K. Varshney (1997).** *Lepidoptera- Heterocera, Fauna of Delhi*. State Fauna Series 6. Zoological Survey of India, New Alipore, Calcutta, 6: 419 pp.
- Gupta, I.J. (1997).** *Lepidoptera - Nymphalidae, Fauna of Delhi*. State Fauna Series 6. Zoological Survey of India, New Alipore, Calcutta 6: 409–414 pp.
- iNaturalist (2026).** Striped Blue Crow (*Euploea mulciber*). <https://www.inaturalist.org/observations/60591280>. Accessed on 12.i.2026.
- Jandu, A.S. (1941).** Some butterflies from Delhi. *Indian Journal of Entomology* 3: 337–338.
- Jandu, A.S. (1942).** Biological notes on the butterflies of Delhi. Part I. Papilionidae and Pieridae. *Indian Journal of Entomology* 4: 201–214.
- Jandu, A.S. (1943).** Biological notes on the butterflies of Delhi. Part II. Danaidae, Satyridae, Nymphalidae, Lycaenidae and Hesperidae. *Indian Journal of Entomology* 5: 223–241.
- Kehimkar, I. (2008).** *The Book of Indian Butterflies*. Bombay Natural History Society, Oxford University Press, 497 pp.
- Kunte, K. (2000).** *India, a Lifescape: Butterflies of Peninsular India*. Universities Press, New Delhi, 254 pp.
- Larsen, T.B. (2002).** The butterflies of Delhi, India - an annotated checklist. *Esperiana* 9: 459–479.
- Mondal, D.K., D.P. Bhattachaya, D.R. Maulik & M. Majumdar (1997).** *Lepidoptera: Papilionidae and Hesperidae. Fauna of Delhi*. State Fauna Series 6. Zoological Survey of India, New Alipore, Calcutta 6: 393–407.
- Parmesan, C., N. Ryrholm, C. Stefanescu, J.K. Hill, C.D. Thomas, H. Descimon, B. Huntley, L. Kaila, J. Kullberg, T. Tammaru, W.J. Tennent, J.A. Thomas & M. Warren (1999).** Poleward shifts in geographical ranges of butterfly species associated with regional warming. *Nature* 399: 579–583. <https://doi.org/10.1038/21181>
- Paul, M. & A. Sultana (2020).** Studies on butterfly (Insecta: Lepidoptera) diversity across different urban landscapes of Delhi, India. *Current Science* 118(5): 819–827. <https://doi.org/10.18520/CS/V118/5/819-827>
- Paul, M. & A. Sultana (2021a).** Diurnal activity budget of some notable butterfly (Insecta: Lepidoptera) species of selected families in Delhi, India: a comparative study. *Indian Forester* 147(10): 813–823. <https://doi.org/10.36808/if/2021/v147i10/156785>
- Paul, M. & A. Sultana (2021b).** Is habitat heterogeneity effective for conservation of butterflies in urban landscape of Delhi, India? *Journal of Threatened Taxa* 13(9): 19302–19309. <https://doi.org/10.11609/jott.6412.13.9.19302-19309>.
- Pollard, E. & T.J. Yates (1994).** *Monitoring Butterflies for Ecology and Conservation*. Chapman & Hall publication, 274 pp.
- Prakash, S., C.B. Maurya, V. Prakash, S. Singh & A. Jaiswal (2022).** Butterfly diversity of Jawaharlal Nehru University Campus, Delhi-India. *Geodiversity and Impact on Environment JNU-Eiacp* 26(4): 2–18.
- Smetacek, P. (2000).** *The Butterflies of Delhi*. Kalpavriksha Environmental Action group, Aditi Print o fast, New Delhi, 68 pp. Online Archive. <https://archive.org/details/TheButterfliesOfDelhi-PeterSmetacek>. Accessed on 24.iii.2025
- Varshney, R.K. & P. Smetacek (eds.) (2015).** *A Synoptic Catalogue of the Butterflies of India*. Butterfly Research Centre, Bhimtal and Indinov Publishing, New Delhi, 261 pp.
- Zaidi, M. (2010).** *Birds and Butterflies of Delhi*. Tara India Research Press, New Delhi, 172 pp.



Hump-nosed Pit Viper *Hypnale hypnale* feeding on an Allapalli Skink *Eutropis allapallensis* in Karwar, India

Nonita Rana¹ , Karthy Shivapushanam² , S.J.D. Frank³  & Govindan Veeraswami Gopi⁴ 

¹⁻⁴ Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India.

¹nonitarana04@gmail.com, ²karthysp08@gmail.com, ³frank.sadrack@gmail.com, ⁴gopigv@wii.gov.in (corresponding author)

Snakes are known to possess characteristically unique feeding systems (Moon et al. 2019) and documenting their food habits is vital to understanding their natural history, ecosystem functions, and evolutionary history (Kalki & Weiss 2020). Pit-vipers belong to the subfamily Crotalinae of the Viperidae family and are characterised by presence of infrared radiation sensing loreal pits, that are located below the mid-line connecting the eye and nostril (Alencar et al. 2018). Here, we report our observation on a case of the hunting and feeding of Hump-nosed Pit Viper based on wild, in situ observation from India.

Field surveys reported here, were undertaken with due approvals and accompaniment of the Karnataka Forest Department. The case reported was video-recorded using point and shoot digital cameras (Nikon P900 & Canon SX 70 HS). The images are given here as vouchers and the video recording is available on YouTube <<https://youtu.be/ZrpJmW3967U>> (Video 1).

Hump-nosed Pit Viper *Hypnale hypnale*, a common species known to inhabit evergreen, moist, and dry deciduous forests, and human modified areas such as plantations in the Western Ghats – Sri Lanka biodiversity hotspot (Gunawardene et al. 2007). It is a fairly small-sized (< 0.6 m), terrestrial species, with a flat, triangular

head that is broader than the neck, and back covered with alternating black/ brown specks and large dark triangular spots on each side. It is known to feed on small mammals like rodents and lizards, geckos, skinks, & frogs (Wall 1906, 1919, 1921; Smith 1943; Das 2002; Whitaker & Captain 2004; Das & DeSilva 2005; Maduwage et al. 2009). Young ones lure skinks within striking range by enticing them with colourful tail tips (Henry 1925; Smith 1943; Daniel 2002). Despite being known to science for over two centuries, and being a common species to the region, there seems to be a lacuna in the knowledge of its ecology, with only a few ecological studies available on its fine-scale distribution and abundance (Ganesh et al. 2010; Sawant et al. 2010a,b).

Soon after the first rains in Karwar forests, Uttara Kannada District, Karnataka, on the night of 23 May 2024, at around 2200 h, we observed a small snake coiled in the leaf litter. Its pointed snout, distinctive yellow-white line separating the top and sides of the head, and large triangular spots on the sides helped us identify it as a Hump-nosed Pit Viper *H. hypnale*. The snake was about 25 cm long. It straightened its vertebrae, angled its head out and started to flick its tongue. The pit viper seemingly sensed its prey, an Allapalli Skink *Eutropis allapallensis* (Schmidt, 1926) of 10–12cm in length,

Editor: S.R. Ganesh, Kalinga Foundation, Agumbe, India.

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

Citation: Rana, N., K. Shivapushanam, S.J.D. Frank & G.V. Gopi (2026). Hump-nosed Pit Viper *Hypnale hypnale* feeding on an Allapalli Skink *Eutropis allapallensis* in Karwar, India. *Journal of Threatened Taxa* 18(2): 28433–28435. <https://doi.org/10.11609/jott.10034.18.2.28433-28435>

Copyright: © Rana et al. 2026. 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: Wildlife Institute of India.

Competing interests: The authors declare no competing interests.



Acknowledgements: We gratefully thank the director and dean, Wildlife Institute of India for their support during this study. We extend our sincere thanks to the PCCF (HoFF), PCCF (WL) & CWLW, APCCF (WL) Karnataka Forest Department for the permission to carry out the field survey. We thank the field director of Kali Tiger Reserve, deputy conservators of forests of Karwar and Yellapur Forest Division for the permission and logistical support during the field work. We are thankful to Mr. Bilal, Mr. Parashuram, and Mr. Surya (Karnataka Forest Department) and researchers Mr. Avinash Yadav, Mr. P.K. Tousif, and Mr. Rounak Patra.

which was foraging on the nearby rocks. The skink was identified by its dorso-lateral lines that run along the length of the body, fronto-parietal scale which is united, and keels on body scales (Image 1) (Deuti et al. 2020). It was surprising that the diurnal skink was seen moving on leaf litter at night; but ants were seen close by, suggesting the sleeping skink could have been disturbed by ants, causing the lizard to move out. The snake, stealthily observing the movements of the skink, bit it quickly when the skink ventured too close to the snake. While trying to dodge the attack, the skink slipped and fell down (approximately 25 cm) and eventually after getting bitten, the immobile skink was deduced to be dead out of the effects of venom in 40 s. The viper may have traced its prey using its chemosensory tongue, thermo-sensory labial pits between the nasal cavity, and its vision to identify the prey that had slipped down. By this time, the dead skink had already attracted the attention of the ants on the forest floor. Upon finding the skink, the snake thoroughly examined it from head

to tail by flicking its tongue (approximately 147 times) at the dead skink. This thorough examination continued for over two minutes when the snake finally moved back to the head of the skink and started to swallow the skink slowly, using its fangs to hold the prey ventrally between the jaws. The prey was then pushed into the stomach by the movement of the jaws. While the snake was about to ingest the hind limbs of the skink, it gave a jerk reaction in response to the disturbing ant bite on its head. The feeding (from examining the dead prey to entirely swallowing it) lasted for 6 m 40 s and was achieved over 44 jaw-walks. The peristaltic movement took over the swallowing process after the hind limbs were consumed (Image 2). After fully consuming the skink, the viper continued resting on the rock.

Hump-nosed Pit Vipers have been observed to feed on skinks, frogs, and agamids in the wild in India (Wall 1906, 1919, 1921; Smith 1943; Daniel 2002; Das 2002; Whitaker & Captain 2004; Das & DeSilva 2005; Maduwage et al. 2009). Henry (1925) observed a captive



Image 1. Allapalli Skink *Eutropis allapallensis* approaching the Hump-nosed Pit Viper *Hypnale hypnale* lying in wait, in ambush, at night; note the ant near the skink.



© Avinash Yadav

Image 2. Hump-nosed Pit Viper *Hypnale hypnale* swallowing the dead Allapalli Skink *Eutropis allapallensis*; note the dead skink manoeuvred upside-down inside the mouth of the snake.

Hypnale sp. of Sri Lankan origin feeding on another conspecific individual. Wall (1919) reported the Rock Agama *Psammophilus drosalis* in the gut of a young one of this snake from Nilgiris, attesting that diurnal lizard as prey had earlier been reported. Literature from India, usually reported mice / small mammal in the gut of this snake (Inger et al. 1984; Wall 1919). Henry (1925), Daniel (2002) specifically mentioned skinks as being enticed by caudal luring exhibited by baby Hump-nosed Pit Vipers, another explicit indication associating a diurnal prey, with this nocturnal species (also see Smith 1943). Maduwage et al. (2009) recorded skinks and shrews in their gut content in Sri Lankan populations of *H. hypnale*.

Though the snake species itself is common in the Western Ghats, its behaviours are rarely documented in the wild (Inger et al. 1984; Wall 1919; Daniel 2002; Das 2002; Whitaker & Captain 2004; Ganesh et al. 2010; Sawant et al. 2010a,b). Our feeding observation reported, agrees with published information on *Hypnale* as summarised here, and also with the more voluminous body of scholarship generally on viper feedings. Many terrestrial vipers are known to rapidly release their prey once bitten (Cundall 2002). Swallowing action of the pit viper, in engulfing the skink was very similar to what is called pterygoid walk (Carrasco et al. 2023). To the best of our knowledge, this record is the first live recorded field observation of a Hump-nosed Pit Viper hunting and feeding on a skink, in the wild.

References

- Alencar, L.R., M. Martins & H.W. Greene (2018). Evolutionary history of vipers. *Encyclopedia of Life Sciences - eLS* 1–10. <https://doi.org/10.1002/9780470015902.a0027455>
- Carrasco, P. A., L. Prystupczuk, C. Koch, G.A. González, G.C. Leynaud & F.G. Graziotin (2023). Patterns of morphological variation and ecological correlates in the skull of vipers (Serpentes: Viperidae). *Journal of Morphology* 284(8): e21617. <https://doi.org/10.1002/jmor.21617>
- Cundall, D. (2002). Envenomation strategies, head form, and feeding ecology in vipers, pp. 149–162. In: Gordon, W., G.W. Schuett, M. Hoggren, M.E. Douglas & H.W. Greene (eds.) *Biology of the Vipers*. Eagle Mountain Pub Lc, 580 pp.
- Daniel, J.C. (2002). *The Book of Indian Reptiles and Amphibians*. Oxford University Press, Mumbai, 238 pp.
- Das, I. (2002). *A Photographic Guide to Snakes and other Reptiles of India*. New Holland Publications, London, 144 pp.
- Das, I. & A. De Silva (2005). *A Photographic Guide to Snakes and other Reptiles of Sri Lanka*. New Holland Publications, London, 144 pp.
- Deuti, K., S. Raha, P. Bag, S. Debnath, A.N. Srikanthan & K. Chandra (2020). *Skinks of India*. Zoological Survey of India, Kolkata, 383 pp.
- Gunawardene, N.R., A.E. Daniels, I.A.U.N. Gunatilleke, C.V.S. Gunatilleke, P.V. Karunakaran, K.G. Nayak, S. Prasad, P. Puyravaud, B.R. Ramesh, K.A. Subramanian & G. Vasanthy (2007). A brief overview of the Western Ghats-Sri Lanka biodiversity hotspot. *Current Science* 93(11): 1567–1572.
- Henry, G.M. (1925). Notes on *Ancistrodon hypnale*, the hump-nosed viper. *Spolia Zeylanica* 13: 257–258.
- Inger, R.F., H.B. Shaffer, M. Koshy & R. Bakde (1984). A report on a collection of amphibians and reptiles from the Ponmudi, Kerala, South India. *Journal of the Bombay Natural History Society* 81(3): 551–570.
- Kalki, Y. & M. Weiss (2020). Understanding the food habits of the green vine snake (*Ahaetulla nasuta*): a crowdsourced approach. *Herpetology Notes* 13: 835–843.
- Maduwage, K., A. Silva, K. Manamendra-Arachchi & R. Pethiyagoda (2009). A taxonomic revision of the South Asian hump-nosed pit vipers (Squamata: Viperidae: Hypnale). *Zootaxa* 2232(1): 1–28. <https://doi.org/10.11646/zootaxa.2232.1.1>
- Moon, B.R., D.A. Penning, M. Segall & A. Herrel (2019). Feeding in snakes: form, function, and evolution of the feeding system. pp. 527–74. In: Bels V. & I.Q. Whishaw (eds.). *Feeding in Vertebrates: Evolution, Morphology, Behavior, Biomechanics*. Springer, 865pp.
- Sawant, N.S., T.D. Jadhav & S.K. Shyama (2010a). Distribution and abundance of pit vipers (Reptilia: Viperidae) along the Western Ghats of Goa, India. *Journal of Threatened Taxa* 2(10): 1199–1204. <https://doi.org/10.11609/JoTT.o2489.1199-204>
- Sawant, N.S., T.D. Jadhav & S.K. Shyama (2010b). Habitat suitability, threats and conservation strategies of Hump-nosed Pit Viper *Hypnale hypnale* Merrem (Reptilia: Viperidae) found in Western Ghats, Goa, India. *Journal of Threatened Taxa* 2(11): 1261–1267. <https://doi.org/10.11609/JoTT.o2490.1261-7>
- Smith, M. A. (1943). *Fauna of British India, including Ceylon and Burma. Vol- III Serpentes*, Taylor and Francis, London, 583 pp.
- Wall, F. (1906). The poisonous snakes of India and how to recognize them, Part II. *Journal of the Bombay Natural History Society* 17: 299–334.
- Wall, F. (1919). Notes on a collection of snakes made in the Nilgiri hills and adjacent Wynaad. *Journal of the Bombay Natural History Society* 26: 552–584.
- Wall, F. (1921). *Ophidia Taprobanica or the Snakes of Ceylon*. Colombo Mus. (H.R. Cottle, govt. printer), Colombo. xxii, 581 pp.
- Whitaker, R & A. Captain (2004). *Snakes of India – The Field Guide*. Westland Publications & Draco books, India, 480 pp.



Sighting of vagrant Red-backed Shrike *Lanius collurio* in the coastal areas of Thoothukudi, Tamil Nadu, India

Kishore Muthu¹ , Anand Shibu²  & Santhanakrishnan Babu³ 

^{1,2,3}Sálim Ali Centre for Ornithology and Natural History (South India Centre of Wildlife Institute of India), Anaikatty, Coimbatore, Tamil Nadu 641108, India.

¹kishoreak1999@gmail.com, ²anandshibu12@gmail.com, ³sanbabs@gmail.com (corresponding author)

Shrikes (genus *Lanius*) are medium-sized passerines known for their distinctive predatory behaviour. India has 14 species of shrikes, comprising resident, migratory, and vagrant species (Lefranc & Worfolk 2013; Praveen & Jayapal 2025). The resident shrikes are the Long-tailed Shrike *Lanius schach*, Bay-backed Shrike *Lanius vittatus*, Grey-backed Shrike *Lanius tephronotus*, and Great Grey Shrike *Lanius excubitor lahtore*. The winter migrants to the country are Brown Shrike *Lanius cristatus*, Isabelline Shrike *Lanius isabellinus*, and Burmese Shrike *Lanius collurio*. Vagrants such as the Red-backed Shrike *Lanius collurio*, Lesser Grey Shrike *Lanius minor*, Masked Shrike *Lanius nubicus*, Tiger Shrike *Lanius tigrinus*, Red-tailed Shrike *Lanius phoenicuroides*, Woodchat Shrike *Lanius senator*, and Giant Shrike *Lanius giganteus* are occasionally recorded. In Peninsular India, the Long-tailed Shrike, Bay-backed Shrike, Brown Shrike, and Isabelline Shrike are commonly recorded, while the Red-backed Shrike is a vagrant to peninsular India.

As part of a bird survey, we have been surveying wetland and terrestrial habitats within the coastal zones of Tamil Nadu State for both migratory and resident birds. We included terrestrial habitats (e.g., shrubs and mixed woodlands) because they often support passerine passage migrants that winter in Sri Lanka.

During one such survey in the Thoothukudi District, we encountered a shrike near the Periyasamy Puram salt pan (9.071° N, 78.322° E) on 02 November 2025. It exhibited some distinctive plumage patterns compared to other shrike species common to this site. Therefore, a series of photos was taken using a NIKON D7200 for further identification. Upon careful examination of the photographs and field notes, we confirmed the shrike's identity as a Red-backed Shrike *Lanius collurio* based on unique plumage characteristics. The same individual was observed at the same location on 06 November, confirming that this vagrant had remained in the area for at least four days.

The key identification features of an adult male are a grey crown, a bold black mask, a bright chestnut back, and a grey rump, along with a distinctive tail pattern characterized by white bases that form a "T" shape in flight. The Red-backed Shrike is a long-distance migratory bird, which primarily uses the Eastern Mediterranean–Middle Eastern–East African flyway (BirdLife International 2024). It breeds across the Palearctic region, including most of Europe, and winters in southern and eastern Africa (Lefranc & Worfolk 2013; Yosef et al. 2020).

Apart from the present sightings, there is one

Editor: H. Byju, Coimbatore, Tamil Nadu, India.

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

Citation: Muthu, K., A. Shibu & S. Babu (2026). Sighting of vagrant Red-backed Shrike *Lanius collurio* in the coastal areas of Thoothukudi, Tamil Nadu, India. *Journal of Threatened Taxa* 18(2): 28436–28437. <https://doi.org/10.11609/jott.10269.18.2.28436-28437>

Copyright: © Muthu et al. 2026. 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 Tamil Nadu State Land Use Research Board (TNSLURB), State Planning Commission.

Competing interests: The authors declare no competing interests.

Acknowledgements: We thank the Tamil Nadu State Land Use Research Board (TNSLURB) for the financial support. The authors thank the director, dean, registrar, and head of office at WII-SACON for administrative support.





Image 1. Red-backed Shrike *Lanius collurio* sighted in the saltpans of Thoothukudi District, Tamil Nadu. © Anand Shibu.

previous sighting record of this species from Tamil Nadu, observed in 2023 at the Point Calimere Wildlife Sanctuary, Nagapattinam (Haemoglobin 2023). Furthermore, several observations of the species were recorded in Adayar, Chennai, during December 2025 and have been submitted to eBird (e.g., Kesavan 2025). Along its broader migratory route, it is reported in the northwestern part of the country. A substantial number of sighting reports are available on eBird from Gujarat, with a few scattered sightings from Rajasthan and Maharashtra (eBird 2025). Most of these records were reported between August and November. However, due to the limited sighting records from this region, the species is considered a vagrant in southern India. Continuous monitoring of wetland and terrestrial habitats of the East Coast of Tamil Nadu areas may shed more light on several passage migrants and vagrants to India.

References

- BirdLife International (2024).** Species factsheet: Red-backed Shrike *Lanius collurio*. <https://datazone.birdlife.org/species/factsheet/red-backed-shrike-lanius-collurio>. Downloaded on 21.xi.2025
- eBird (2025).** An online database of bird distribution and abundance. Cornell Lab of Ornithology, Ithaca, NY. <https://ebird.org>. Accessed on 17.xi.2025.
- Haemoglobin, D. (2023).** eBird Checklist. <https://ebird.org/checklist/S152479957>. Accessed on 17.xi.2025.
- Lefranc, N. & T. Worfolk (2013).** *Shrikes: A Guide to the Shrikes of the World*. Christopher Helm, 192 pp.
- Praveen J. & R. Jayapal (2025).** Checklist of the birds of India (v9.1). <http://www.indianbirds.in/india/>. Accessed on 17.xi.2025.
- Kesavan, R. (2025).** eBird Checklist. <https://ebird.org/checklist/S287440550>. Accessed on 05.ii.2026.
- Yosef, R., International Shrike Working Group & D.A. Christie (2020).** Red-backed Shrike (*Lanius collurio*), version 1.0. In: del Hoyo, J., A. Elliott, J. Sargatal, D.A. Christie & E. de Juana (eds.). *Birds of the World*. Cornell Lab of Ornithology, Ithaca, NY, USA. <https://doi.org/10.2173/bow.rebshr1.01>. Accessed on 17.xi.2025.



First record of the Diamond Dove *Geopelia cuneata*, an Australian endemic, in Sikhna Jwhlwao National Park, Assam, India

Bibhash Sarkar¹ , Bijay Basfore² , Leons Mathew Abraham³  & Anjana Singha Naorem⁴ 

¹Department of Zoology, Pandu College, Pandu, Guwahati, Assam 781012, India.

^{2,4}Department of Zoology, Cotton University, Panbazar, Guwahati, Assam 781001, India.

³Pygmy Hog Research & Breeding Centre, Indira Nagar, Basistha, Guwahati, Assam 781029, India.

¹bibhashsarkar2810@gmail.com, ²zoo2491005_bijay@cottonuniversity.ac.in (corresponding author),

³leonsreptar@gmail.com, ⁴anjanasingha@cottonuniversity.ac.in (corresponding author)

The Diamond Dove *Geopelia cuneata* (Latham, 1801) is an Australian endemic and among the smallest species of the Columbidae family, inhabiting the arid and semi-arid regions of central, western, and northern Australia (Schleucher et al. 1991). This delicate dove is characterized by a long, pointed tail and sexually dimorphic plumage. Males are pale blue-grey with spotted scapulars, a chestnut wing panel, white underparts, black-and-white tail, scarlet iris, and pink legs, while females are browner with a duller orbital ring, and juveniles are overall duller with fine barring, fewer spots, a lighter bill, and paler eyes and legs (Gibbs et al. 2001; Baptista et al. 2017).

Globally, the Diamond Dove is assessed as ‘Least Concern’ on the IUCN Red List of Threatened Species (IUCN 2025). However, it was listed as threatened on the 2013 advisory list of threatened vertebrate fauna in Victoria, Australia, under the provisions of part 3 of the Victorian Flora and Fauna Guarantee Act 1988 (FFG Act) (DSE 2013). On eBird, 31,891 observations are documented from: Oceania, North America, Europe, Asia, and South America. Among these, 214 records are categorized

as escapees, denoting birds observed outside their natural range (eBird 2026). This distribution highlights the species’ restriction to Oceania and suggests that most extra-limital records represent escapees, captive releases, or vagrants rather than natural dispersal.

On 4 April 2025, around 1115 h, we documented two individuals of Diamond Dove (Image 1) in the Runikhata Range of the recently declared Sikhna Jwhlwao National Park (26.835° N, 90.413° E), located in the Kokrajhar District of Assam, India. Two birds were observed foraging on the ground approximately 200 m from a dried-up stream. Given that the Diamond Dove is strictly resident in Australia and does not naturally occur in southern Asia, its presence in Assam is best explained as a human-mediated introduction. The species is extensively bred and traded in the global cage-bird industry due to its small size, ease of maintenance, and ornamental plumage. Thus, the most plausible explanation for our record is that these individuals were escapees or intentional releases from captivity.

To further understand the context of this record, we searched major citizen science platforms, including

Editor: Ashutosh Singh, Salim Ali Centre for Ornithology and Natural History, Coimbatore, India.

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

Citation: Sarkar, B., B. Basfore, L.M. Abraham & A.S. Naorem (2026). First record of the Diamond Dove *Geopelia cuneata*, an Australian endemic, in Sikhna Jwhlwao National Park, Assam, India. *Journal of Threatened Taxa* 18(2): 28438–28440. <https://doi.org/10.11609/jott.10119.18.2.28438-28440>

Copyright: © Sarkar et al. 2026. 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: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We sincerely thank the divisional forest officer, Chirang Division, Kajalgaon, for granting us the permit to study the avian diversity and ecology in the Runikhata Range of Sikhna Jwhlwao National Park (Permit No. B/CRD/permission/974-75). Our gratitude also goes to the range officers and frontline staff for their invaluable support in the field and for their unwavering dedication to conservation. BS gratefully acknowledges the Department of Zoology, Pandu College, for providing academic support.



Image 1. Diamond Dove *Geopelia cuneata* observed in Sikhna Jwhlwao National Park, Assam, India.

eBird, iNaturalist, and GBIF, to compile all available Indian records of the Diamond Dove. These data revealed that the Diamond Dove has been previously reported from Delhi, Karnataka, Kerala, and Punjab, all being considered escapee occurrences (Table 1).

Additionally, our review of citizen science databases also revealed that India has reported escapees of several other exotic bird species, including the Blue-bellied Roller *Coracias cyanogaster* from West Bengal, Mute Swan *Cygnus olor* from Gujarat, Japanese Quail *Coturnix japonica* from the Andaman and Nicobar Islands, and Black Vulture *Coragyps atratus* from Haryana. In Assam, the only previously documented escapee bird records include Domestic Goose *Anser* sp. and Mallard *Anas platyrhynchos*, making the present observation of Diamond Dove particularly noteworthy as the first record of this species in the state.

Although many escapees fail to establish, certain species may adapt and form feral populations under favourable conditions. Factors such as captive origin, availability of urban resources, and reduced predation can facilitate persistence, as exemplified by Monk

Parakeet *Myiopsita monachus* and Ring-necked Parakeet *Psittacula krameri* in Spain, where heavy importation enabled self-sustaining populations despite subsequent import bans (Souviron-Priego et al. 2018). The present observation emphasizes the importance of monitoring escapees, as they may compete with native species (Charter et al. 2016), alter the native plant communities (Menchetti & Mori 2014), facilitate transmission of zoonotic diseases (Ancillotto et al. 2018), potentially establish invasive populations (Souviron-Priego et al. 2018), and negatively impact human economy by damaging crops (Haubrock et al. 2021).

Furthermore, public awareness is crucial, as uninformed bird owners may release captive birds into the wild, inadvertently promoting the spread of zoonotic diseases transmissible to humans and native avifauna (Nair et al. 2022). Continuous documentation of such occurrences in India is essential to evaluate the frequency and ecological impact of non-native introductions. Although many escapees may not survive, repeated introductions heighten the risk of local adaptation, successful breeding, and long-term establishment.

Table 1. Records of Diamond Dove *Geopelia cuneata* from India based on citizen science data.

	Source	Date of observation	Location
1	eBird (Checklist ID S71738406) and GBIF	23 September 2020	South City, Ludhiana, Punjab
2	eBird (Checklist ID S149444154) and GBIF	09 June 2023	Shivakote Kere, Bengaluru Urban, Karnataka
3	eBird (Checklist ID S270286303)	28 April 2025	2 Jasola Metro Road, South-East Delhi, Delhi
4	eBird (Checklist ID S296356343)	26 January 2026	Thrissur, Kerala

Such events could alter community dynamics, increase competition, introduce novel pathogens, and complicate conservation of native bird communities.

We therefore advocate vigilant monitoring and systematic reporting of exotic bird escapees in India to assess their ecological consequences. Where permitted, the exotic bird trade should be strictly licensed and regulated, with safeguards to prevent accidental or deliberate releases. Effective regulatory frameworks will be critical to minimising risks to native biodiversity while balancing avicultural practices.

References

- Ancillotto, L., V. Studer, T. Howard, V.S. Smith, E. McAlister, J. Beccaloni, F. Manzia, F. Renzopoli, L. Bosso, D. Russo & E. Mori (2018). Environmental drivers of parasite load and species richness in introduced parakeets in an urban landscape. *Parasitology Research* 117(11): 3591–3599. <https://doi.org/10.1007/s00436-018-6058-5>
- Baptista, L.F., P.W. Trail, H.M. Horblit & P.F.D. Boesman (2017). Diamond Dove (*Geopelia cuneata*). In: Hoyo, J.D., A. Elliott, J. Sargatal, D.A. Christie & E.D. Juana (eds.). *Handbook of the Birds of the World Alive*. Lynx Edicions, Barcelona, 696 pp.
- Charter, M., I. Izhaki, Y.B. Mocha & S. Kark (2016). Nest- site competition between invasive and native cavity nesting birds and its implication for conservation. *Journal of Environmental Management* 181(1): 129–134. <https://doi.org/10.1016/j.jenvman.2016.06.021>
- DSE (2013). *Advisory List of Threatened Vertebrate Fauna in Victoria - 2013*. Department of Sustainability and Environment, East Melbourne, Victoria, 19 pp.
- eBird (2026). eBird: An online database of bird distribution and abundance. eBird, Cornell Lab of Ornithology, Ithaca, New York. <http://www.ebird.org>. Accessed on 28.i.2026.
- Gibbs, D., E. Barnes & J. Cox (2001). *Pigeons and Doves: A Guide to the Pigeons and Doves of the World*. Pica Press, Robertsbridge, United Kingdom, 615 pp.
- Haubrock, P.J., A.J. Turbelin, R.N. Cuthbert, A. Novoa, N.G. Taylor, E. Angulo, L. Ballesteros-Mejia, T.W. Bodey, C. Capinha, C. Diagne, F. Essl, M. Golivets, N. Kirichenko, K. Kourantidou, B. Leroy, D. Renault, L. Verbrugge & F. Courchamp (2021). Economic costs of invasive alien species across Europe. *NeoBiota* 67: 153–190. <https://doi.org/10.3897/neobiota.67.58196>
- IUCN (2025). The IUCN Red List of Threatened Species. Version 2025-1. <https://www.iucnredlist.org>. Accessed on 27.viii.2025.
- Menchetti, M. & E. Mori (2014). Worldwide impact of alien parrots (Aves Psittaciformes) on native biodiversity and environment: A review. *Ethology Ecology and Evolution* 26(2–3): 172–194. <https://doi.org/10.1080/03949370.2014.905981>
- Nair, P.M., Anil, M.S. Sivaprasad, V.M. Anand, Akash, A.K. Singh, S. Yadav, R. Chouraddi, P. Gujjalkar, B.M. Baby, V. Dhaigude, Jigyasha, A. Durge & Prabhakar (2022). Public Health Threats from Pet Bird Zoonoses. *Journal of Scientific Research and Reports* 28(11): 10–20. <https://doi.org/10.9734/jsrr/2022/v28i111699>
- Schleucher, E., R. Prinzinger & P.C. Withers (1991). Life in extreme environments: Investigations on the ecophysiology of a desert bird, the Australian Diamond Dove (*Geopelia cuneata* Latham). *Oecologia* 88: 72–76. <https://doi.org/10.1007/BF00328405>
- Souviron-Priego, L., A.R. Muñoz, J. Olivero, J.M. Vargas & J.E. Fa (2018). The Legal International Wildlife Trade Favours Invasive Species Establishment: The Monk and Ring-Necked Parakeets in Spain. *Ardeola* 65(2): 233–246. <https://doi.org/10.13157/arla.65.2.2018.ra3>





NOTE

Small Wild Cats Special Series

First photographic record of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Kuldiha Wildlife Sanctuary, Odisha, India

Tarun Singh¹ , Harshvardhan Singh Rathore² , N. Abhin³ , Subhalaxmi Muduli⁴ , Yash Deshpande⁵ , Vivek Sarkar⁶ , Diganta Sovan Chand⁷ , Samrat Gowda⁸ , Prakash C. Gogineni⁹ , Manoj V. Nair¹⁰ , Bivash Pandav¹¹  & Samrat Mondol¹² 

^{1–6, 11, 12} Wildlife Institute of India, Chandrabani, Dehradun, Uttarakhand 248001, India.

^{7–10} Odisha Forest Department, Aranyabhawan Plot No 2/12 Chandrasekharpur Bhubaneswar, Odisha 751023, India.

¹ tarunsingh2103@gmail.com, ² harshrathore691@gmail.com, ³ abhintothewild@gmail.com, ⁴ subhalaxmimuduli959@gmail.com,

⁵ yashdeshpande6497@gmail.com, ⁶ viveksarkar87@gmail.com, ⁷ djdschand@gmail.com, ⁸ samrat120@gmail.com,

⁹ chandgp2007@gmail.com, ¹⁰ nairmanojvasudevan@gmail.com, ¹¹ bivash.pandav@wii.gov.in,

¹² samrat@wii.gov.in (corresponding author)

We report a camera trap photograph of a Rusty-spotted Cat *Prionailurus rubiginosus* in Kuldiha Wildlife Sanctuary, Odisha (Image 1). A single individual was recorded on 18 May 2025 at 0140 h by one of 73 camera traps deployed from April to May 2025, for a total of 2,206 camera trap days. This camera trap was installed beside a forest road near a seasonal stream at an elevation of 215 m. It was operational for 24 hours per day and active for 32 days. It also recorded a Jungle Cat *Felis chaus*, Small Indian Civet *Viverricula indica*, Indian Grey Mongoose *Herpestes edwardsii*, and a feral Dog *Canis familiaris*. The vegetation around this location is mainly composed of Sal *Shorea robusta* and *Clerodendrum infortunatum* dominating the ground cover. The Euclidean distance to the nearest village boundary is 3.2 km. There was no human disturbance at this location, except for patrolling vehicles of the forest department.

Kuldiha Wildlife Sanctuary covers an area of 272.75

km² and is characterized by rugged, hilly terrain (Sahu et al. 2014; Figure 1). Tropical moist deciduous, dry deciduous and semi-evergreen forests are the predominant forest types in this region of Odisha (Champion & Seth 1968).

Our record is the first in Kuldiha Wildlife Sanctuary. A previous camera trapping survey from January to August 2013 failed to detect the cat despite 916 camera trap days across 65 locations in Kuldiha Wildlife Sanctuary (Debata & Swain 2018). The next closest records of the Rusty-spotted Cat in northern Odisha were obtained in Similipal Tiger Reserve (Palei & Debata 2017; Mishra et al. 2019) and in Hadagarh Wildlife Sanctuary (Palei et al. 2022; Mishra & Mohan 2023). In Odisha, the Rusty-spotted Cat has been recorded by camera traps in both protected and non-protected areas, including the mixed deciduous forests of Debrigarh Wildlife Sanctuary (Palei et al. 2023a) and the forest divisions of Bargarh, Bolangir,

Editor: Angie Appel, Wild Cat Network, Germany.

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

Citation: Singh, T., H.S. Rathore, N. Abhin, S. Muduli, Y. Deshpande, V. Sarkar, D.S. Chand, S. Gowda, P.C. Gogineni, M.V. Nair, B. Pandav & S. Mondol (2026). First photographic record of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Kuldiha Wildlife Sanctuary, Odisha, India. *Journal of Threatened Taxa* 18(2): 28441–28443. <https://doi.org/10.11609/jott.10209.18.2.28441-28443>

Copyright: © Singh et al. 2026. 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 Odisha Forest Department provided funding for this work.

Competing interests: The authors declare no competing interests.

Acknowledgements: We express our gratitude to the Odisha Forest Department for granting the necessary permission (Letter no. 3964/4WL-475/2024) and for providing logistic support during the fieldwork. We also thank the director, dean, and research coordinator of the Wildlife Institute of India for offering us facilities and infrastructure. Special thanks are due to Khushwant Singh, Subrat Kumar Behera, and all the frontline staff of Kuldiha Wildlife Sanctuary for their invaluable assistance in the field.

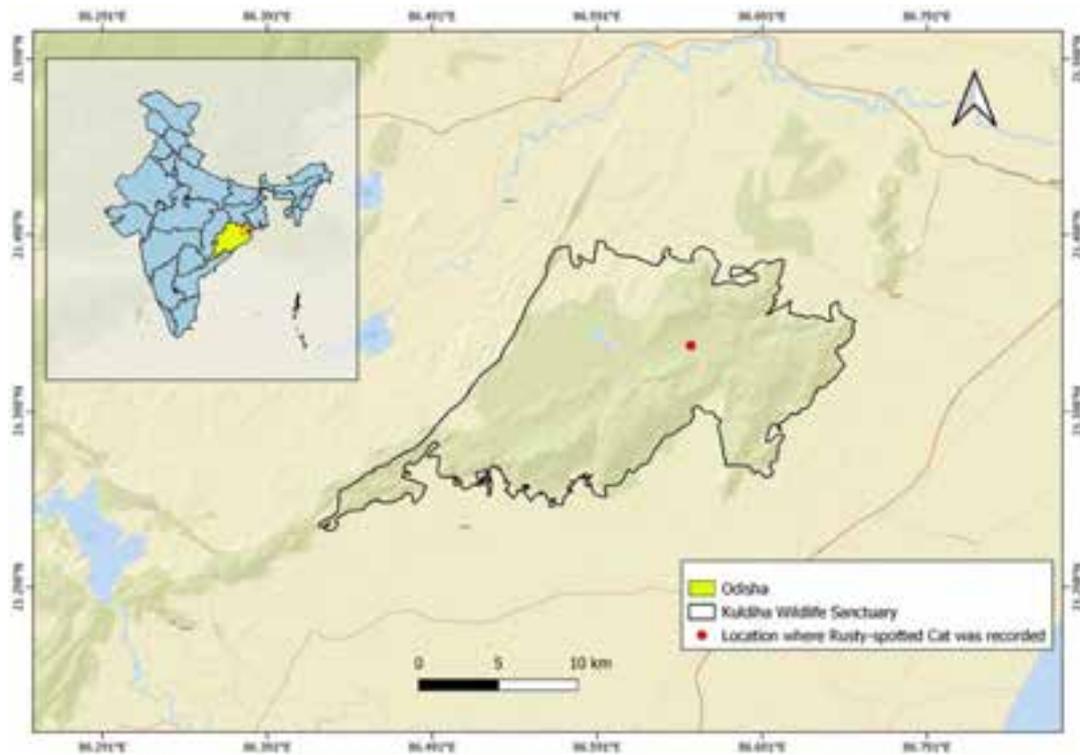


Figure 1. Kuldiha Wildlife Sanctuary showing the location of the camera trap station where the Rusty-spotted Cat was photographed.



Image 1. Camera trap photograph of the Rusty-spotted Cat *Prionailurus rubiginosus* in Kuldiha Wildlife Sanctuary on 18 May 2025. © Wildlife Institute of India and Odisha Forest Department.

Bonai, and Sundargarh (Palei et al. 2019, 2023b; Kumar et al. 2021; Patra et al. 2025). Rescued individuals have been reported in Karlapat Wildlife Sanctuary and the Ghumusur and Phulbani Forest Divisions (Palei & Debata 2017; Palei et al. 2019). It was also recorded in the Atei Reserve Forest, which forms part of an important wildlife corridor linking Similipal and Satkosia Tiger Reserves (Hanumant et al. 2025).

Given the widespread occurrence of the Rusty-spotted Cat in Odisha, dedicated camera trap surveys should be undertaken to assess its population status. Information generated from such studies would also enhance our understanding of its ecological requirements and aid in developing a conservation action plan.

References

- Champion, H.G. & S.K. Seth (1968).** *A Revised Survey of the Forest Types of India*. Government of India Press, 404 pp.
- Debata, S. & K. Swain (2018).** Estimating mammalian diversity and relative abundance using camera traps in a tropical deciduous forest of Kuldiha Wildlife Sanctuary, Eastern India. *Mammal Study* 43: 1–9. <https://doi.org/10.3106/ms2017-0078>
- Hanumant, D.D., N.C. Palei, H.S. Palei & A.K. Mishra (2025).** Lenses on the linkage: camera trapping unveils high mammalian diversity in a wildlife corridor in Odisha, India. *Biodiversity* 26(4): 333–342. <https://doi.org/10.1080/14888386.2025.2531342>
- Kumar, N.S., S. Sahoo & S. Kumar (2021).** Photographic record of Rusty-spotted Cat *Prionailurus rubiginosus* in Bonai Forest Division, Odisha, India. *Biodiversity and Conservation* 5(2): 452–454. <https://doi.org/10.5281/ZENODO.5827577>
- Mishra, S.R. & M. Mohan (2023).** Recent record of Rusty-spotted Cat (*Prionailurus rubiginosus*) in Hadgarh Wildlife Sanctuary, Odisha, India. *Cheetal* 60(2): 1–6.
- Mishra, S.R., M. Mohan & J. Pati (2019).** Camera trap records of Rusty-spotted Cat from Similipal Tiger Reserve, Odisha, India. *Cat News* 69: 26–27.
- Palei, H.S. & S. Debata (2017).** On the occurrence of Rusty-spotted Cat *Prionailurus rubiginosus* in Odisha, Eastern India. *Proceedings of the Zoological Society* 72: 102–105. <https://doi.org/10.1007/s12595-017-0243-x>
- Palei, H.S., N.C. Palei, B.P. Rath & A.K. Mishra (2019).** Records of the globally threatened Rusty-spotted Cat in Odisha, India. *Nature Conservation Research* 4: 112–116. <https://doi.org/10.24189/ncr.2019.053>
- Palei, N., R. Mohalik & S. Acharya (2022).** Camera trap record of the Rusty-spotted Cat in Hadgarh Wildlife Sanctuary, Odisha, India. *Cat News* 75: 8–9.
- Palei, N.C., B.P. Rath & S. Nayak (2023a).** Mammalian diversity of Debrigarh Wildlife Sanctuary, Odisha, India. *Journal of Threatened Taxa* 15(4): 23005–23015. <https://doi.org/10.11609/jott.7337.15.4.23005-23015>
- Palei, N.C., B.P. Rath, H.S. Palei & A.K. Mishra (2023b).** Camera trap surveys reveal a wildlife haven: mammal communities in a tropical forest adjacent to a coal mining landscape in India. *Journal of Threatened Taxa* 15(8): 23653–23661. <https://doi.org/10.11609/jott.8481.15.8.23653-23661>
- Patra, L.K., S.K. Jena, N.C. Palei, B.P. Rath, M. Giri & A.K. Mishra (2025).** Camera trap survey in mammalian diversity hotspot in Bonai Forest Division North Western Odisha, India. *Indian Forester* 151(10): 935–945. <https://doi.org/10.36808/if/2025/v151i10/170514>
- Sahu, H.K., H.B. Udgata, S. Debata & H.S. Palei (2014).** *Vertebrate Fauna of Kuldiha Wildlife Sanctuary*. Himalaya Publishing House, Mumbai, 127 pp.





Small Wild Cats Special Series

First photographic evidence of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Kapilash Wildlife Sanctuary, Odisha, India

Alok Kumar Naik¹, Sumit Kumar Kar², Shyama Bharati³, Ashit Chakraborty⁴ & Ashis Kumar Das⁵

^{1,2,3,4} Dhenkanal Forest Division, Dhenkanal, Odisha 759001, India.

⁵ IGNOU Regional Study Centre, Bhubaneswar, Odisha 751013, India.

¹alokkumarnayak702@gmail.com, ²dfo.dhenkanal@gmail.com, ³drshyama.bharati@gmail.com, ⁴vetyashit@gmail.com,

⁵ashis.ridley@gmail.com (corresponding author)

During a routine wildlife patrolling survey on 30 April 2025, we sighted a single Rusty-spotted Cat *Prionailurus rubiginosus* at 21.57 h at the southwestern edge of Kapilash Wildlife Sanctuary, Odisha. The individual rested on a branch of a Forest Ebony *Diospyros sylvatica* tree (Image 1) at a height of about 2 m above ground. The habitat around this location consists of dry deciduous forest next to a small seasonal stream. The closest village is about 100 m away from this location.

Our record of the Rusty-spotted Cat represents the first in Kapilash Wildlife Sanctuary and therefore merits further surveys in the vicinity. This protected area is located in the undulating hills of the Dhenkanal Forest Division in Odisha (Figure 1) at an elevation of 76–643 m. This division harbours tropical moist, dry deciduous to semi-evergreen forest composed of Sal *Shorea robusta*, Bael *Aegle marmelos*, Coromandel Ebony *Diospyros melanoxylon*, Burma Ironwood *Xylocarpus xylocarpa*, Indian Butter Tree *Madhuca longifolia* and several *Dillenia*, *Ficus* and *Terminalia* species (Champion & Seth 1968; Palei et al. 2017). The average rainfall is 1,500–1,700 mm from June to September (Palei et al. 2019). The cold

season from early November to late March exhibits an average temperature of 10–30 °C, which rises to 41 °C in the summer (Alok Kumar Naik personal observation).

Elsewhere in Odisha, the Rusty-spotted Cat has been recorded during camera trapping surveys in similar habitats and climatic conditions, including Similipal Tiger Reserve, several wildlife sanctuaries and forest divisions (Mishra et al. 2019; Palei & Debata 2019; Palei et al. 2019, 2022; Hanumant et al. 2025; Patra et al. 2025). The next closest locality record in Hadagarh Wildlife Sanctuary (Palei et al. 2022) is about 85 km to the northeast but segregated by a largely human-dominated agricultural landscape. Given the widely scattered records of the Rusty-spotted Cat in Odisha, we recommend detailed studies to determine the connectivity between population units. It is also necessary to assess human-induced disturbances, forest loss, forest fire and other threats to the Rusty-spotted Cat in Odisha.

References

Champion, H.G. & S.K. Seth (1968). A Revised Survey of the Forest Types of India. Natraj Publishers, Dehradun, 404 pp.

Editor: Angie Appel, Wild Cat Network, Germany.

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

Citation: Naik, A.K., S.K. Kar, S. Bharati, A. Chakraborty & A.K. Das (2026). First photographic evidence of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Kapilash Wildlife Sanctuary, Odisha, India. *Journal of Threatened Taxa* 18(2): 28444–28446. https://doi.org/10.11609/jott.10132.18.2.28444-28446

Copyright: © Naik et al. 2026. 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: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We are thankful to the principal chief conservator of forest (Wildlife) and chief wildlife warden, Odisha and the divisional forest officer, Dhenkanal Forest Division, Dhenkanal for their support in carrying out the study. We are also very thankful to Sri Tarun Kumar Mohanty, forest range officer of the Kapilash Range, Sri Pratap Dehury of the protection squad and Sri Ramakanta Parida, forest range staff for their extended help during the fieldwork.

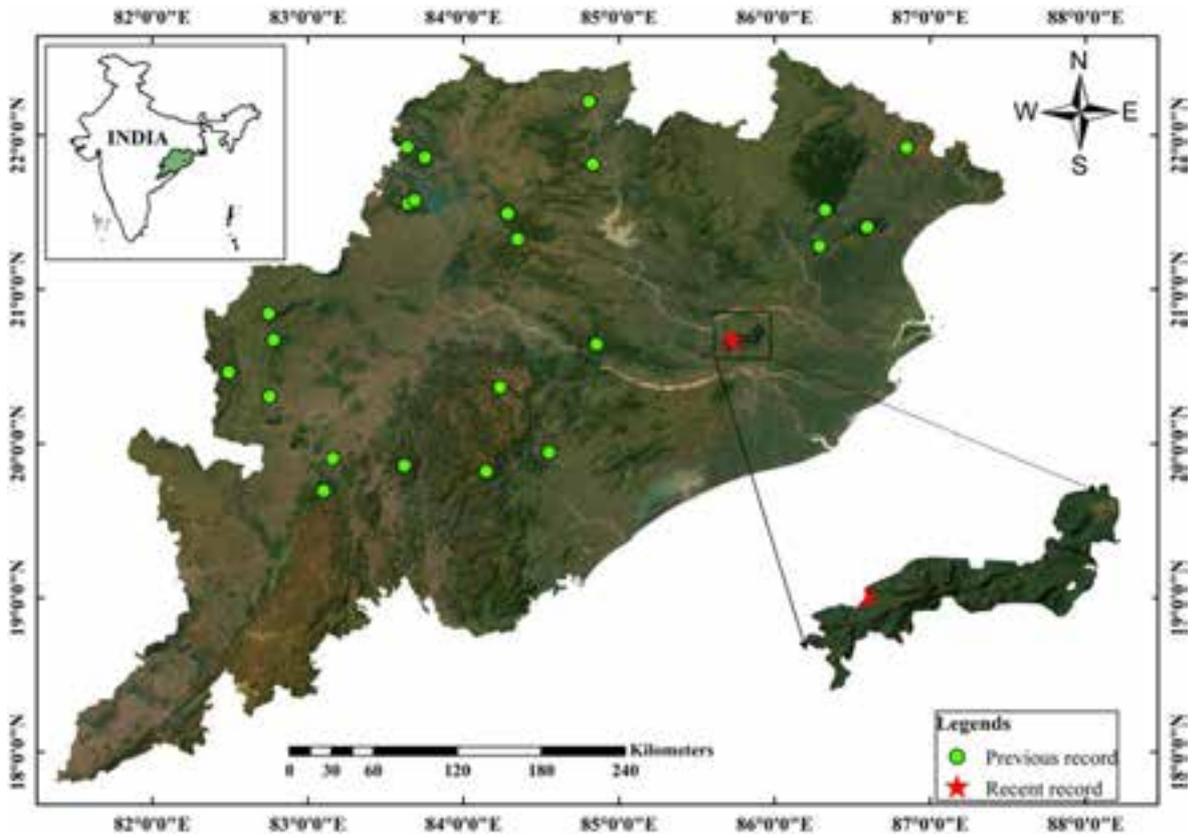


Figure 1. Map with record locations of the Rusty-spotted Cat in Odisha.



Image 1. Rusty-spotted Cat photographed on 30 May 2025 in Kapilash Wildlife Sanctuary. © Ashis Kumar Das & Alok Kumar Naik.

- Debata, S. & H.S. Palei (2020).** An updated checklist of mammals of Odisha, India. *Journal of Threatened Taxa* 12(10): 16219–16229. <https://doi.org/10.11609/jott.6025.12.10.16219-16229>
- Hanumant, D.D., N.C. Palei, H.S. Palei & A.K. Mishra (2025).** Lenses on the linkage: camera trapping unveils high mammalian diversity in a wildlife corridor in Odisha, India. *Biodiversity* 26(4): 333–342. <https://doi.org/10.1080/14888386.2025.2531342>
- Mishra S.R., M. Mohan & J. Pati (2019).** Camera trap records of Rusty-spotted Cat from Similipal Tiger Reserve, Odisha, India. *Cat News* 69: 26–27.
- Mukherjee, S., J.W. Duckworth, A. Silva, A. Appel & A. Kittle (2016).** *Prionailurus rubiginosus*. The IUCN Red List of Threatened Species 2016: e.T18149A50662471. Downloaded on 05 June 2025. <https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T18149A50662471.en>
- Palei, H.S. & S. Debata (2019).** On the Occurrence of Rusty-spotted Cat *Prionailurus rubiginosus* (l. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Odisha, eastern India. *Proceedings of the Zoological Society* 72: 102–105. <https://doi.org/10.1007/s12595-017-0243-x>
- Palei, H.S., N.C. Palei, B.P. Rath & A.K. Mishra (2019).** Records of the globally threatened Rusty-spotted Cat in Odisha, India. *Nature Conservation Research* 4: 112–116. <https://doi.org/10.24189/ncr.2019.053>
- Palei, N.C., H.S. Palei, B.P. Rath & A.K. Mishra (2017).** Fodder plants of Indian Giant Squirrel (*Ratufa indica*) in Kapilash Wildlife Sanctuary, Odisha, India. *E-planet* 15(2): 155–160.
- Palei, N.C., B.P. Rath, A.K. Satapathy, S.N. Acharya & R.K. Mohalik (2022).** Camera trap record of Rusty-spotted Cat in Hadgarh Wildlife Sanctuary, Odisha, India. *Cat News* 75: 8–9.
- Patra, L.K., S.K. Jena, N.C. Palei, B.P. Rath, M. Giri & A.K. Mishra (2025).** Camera trap survey in mammalian diversity hotspot in Bonai Forest Division, north western Odisha, India. *Indian Forester* 151(10): 935–945. <https://doi.org/10.36808/if/2025/v151i10/170514>





Record of a Tiger *Panthera tigris* (Linnaeus, 1758) (Mammalia: Carnivora: Felidae) in Saptari District of eastern Nepal: implications for conservation and habitat connectivity

Gobinda Prasad Pokharel¹, Chiranjibi Prasad Pokheral², Ashish Gurung³, Bishnu Singh Thakuri⁴,
Ambika Prasad Khatiwada⁵, Aastha Joshi⁶, Birendra Gautam⁷, Mithilesh Mahato⁸,
Naresh Subedi⁹ & Madhu Chetri¹⁰

^{1-7,9-10} National Trust for Nature Conservation, P.O. Box 3712, Khumaltar, Lalitpur, Nepal.

⁸ Department of National Parks and Wildlife Conservation, P.O. Box 860, Babar Mahal, Kathmandu, Nepal.

¹ govindapokhrel90@gmail.com, ² pokheralchiran@gmail.com, ³ asisgrg1984@gmail.com, ⁴ bishnu.thakuri@gmail.com,
⁵ ambikapdkhatiwada@gmail.com, ⁶ merry.aj21@gmail.com, ⁷ birendragtm@gmail.com, ⁸ mithilesh.mahato12@gmail.com,
⁹ nareshsubedi@gmail.com, ¹⁰ mchetri@gmail.com (corresponding author)

The Tiger *Panthera tigris* occurs in 10 countries with a global population estimated at fewer than 4,000 mature individuals; it is listed as 'Endangered' in the IUCN Red List of Threatened Species (Goodrich et al. 2022). In Nepal, it has been legally protected as a priority species under the National Parks and Wildlife Conservation Act, 1973 (Jnawali et al. 2011). Despite persistent threats due to poaching and habitat loss (Goodrich et al. 2022), populations have gradually increased in India and Nepal since 2010 (Jhala et al. 2019; DNPWC & DFSC 2022).

Nepal's Tiger population is distributed primarily in the lowlands of the Terai, straddling along the international border with India (Thapa & Kelly 2017). This region is included in the transboundary Terai Arc Landscape (TAL) covering 50,911 km² from Rajaji National Park in northwestern India to Parsa National Park and adjoining forests in southcentral Nepal (Thapa et al. 2017). The Nepal part of the TAL comprises about 24,710 km² and

encompasses five protected areas and seven wildlife corridors, all surrounded by a largely agricultural landscape (Bhatt et al. 2023; Figure 1). The Tiger was documented in 16 districts during the 2022 National Tiger Survey, which covered a sampling area of 18,928 km² in the TAL (DNPWC & DFSC 2022). The national population was estimated at 344–403 individuals, with the easternmost record in a forest in Rautahat District, located to the east of Parsa National Park (DNPWC & DFSC 2022). As the Tiger population continues to rise, available habitats inside protected areas are becoming increasingly limited, highlighting the urgent need for habitat expansion and improving management (DNPWC & DFSC 2022).

Beyond the TAL, a Tiger was killed in the early 2000s in a village at the southern edge of the Trijuga Forest in Saptari District (Shah et al. 2018). The Tiger was known to exist in this area in the early 1970s, but was not

Editor: Angie Appel, Wild Cat Network, Germany.

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

Citation: Pokharel, G.P., C.P. Pokheral, A. Gurung, B.S. Thakuri, A.P. Khatiwada, A. Joshi, B. Gautam, M. Mahato, N. Subedi & M. Chetri (2026). Record of a Tiger *Panthera tigris* (Linnaeus, 1758) (Mammalia: Carnivora: Felidae) in Saptari District of eastern Nepal: implications for conservation and habitat connectivity. *Journal of Threatened Taxa* 18(2): 28447–28450. https://doi.org/10.11609/jott.10022.18.2.28447-28450

Copyright: © Pokharel et al. 2026. 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: None.

Competing interests: The authors declare no competing interests.

Acknowledgements: We thank all the people involved in the rescue operation of the Tiger in Fatepur for their collaboration and support. In particular, we are thankful to personnel of the National Trust for Nature Conservation – Purusottam Mudbary (Senior veterinary technician) and Suresh Shahi (Wildlife technician), and to Major Ramesh Gurung (Nepal Army), Ramdev Chaudhary (Senior conservation officer, KTWR), Krishna Dhakal (Mayor of Saptakoshi Municipality). We are also grateful to Dr. Ramchandra Kandel, director general of the Department of National Parks and Wildlife Conservation, and Ramchandra Khatiwada, senior conservation officer of Parsa National Park for coordinating and supporting our team in the field.



recorded during a survey in 1994 (Smith et al. 1998). This national forest covers about 442 km² at an elevation of 104–430 m and is surrounded by community-managed forests, croplands, and settlements (Pokharel et al. 2022). It predominantly harbours deciduous tree species and hosts at least 86 vertebrates including 37 mammals (Shah et al. 2018). The area receives an annual rainfall of 1,159–2,827 mm, and the average annual temperature is in the range of 23–25.5°C (Pokharel et al. 2022).

Further east in Nepal, a single adult Tiger was photographed in November 2020 at an elevation of 3,165 m during a camera trapping survey in Ilam District (Bista et al. 2021). Across the international border with India, the Tiger has also been recorded in Mahananda Wildlife Sanctuary and Neora Valley National Park located in the northeastern hills of West Bengal (Qureshi et al. 2023).

OBSERVATION

On 3 March 2025, a female Tiger had entered a residential house in Fattepur Village in the north-east of the Trijuga Forest (Image 1). It was subsequently rescued by a team of wildlife and veterinary technicians from the National Trust for Nature Conservation (NTNC) and Koshi Tappu Wildlife Reserve (KTWR), local forest

officials, and security personnel. It was then transferred to the headquarters of KWTR in Sunsari District (Image 2), where it was examined (Image 3). It measured 243 cm from nose to tail tip, weighed 126 kg and was in good physical condition. Dental profile examination revealed intact, creamy white canines. We estimated its age at less than five years. After six hours of observation under veterinary care, it was transported to Parsa National Park (Image 4) and released near Sitalpur Khola.

DISCUSSION

We manually compared the stripe pattern of the Tigress against profiles of identified individuals in the Chitwan-Parsa National Parks complex (DNPWC & DFSC 2022). We did not find any match, indicating that this individual has not been documented and identified in Nepal before. We could not assess whether it has been recorded in India as we did not have access to the Indian database of Tiger profiles.

Long-distance dispersal by female Tigers was considered rather unusual, with a maximum linear distance of 43.2 km documented in Chitwan National Park in the early 1990s (Smith 1993). However, in central India, a female Tiger moved 340 km, traversed

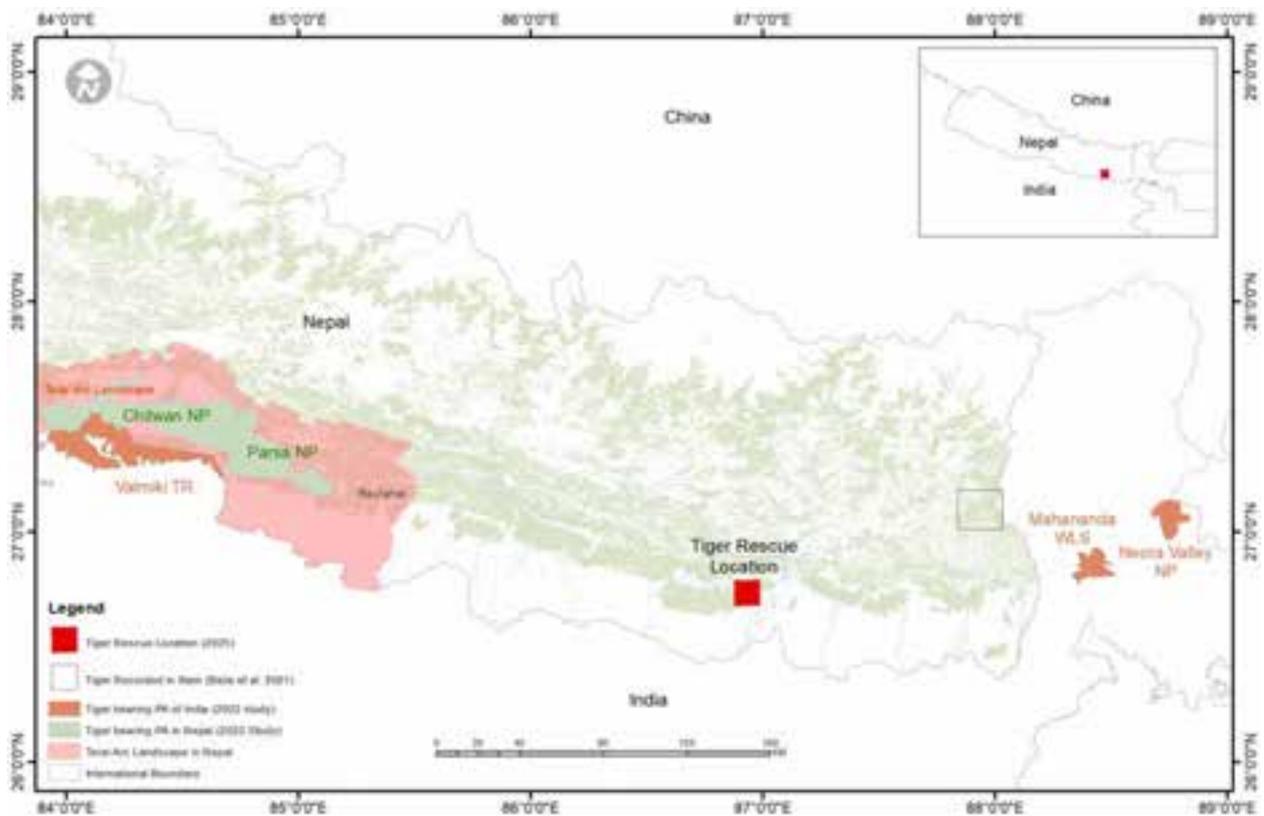


Figure 1. Protected areas with records of the Tiger in southern Nepal and northern India.



Image 1. The dental profile of the Tiger. © Birendra Gautam.



Image 2. The Tiger after sedation. © Birendra Gautam.



Image 3. A team of wildlife technicians and veterinarians inspects the health of the Tiger. © Birendra Gautam.



Image 4. The Tiger shortly before being released into Parsa National Park, Nepal. © Suresh Shahi.

19 stopover sites in 78 days and established her home range 99.1 km away from her natal area (Sarkar et al. 2021).

In light of this dispersal distance, two scenarios for the arrival of the Tigress in the Trijuga Forest area are plausible. It may have come from the eastern part of the TAL, traversing the hills in an easterly direction. The linear distance between the eastern edge of the TAL and the Trijuga Forest is about 120 km (Shah et al. 2018). The Tigress may also have crossed through the hills from Ilam District in a south-westerly direction. The linear distance from the locality record of the Tiger in this area is about 100 km.

Wherever the Tigress came from, its arrival in Saptari District underscores the need to extend surveys to remnant forests beyond the TAL in eastern Nepal. As documented in the Chitwan-Parsa National Parks

complex, tigers readily and rapidly resettle areas as prey availability, habitat quality and connectivity are improved (Lamichhane et al. 2018). Potential Tiger prey species in the Trijuga Forest include Chital *Axis axis*, Northern Red Muntjac *Muntiacus vaginalis*, and Wild Boar *Sus scrofa* (Shah et al. 2018). Wildlife corridors connecting the Trijuga Forest with Tiger-bearing areas in the TAL and in eastern Nepal will still need to be identified to establish safe migration routes and facilitate the expansion of Nepal's Tiger population (DNPWC 2023). However, human-dominated areas pose significant conservation challenges, including an increased risk of human-wildlife negative interactions (Karanth et al.

2012; Sharma & Neupane 2023). An evidence-based, community-centred approach combined with programs to raise conservation awareness is, therefore, essential to ensure the long-term survival of the Tiger also outside designated protected areas.

References

- Bista, D., S.T. Lama, J. Shrestha, Y.B. Rumba, J. Weerman, M. Thapa, H. Acharya, A.P. Sherpa, N.J. Hudson, G.S. Baxter & P.J. Murray (2021). First record of Bengal Tiger, *Panthera tigris tigris* Linnaeus, 1758 (Felidae), in eastern Nepal. *Check List* 17(5): 1249–1253. <https://doi.org/10.15560/17.5.1249>
- Bhatt, T.R., J.G. Castley, R. Sims-Castley, H.S. Baral & A.L. Chauvenet (2023). Connecting Tiger (*Panthera tigris*) populations in Nepal: Identification of corridors among Tiger-bearing protected areas. *Ecology and Evolution* 13(5): e10140. <https://doi.org/10.1002/ece3.10140>
- DNPWC & DFSC (2022). *Status of Tigers and Prey in Nepal 2022*. Department of National Parks and Wildlife Conservation and Department of Forests and Soil Conservation, Ministry of Forests and Environment, Kathmandu, Nepal, 148 pp.
- DNPWC (2023). *Tiger Conservation Action Plan (2023–2032)*. Department of National Parks and Wildlife Conservation, Kathmandu, Nepal, 80 pp.
- Goodrich, J., H. Wibisono, D. Miquelle, A.J. Lynam, E. Sanderson, S. Chapman, T.N.E. Gray, P. Chanchani & A. Harihar (2022). *Panthera tigris*. The IUCN Red List of Threatened Species 2022: e.T15955A214862019. <https://doi.org/10.2305/IUCN.UK.2022-1.RLTS.T15955A214862019.en>. Accessed on 27.vi.2025.
- Jhala, Y.V., Q. Qureshi & A.K. Nayak (2019). *Status of Tigers, Co-predators and Prey in India 2018*. Summary Report. National Tiger Conservation Authority, Government of India, New Delhi and Wildlife Institute of India, Dehradun, 40 pp.
- Jnawali, S.R., H.S. Baral, S. Lee, K.P. Acharya, G.P. Upadhyay, M. Pandey, R. Shrestha, D. Joshi, B.R. Laminchane, J. Griffiths, A.P. Khatiwada, N. Subedi & R. Amin (2011). *The Status of Nepal Mammals: The National Red List Series*. Department of National Parks and Wildlife Conservation, Kathmandu, Nepal, 276 pp.
- Karant, K.K., A.M. Gopalaswamy, R. DeFries & N. Ballal (2012). Assessing patterns of human-wildlife conflicts and compensation around a central Indian protected area. *PLoS One* 7(12): e50433. <https://doi.org/10.1371/journal.pone.0050433>
- Lamichhane, B.R., C.P. Pokharel, S. Poudel, D. Adhikari, S.R. Giri, S. Bhattarai, T.R. Bhatta, R. Pickles, R. Amin, K.P. Acharya, M. Dhakal, U.R. Regmi, A.K. Ram & N. Subedi (2018). Rapid recovery of Tigers *Panthera tigris* in Parsa Wildlife Reserve, Nepal. *Oryx* 52(1): 16–24. <https://doi.org/10.1017/S0030605317000886>
- Pokharel, M., A. Subba, D. Rai, S. Bhandari & Y. Ghimirey (2022). Fine-scale ecological and anthropogenic variables predict the habitat use and detectability of Sloth Bears in the Churia habitat of east Nepal. *Ecology and Evolution* 12(1): e8512. <https://doi.org/10.1002/ece3.8512>
- Qureshi, Q., Y.V. Jhala, S.P. Yadav & A. Mallick (2023). *Status of Tigers in India 2022*. Summary Report. National Tiger Conservation Authority and Wildlife Institute of India, Dehradun, 52 pp.
- Sarkar, M.S., R. Niyogi, R.L. Masih, P. Hazra, L. Maiorano & R. John (2021). Long-distance dispersal and home range establishment by a female sub-adult Tiger (*Panthera tigris*) in the Panna landscape, central India. *European Journal of Wildlife Research* 67(3): 54. <https://doi.org/10.1007/s10344-021-01494-2>
- Shah, K.B., K.B. Thapa, H.R. Poudel, H. Basnet & B. Gautam (2018). *Habitat Suitability Assessment for Tiger in Trijuga Forest, East Nepal*. Report submitted to WildCats Conservation Alliance, London, 70 pp.
- Sharma, B. & D. Neupane (2023). Enhancing human-Tiger coexistence in forest corridors of Nepal through a socio-ecological approach to conservation. *Trees, Forests and People* 13: 100402. <https://doi.org/10.1016/j.tfp.2023.100402>
- Smith, J.L.D. (1993). The role of dispersal in structuring the Chitwan Tiger population. *Behaviour* 124(3/4): 165–195.
- Smith, J.L.D., S.C. Ahearn & C. McDougal (1998). Landscape analysis of Tiger distribution and habitat quality in Nepal. *Conservation Biology* 12(6): 1338–1346. <https://doi.org/10.1111/j.1523-1739.1998.97068.x>
- Thapa, K. & M.J. Kelly (2017). Density and carrying capacity in the forgotten Tigerland: Tigers in the understudied Nepalese Churia. *Integrative Zoology* 12(3): 211–227. <https://doi.org/10.1111/1749-4877.12240>
- Thapa, K., E. Wikramanayake, S. Malla, K.P. Acharya, B.R. Lamichhane, N. Subedi, C.P. Pokharel, G.J. Thapa, M. Dhakal, A. Bista, J. Borah, M. Gupta, K.K. Maurya, G.S. Gurung, S.R. Jnawali, N.M.B. Pradhan, S.R. Bhata, S. Koirala, D. Ghose & J. Vattakaven (2017). Tigers in the Terai: Strong evidence for meta-population dynamics contributing to Tiger recovery and conservation in the Terai Arc Landscape. *PLoS One* 12(6): e0177548. <https://doi.org/10.1371/journal.pone.0177548>



OPEN
ACCESS

BOOK REVIEW

At the Point of No Return? – Reading Pankaj Sekhsaria’s *Island on Edge: The Great Nicobar Crisis*

Himangshu Kalita

PhD Scholar, National Institute of Advanced Studies, Bengaluru, India
himangshu@nias.res.in

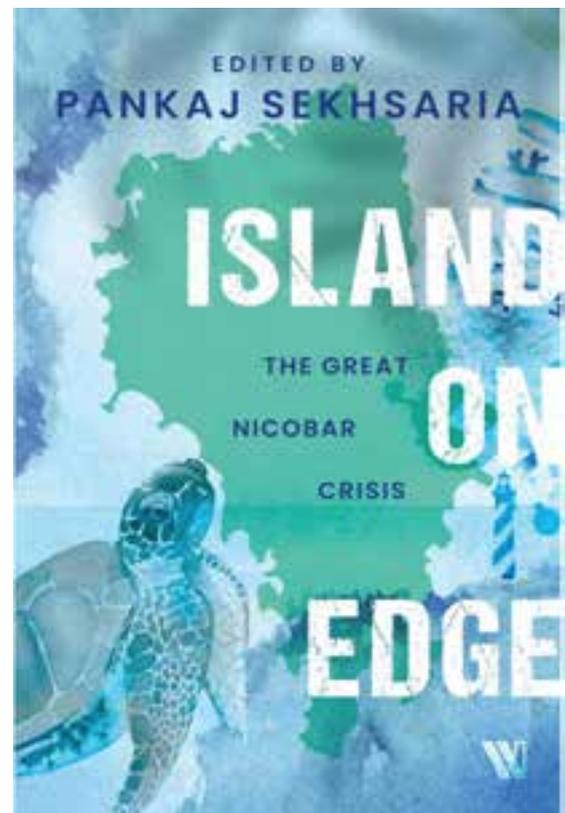
When I first began writing this review, there was still a cautious sense of anticipation. The matter of the Great Nicobar project was before the National Green Tribunal (NGT). There remained hope that judicial scrutiny might reassess the ecological and social implications of the proposed development. Despite widespread recognition of the project’s deleterious impacts, the evidence remained scattered and environmental concerns were often dismissed as emotive and ideological rather than empirical. What was urgently needed was consolidation, an arsenal of credible, structured evidence. *Island on Edge* edited by Pankaj Sekhsaria, accomplishes precisely this, transforming dispersed documentation into a coherent and rigorous case. The essays in the book felt like an intervention unfolding in real time. It assembles ecological evidence, procedural irregularities, legal scrutiny, and social concerns with great clarity at a moment when institutional pause still seemed possible.

On 16 February 2026, however, the NGT upheld the environmental clearance granted to the Great Nicobar ‘Holistic’ Development Project, now amounting to almost INR 92,000 crore, observing that adequate safeguards had been incorporated and declining to interfere in what it termed a project of “strategic importance.” The tone in which this book must now be read has shifted. What might have functioned as a preventive critique now stands as a record, an archive of warnings at a developmental threshold.

Framing the Crisis

At a time when environmental governance in India is increasingly reframed through the vocabulary of “strategic importance,” “national interest,” and “sustainable development”, *Island on Edge* intervenes with clarity. The Foreword by Vaishna Roy underscores the seismic and ecological precarity of Great Nicobar, and outlines both the island’s ecological significance and the scale of the proposed transformation. It offers

Island on Edge: The Great Nicobar Crisis Kindle Edition
ASIN: B0DD49NN6D
First Edition 2025, 263 pages
Publisher: Westland Non-Fiction



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

Citation: Kalita, H. (2026). At the Point of No Return? – Reading Pankaj Sekhsaria’s *Island on Edge: The Great Nicobar Crisis*. *Journal of Threatened Taxa* 18(2): 28451–28454. <https://doi.org/10.11609/jott.10481.18.2.28451-28454>

Copyright: © Kalita 2026. 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.

readers, particularly those unfamiliar with the unfolding crisis, a grounded understanding of what is at stake. Importantly, it situates the project within its social and ethical context, noting that it unfolds within a tribal reserve and UNESCO-recognized biosphere reserve. Further anchored by Sekhsaria's Editor's Note, the volume positions itself as a continuation of an ongoing effort to document what he calls the multiple "betrayals" unfolding in Great Nicobar. Drawing from investigative journalism, scientific analysis, creative expression, and expert testimony, the volume assembles what might be called a counter-archive of the Great Nicobar project. By invoking the metaphor of being "closer to the precipice," he signals both the accelerating pace of decision-making and the narrowing space for institutional reconsideration.

Structuring the Crisis

One of the book's major strengths lies in its deliberate structural design, which allows the argument to unfold cumulatively rather than episodically. Organized into thematic sections, the book traces a movement from infrastructural promise and administrative claims to lived realities, ecological vulnerability, and long-term consequences.

The volume's strength also lies in the focus on facts and figures. Statistical tables, demographic projections, land diversion figures, and mapped representations provide readers with concrete reference points that anchor the analysis. The annexures — including timelines, legal correspondence, official notifications, and excerpts from impact assessments — enhance transparency and allow readers to trace how regulatory decisions evolved over the years.

The opening section "*An Imperilled Future*" interrogates the foundational assumptions of the megaproject. It examines feasibility projections, financial rationales, and strategic justifications. It brings together four essays to systematically dismantle the ecological, economic, and institutional premises. This section foregrounds large-scale forest diversion, seismic vulnerability, and regulatory dilution; while interrogating the arithmetic of the trans-shipment port, exposing optimistic projections and escalating costs that challenge financial viability. The examination of ANIIDCO, the primary project proponent, raises deeper concerns about governance capacity, conflicts of interest, and the concentration of regulatory authority within the project's own institutional architecture. The section reframes the megaproject as an infrastructural ambition advancing through layered ambiguities.

The focus then shifts to land and indigeneity in *Indigenous Landscapes*, probably my favourite section. Rishika Pardikar's "*Tribal Lands Don't Show Up on Maps*" is perhaps one of the most politically unsettling chapters. At the core is a deceptively simple question: how does one assess the impact of land acquisition when the land itself does not officially exist in state maps? The implications are simple yet profound. If tribal lands are not mapped, they are not counted; if not counted, they are not considered affected. And if they are not considered affected, procedural requirements such as meaningful consultation, consent, and rehabilitation become diluted or symbolic. The essays further show how cartographic abstractions and policy categories marginalize the indigenous Shompen and Nicobarese people. This cartographic invisibility reflects a longer history of extractive governance in Indigenous regions. The section further foregrounds the vulnerability of indigenous languages and raises concerns regarding how tribal rights and consultation processes have been addressed within the project's administrative framework. It recalls the haunting story of Boa Sr, the last speaker of the Great Andamanese language Bo, who — displaced from her ancestral lands — was often described as speaking to birds, believed to be the only beings who still understood her tongue. The episode serves as a stark reminder that the erosion of indigenous rights and habitats can carry irreversible consequences. It also implicitly raises a deeper tension: in contemporary development policy, land increasingly appears as a strategic asset to be mobilized, rather than as a lived landscape embedded in community.

The section "*Two Decades After a Tsunami*" anchors the volume in temporal depth. It reminds the readers that Great Nicobar is not an untouched frontier awaiting development, but a landscape already marked by catastrophe, relocation, and unresolved grief. Through Leesha K. Nair's "*20 Christmases After the Tsunami*" and Ajay Saini's "*The Death of Life*" — the book shifts from infrastructural critique to intimate histories of loss. Nair's essay traces the prolonged afterlife of the 2004 tsunami in the lives of the Nicobarese. Relocated from ancestral coastal villages to state-designed settlements, survivors inhabit spaces that never quite became home. The shift unsettled kinship patterns, gender roles, subsistence practices, and cultural rhythms. Two decades later, demands to return to ancestral lands persist, revealing that displacement was not temporary but structural. Saini extends this argument beyond material loss. The forest is not a resource but an animate presence — foundation of identity, memory, and moral order.

When a survivor describes the proposed deforestation as “the death of life,” it signals not only environmental damage but the severing of bonds that sustain collective identity. The tensions documented here are not new. From colonial forest laws to movements such as Chipko and Silent Valley, conflicts over forest governance have long revealed a divide between state-led developmental visions and community-rooted relationships to land. In India, forests have never been merely resource frontiers; they are entwined with livelihood, memory, and identity. The Great Nicobar debate reflects the persistence of this historical tension — between land as strategic infrastructure and land as lived landscape — making the crisis not only ecological, but reflective of competing visions of development and belonging. The section also reveals how the island’s communities are still living in the shadow of one rupture even as another looms.

The volume then returns to ecological vulnerability in “*Fragile Ecologies*”. It foregrounds the risks of habitat alteration in seismically active, biodiversity-rich island systems where mitigation and compensatory measures offer limited assurance of restoration. It also provides a list of the species, mostly endemic to the region, which are at direct risk of extinction. The inclusion of creative expressions, with poems and art, alongside scientific analysis, underscores that ecological loss has both dimensions - measurable and affective. Among the most analytically compelling contributions is Rohan Arthur and T.R. Shankar Raman’s “*An Obit for Patai Takaru*,” (Patai Takaru meaning ‘the big island’ in the southern Nicobarese language). It interrogates the ecological logic underpinning compensatory afforestation and coral translocation. Drawing a provocative parallel with **Lysenkoism** — the Soviet-era belief that ecological systems could be engineered into compliance through ideological certainty — the authors question whether large-scale “restoration” can meaningfully substitute for the destruction of intact, old-growth ecosystems. They demonstrate with empirical evidence that restoration projects are typically small in scale, uncertain in outcome, and incapable of recreating the structural complexity, species interactions, and ecological functions of mature tropical systems. Translocating thousands of coral colonies or planting trees in distant biogeographic regions, they argue, risks producing ecological ‘simulacra’ rather than functioning ecosystems. Their central caution is stark: once destroyed, the rainforests and reefs of Great Nicobar are not recoverable through engineering fixes, simply put - “There is no turning back from here”. In this sense, the chapter challenges not only the project’s mitigation claims but also a broader

developmental faith that environmental damage can always be offset through technical intervention.

Finally, the sections gathered under “*Expert Speak*”, along with the Afterword and annexures, consolidate the book’s critical engagement with regulatory processes. By examining official claims, legal correspondence, and documentary evidence, these contributions illuminate how environmental safeguards are articulated, contested, and institutionalised. The annexures, in particular, reinforce the book’s value as an evidentiary archive, preserving records that may shape future scrutiny and evaluation.

After the Not-So ‘Green’ Signal

If anything, the National Green Tribunal’s decision to allow the project to proceed has only sharpened the relevance of *Island on Edge*. What might once have been read as a timely intervention in an unfolding debate now reads as a documentary record of how environmental governance, scientific scrutiny, and democratic consultation are negotiated — and often diluted — in real time. The book’s importance has not diminished with the Tribunal’s green signal; it has increased. It stands as both evidence and counter-record: a compilation of data, correspondence, expert testimony, and lived accounts that complicate official narratives of inevitability and national interest.

The relevance of this documentation extends beyond Great Nicobar. Across biodiversity-rich regions, large-scale infrastructure projects are increasingly justified through the language of national interest and economic acceleration. Recent episodes from proposed oil exploration near Hollongapar Gibbon Sanctuary in Assam to coal mining in the forests of Hasdeo Aranya in Chhattisgarh illustrate how ecologically sensitive landscapes continue to be positioned as development frontiers. In many such contexts, environmental safeguards, impact assessments, and consultation processes become central sites of negotiation. *Island on Edge* provides a framework through which similar projects may be examined, reminding readers that precaution, transparency, and ecological thresholds must remain central to conservation discourse. It offers scholars, policymakers, conservation practitioners, and concerned citizens a way to ask harder questions about cost, consent, competence, and consequence. The book’s readability is highly appreciated. It will appeal not only to conservation scholars but also to a wider readership concerned with India’s development pathway.

The book demonstrates how ecology and conservation are embedded within broader governance

systems that define habitat boundaries, interpret safeguards, and authorize transformation. It clearly states how conversion is not only ecological; it is social, political, and institutional as well. Species, habitats, and ecological processes are shaped by decisions taken in boardrooms, tribunals, and ministries as much as in forests and reefs. By assembling ecological science alongside legal critique, economic analysis, and indigenous testimony, *Island on Edge* models the kind of interdisciplinary engagement that contemporary conservation demands.

Although the book excels in assembling an evidentiary archive, and meaningfully incorporating lived narratives and testimonies, it offers comparatively little exploration of grassroots protest or collective resistance—if any, leaving open questions about how affected communities are actively negotiating or challenging the project.

At times, the recurrence of similar arguments across chapters creates a sense of redundancy. While this reinforces urgency, tighter editorial integration could have improved cohesion.

The story of Great Nicobar is far from over. Construction may proceed; forests may fall; ports and runways may rise. Yet the questions it raises — about accountability, ecological limits, and the rights of Indigenous communities — will persist. In documenting this moment with clarity and conviction, *Island on Edge* ensures that the record will not consist solely of official clearances and press releases. It leaves us with a deeper, more unsettling inquiry: not whether development will come to Great Nicobar, but what kind of future is being built, at whose cost and who is expected to bear the burdens of that transformation.



Mr. Jatishwor Singh Irungbam, Biology Centre CAS, Branišovská, Czech Republic.
Dr. Ian J. Kitching, Natural History Museum, Cromwell Road, UK
Dr. George Mathew, Kerala Forest Research Institute, Peechi, India
Dr. John Noyes, Natural History Museum, London, UK
Dr. Albert G. Orr, Griffith University, Nathan, Australia
Dr. Sameer Padhye, Katholieke Universiteit Leuven, Belgium
Dr. Nancy van der Poorten, Toronto, Canada
Dr. Kareen Schnabel, NIWA, Wellington, New Zealand
Dr. R.M. Sharma, (Retd.) Scientist, Zoological Survey of India, Pune, India
Dr. Manju Siliwal, WILD, Coimbatore, Tamil Nadu, India
Dr. G.P. Sinha, Botanical Survey of India, Allahabad, India
Dr. K.A. Subramanian, Zoological Survey of India, New Alipore, Kolkata, India
Dr. P.M. Sureshan, Zoological Survey of India, Kozhikode, Kerala, India
Dr. R. Varatharajan, Manipur University, Imphal, Manipur, India
Dr. Eduard Vives, Museu de Ciències Naturals de Barcelona, Terrassa, Spain
Dr. James Young, Hong Kong Lepidopterists' Society, Hong Kong
Dr. R. Sundararaj, Institute of Wood Science & Technology, Bengaluru, India
Dr. M. Nithyanandan, Environmental Department, La Ala Al Kuwait Real Estate. Co. K.S.C., Kuwait
Dr. Himender Bharti, Punjabi University, Punjab, India
Mr. Purnendu Roy, London, UK
Mr. Saito Motoki, The Butterfly Society of Japan, Tokyo, Japan
Dr. Sanjay Sondhi, TITLI TRUST, Kalpavriksh, Dehradun, India
Dr. Nguyen Thi Phuong Lien, Vietnam Academy of Science and Technology, Hanoi, Vietnam
Dr. Nitin Kulkarni, Tropical Research Institute, Jabalpur, India
Dr. Robin Wen Jiang Ngiam, National Parks Board, Singapore
Dr. 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. Topiltzin Contreras MacBeath, Universidad Autónoma del estado de Morelos, México
Dr. Heok Hee Ng, National University of Singapore, Science Drive, Singapore
Dr. Rajeesh 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, Kalinga Foundation, Agumbe, India.
Dr. Himansu Sekhar Das, Terrestrial & Marine Biodiversity, Abu Dhabi, UAE

Birds

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

Mammals

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

Other Disciplines

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

Reviewers 2021–2023

Due to paucity of space, the list of reviewers for 2021–2023 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.

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

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



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](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)

February 2026 | Vol. 18 | No. 2 | Pages: 28263–28454

Date of Publication: 26 February 2026 (Online & Print)

DOI: 10.11609/jott.2026.18.2.28263-28454

www.threatenedtaxa.org

Articles

Floristic composition and conservation significance of vascular plants in Kalatop-Khajjiar Wildlife Sanctuary, Himachal Pradesh, India

– Sumit, Gulshan Kumar, Sumit Singh, Kanwaljeet Singh, Taslima Sheikh, P. Vishal Ahuja & Arvind Kumar, Pp. 28263–28274

Assessing the tree diversity along the Dudhganga River in Kolhapur District of Maharashtra, India

– Sachin Chavan & Rajaram Gurav, Pp. 28275–28286

Flower bud growth, mortality rate, and population structure of *Sapria himalayana* Griffith f. *albvinosa* Banziger & Hansen (Rafflesiaceae) in a subtropical forest, northeastern India

– K. Shamran Maring & Athokpam Pinokiyo, Pp. 28287–28295

Comparing three sampling techniques for surveying and monitoring arthropods in Moroccan agroecosystems

– Hanae El Harche, Pp. 28296–28306

Community structure of Lepidoptera in Nantu-Bolihuto Wildlife Reserve, Sulawesi, Indonesia

– Chairunnisah J. Lamangantjo, Marini Susanti Hamidun, Sasmianti & Dewi Wahyuni K. Baderan, Pp. 28307–28316

Foraging niche segregation among woodpeckers in the oak-pine forest of Kumaon Himalaya, Uttarakhand, India

– Rafat Jahan, Satish Kumar & Kaleem Ahmed, Pp. 28317–28328

Local knowledge, attitudes, and perceptions of ecosystem services and disservices provided by the Painted Stork *Mycteria leucocephala* Pennant, 1769 (Aves: Ciconiidae) in northern India: insights for conservation

– Yashmita-Ulman & Manoj Singh, Pp. 28329–28342

Communications

Analysis revealed minuscule DNA sequence data availability for Indian marine macroalgal diversity

– Digvijay Singh Yadav, Aswin Alichen & Vaibhav A. Mantri, Pp. 28343–28349

Checklist of rust fungi of the Nuratau Nature Reserve, Uzbekistan

– I.M. Mustafae, M.M. Iminova, I.Z. Ortiqov, S.A. Teshaboyeva & N.Q. Iskanov, Pp. 28350–28357

Checklist of moths (Lepidoptera: Heterocera) from the campus of University of North Bengal, Siliguri, India

– Abhirup Saha, Ratnadeep Sarkar, Rujas Yonle, Subhajit Das, Prapti Das & Dhiraj Saha, Pp. 28358–28369

Vulture diversity and long-term trends in the Ranikhet region, Kumaon Himalaya, Uttarakhand, India

– Mirza Altaf Baig, Nazneen Zehra & Jamal Ahmad Khan, Pp. 28370–28377

Nesting dynamics of Red-wattled Lapwing *Vanellus indicus* Boddaert, 1783 in urban and rural regions of Indore, India

– Kratika Patidar & Vipul Keerti Sharma, Pp. 28378–28386

Assessing avian diversity and conservation status in Dhamapur Lake World Heritage Irrigation Structure, Sindhudurg, Maharashtra, India

– Yogesh Koli, Pravin Sawant & Mayuri Chavan, Pp. 28387–28398

Population status and habitat use of Indian Grey Wolf *Canis lupus pallipes* in Pench Tiger Reserve, Madhya Pradesh, India

– Iqra Rabbani & Sharad Kumar, Pp. 28399–28405

Activity budgets of a zoo-housed Mishmi Takin *Budorcas taxicolor taxicolor* (Mammalia: Artiodactyla: Bovidae) herd

– Nabanita Ghosh, Pranita Gupta, Joy Dey & Basavaraj S. Holeyachi, Pp. 28406–28412

Extended distribution of *Nymphoides peltata* (S.G.Gmel.) Kuntze (Menyanthaceae) in Manipur, India

– Aahen Chanu Waikhom & Bimolkumar Singh Sadokpam, Pp. 28413–28418

Short Communications

***Impatiens chamchumroonii* (Balsaminaceae), a new record for the flora of Vietnam**

– Cuong Huu Nguyen, Diep Quang Dinh, Dinh Duc Nguyen & Keoudone Souvannakhommane, Pp. 28419–28423

Occurrence of the wood fern *Arachniodes sledgei* Fraser-Jenk. (Pteridophyta: Dryopteridaceae) in the northern Western Ghats, India

– Sachin Patil & Jagannath Patil, Pp. 28424–28427

Notes

A note on the Petal-less Caper *Maerua apetala* (B. Heyne ex Roth) Jacobs (Capparaceae)

– Shamsudheen Abdul Kader & Bagavathy Parthipan, Pp. 28428–28429

Record of *Euploea mulciber* (Cramer, [1777]) (Lepidoptera: Nymphalidae) in Delhi, India: evidence of range extension in a restored urban ecosystem

– Aisha Sultana, Mohammad Shah Hussain & Balwinder Kaur, Pp. 28430–28432

Hump-nosed Pit Viper *Hypnale hypnale* feeding on an Allapalli Skink *Eutropis allapallensis* in Karwar, India

– Nonita Rana, Karthy Shivapushanam, S.J.D. Frank & Govindan Veeraswami Gopi, Pp. 28433–28435

Sighting of vagrant Red-backed Shrike *Lanius collurio* in the coastal areas of Thoothukudi, Tamil Nadu, India

– Kishore Muthu, Anand Shibu & Santhanakrishnan Babu, Pp. 28436–28437

First record of the Diamond Dove *Geopelia cuneata*, an Australian endemic, in Sikhna Jwhlwao National Park, Assam, India

– Bibhash Sarkar, Bijay Basfore, Leons Mathew Abraham & Anjana Singha Naorem, Pp. 28438–28440

First photographic record of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Kuldih Wildlife Sanctuary, Odisha, India

– Tarun Singh, Harshvardhan Singh Rathore, N. Abhin, Subhalaxmi Muduli, Yash Deshpande, Vivek Sarkar, Diganta Sovan Chand, Samrat Gowda, Prakash C. Gogineni, Manoj V. Nair, Bivash Pandav & Samrat Mondol, Pp. 28441–28443

First photographic evidence of the Rusty-spotted Cat *Prionailurus rubiginosus* (I. Geoffroy Saint-Hilaire, 1831) (Mammalia: Carnivora: Felidae) in Kapilash Wildlife Sanctuary, Odisha, India

– Alok Kumar Naik, Sumit Kumar Kar, Shyama Bharati, Ashit Chakraborty & Ashis Kumar Das, Pp. 28444–28446

Record of a Tiger *Panthera tigris* (Linnaeus, 1758) (Mammalia: Carnivora: Felidae) in Saptari District of eastern Nepal: implications for conservation and habitat connectivity

– Gobinda Prasad Pokharel, Chiranjibi Prasad Pokharel, Ashish Gurung, Bishnu Singh Thakuri, Ambika Prasad Khatiwada, Aastha Joshi, Birendra Gautam, Mithilesh Mahato, Naresh Subedi & Madhu Chetri, Pp. 28447–28450

Book Review

At the Point of No Return? – Reading Pankaj Sekhsaria's Island on Edge: The Great Nicobar Crisis

– Himangshu Kalita, Pp. 28451–28454

Publisher & Host



Threatened Taxa